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Abstract

Detailed mass balance food web models were constructed to compare ecosystem characteristics for three Alaska regions: the eastern Bering Sea (EBS), the Gulf of Alaska (GOA), and the Aleutian Islands (AI). This paper documents the methods and data used to construct the models and compares ecosystem structure and indicators across models. The common modeling framework, including biomass pool and fishery definitions, resulted in comparable food webs for the three ecosystems which showed that they all have the same apex predator—the Pacific halibut longline fishery. However, despite the similar methods used to construct the models, the data from each system included in the analysis clearly define differences in food web structure which may be important considerations for fishery management in Alaska ecosystems. The results showed that the EBS ecosystem has a much larger benthic influence in its food web than either the GOA or the AI. Conversely, the AI ecosystem has the strongest pelagic influence in its food web relative to the other two systems. The GOA ecosystem appears balanced between benthic and pelagic pathways, but is notable in having a smaller fisheries catch relative to the other two systems, and a high biomass of fish predators above trophic level (TL) 4, arrowtooth flounder and halibut. The patterns visible in aggregated food webs were confirmed in additional more detailed analyses of biomass and consumption in each ecosystem, using both the single species and whole ecosystem indicators developed here.

Contents

1. Introduction

1.1 Purpose and Background of Past Models

Modeling food webs for use in large marine ecosystem (LME) fisheries management has been identified as a key element of an “ecosystem-based” approach to management (EPAP 1998). Such models provide a context for traditional single species approaches, rather than a replacement (Hollowed et al. 2000a), as they may identify key shifts in marine populations that arise out of changes in prey availability, predation mortality, or may identify climatic changes as they appear through shifts in these parameters.

Moreover, such models, updated on 3-5 year intervals, may provide a basis for: i) the calculation of indicators specific to energy flow through modeled ecosystems; ii) an evaluation of sensitivity of species to perturbations in their predators or prey; iii) targeting research on ecologically important but poorly understood species; or iv) evaluation of management alternatives as they may affect long-term changes in food web structure.

Here we present and compare the results of stock-scale food web models for the Bering Sea, Gulf of Alaska, and Aleutian Islands management regions (Fig. 1), focusing on the early to mid-1990s (1990-1996). The mass-balance modeling methodology used for these food webs (Ecopath) was initially developed for the eastern Bering Sea region (Laevastu and Favorite 1979). This work was generalized and extended by Polovina (1985) into a set of Microsoft Visual Basic routines, most recently updated and extended by Christensen and Pauly (1992) and Christensen and Walters (2004) as the free software package Ecopath. Ecopath allows for the consistent estimation and comparison of mass-balance results between multiple fisheries ecosystems. (While Ecopath is currently distributed with a dynamic modeling program, Ecosim, and a spatial analysis tool, Ecospace, in the package Ecopath with Ecosim (EwE) we limit our analysis and discussion primarily to mass balance modeling except where noted.)

Ecopath is designed to make extensive use of data as it is already collected for single-species fisheries management; base parameters, survey biomass estimates, age, weight, and mortality studies are supplemented with consumption rate data either from laboratory or shipboard experiments, to determine production and consumption rates for each species. Ecopath has been associated and packaged with a biomass dynamics/age structured simulation tool, Ecosim (Walters et al. 1997; Christensen and Walters 2004), which provides a theoretical framework for providing dynamic deterministic projections of changes in species and fisheries in response to changes in fishing or natural predation mortality. However, we believe that the use of this tool in the context of Alaskan fishery management decision making requires a more formal statistical estimation procedure for parameters than is currently available in EwE. Ecosim in its packaged form is only recommended for use in hypothesis exploration or first-order perturbation and sensitivity analyses as a supplement to other forecasting methods.

For the eastern Bering Sea (EBS), Ecopath has previously been used to reconstruct food webs of the region as they existed in the early 1980s. Three initial efforts explored ecosystem changes from 1950 through 1980, including a major shift from what was thought to be a mammal-dominated ecosystem to a more groundfish-dominated ecosystem (Trites et al. 1999), compared the geographically linked but structurally distinct eastern and western Bering Sea ecosystems (Aydin et al. 2002), and tested hypotheses regarding the decline of Steller sea lions in the North Pacific (NRC 2003). While clearly demonstrating the value of describing ecosystem interactions both in general and in an attempt to answer very specific conservation questions, each of these analyses also highlighted areas for improvement in the approach. For example, both Trites et al. (1999) and Aydin et al. (2002) had to aggregate taxonomic groups considerably, especially important forage species, zooplankton and phytoplankton, generally due to a lack of resolution in species specific data for a given time period or area (e.g., the 1950s and the western Bering Sea). In addition, geographic resolution in previous analyses was sometimes poorly defined. The Ecosim model used in NRC (2003) was based on the 1980s Bering Sea mass balance model from Trites et al. (1999), but the NRC (2003) analysis suffered from poor geographic precision in the inclusion of time series from both the Bering Sea and the Gulf of Alaska (GOA); for example, pollock biomass and recruitment time series from the Bering Sea were mixed with small pelagic and invertebrate time series derived from Anderson and Piatt (1999) which apply only to the GOA, and with the arrowtooth flounder time series from the GOA. It is difficult to interpret the NRC (2003) results for management in a specific ecosystem when the analysis was based on information from multiple ecosystems with demonstrably different dynamics.

The models detailed in this report represent a redesign of this initial work to improve species and geographic resolution, as well as to update in time to the beginning of fully domestic fishery management in the 1990s. In addition, we extend mass balance modeling and analysis beyond the Bering Sea to all areas managed by the North Pacific Fishery Management Council (NPFMC), including the Aleutian Islands (AI) and western Gulf of Alaska. Data for this modeling has been supplied from multiple agencies and programs, including the Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) and Resource Ecology and Fisheries Management (REFM) Divisions and National Marine Mammal Laboratory (NMML). Additional data were collected from the Alaska Department of Fish and Game (ADF&G) and the U.S. Fish and Wildlife Service (USFWS). Overall, these new models represent the most comprehensive synthesis of predator/prey relationships to date for the large marine ecosystems of the EBS, GOA, and AI.

Recent publications suggest that the importance of predator prey interactions may shift in time as ecosystems adjust to climate fluctuations (Bailey 2000, Hunt et al. 2002). Building on Ecopath-type mass balance models, dynamic Ecosim-type models may be useful in understanding and evaluating hypotheses regarding the shifting control of marine fish production from bottom up to predator control. In a complex multispecies system, the most powerful hypothesis evaluation methods will employ dynamic projections across the ecosystem, including both sensitive species and trophically important but undersampled species. Because data quality varies by ecosystem and species group, it can be difficult to draw conclusions about species sensitivity and energetic influence within the ecosystem if that species is undersampled. Therefore, we believe it is important to introduce a more rigorous evaluation of uncertainty than EwE can supply. While exercises such as those presented in NRC (2003) are a step towards addressing real-life management problems in an ecosystem context, we believe that failure to include an appropriate evaluation of uncertainty makes this particular iteration of EwE an inappropriate tool for management applications. However, it is equally inappropriate to assume that there is too much uncertainty to evaluate hypotheses in the ecosystem context, especially because the ecosystem context itself imposes constraints which can be used to advantage. The thermodynamic constraints inherent in food webs and modeled within Ecopath may be used to bound the estimation problem for species about which too little data are available: this procedure may add information to dynamic projections in a formal sense.

To this end, we introduce our Ecosense routines and results in this report. Ecosense is a method for incorporating Ecopath thermodynamic constraints and model structure into dynamic ecosystem model projections within a Bayesian Synthesis framework (e.g. Givens et al. 1993). An outline of this method was previously published for a simplified case in the subarctic Pacific gyres, in which model structure provides the only additional information to the model (Aydin et al. 2003). Here, we apply this method to much more species rich and data rich models which nevertheless have data-poor groups.

As a whole, Ecopath and Ecosense are tools designed to examine explicit predator/prey relationships and their effects on changes in mortality throughout each modeled ecosystem. Accounting for this food web variability is an important component of ecosystem management, but should not be seen as a complete view: habitat, life-history, climate, and other non predator/prey interactions are not directly captured by the use of these models.

1.2 Model Setting

The food web models described in this document are based on a mass-balance approach; that is, the flows of biomass between functional components in the food web (species or aggregated species compartments) are accounted for in such a way that any imbalance (positive or negative) between input and output of a compartment may be considered either indication of data uncertainty or true energy loss/gain between the compartment and the remainder of the system. The ideal methodology provides relatively independent estimates of input (bottom-up supply) and output (top-down removal) so that the relative consistency of the multiple sources of data may be assessed.

1.2.1 Time scale

The mass balance approach provides a “snapshot” of the system state during a particular period of time. The base time period for the three models was taken to be 1990-1994, with data included from adjacent time periods as necessary. This time period was selected to represent a recent time period covering several surveys, but with enough years between the base model and the present year to tune dynamic forward projections. Cetacean and seabird estimates, not available as time series from this earlier period, were included as “most recent” (1997-2002) estimates.

The models are considered “annual” models and growth and consumption rates are scaled to yearly totals. However, fish diet data is primarily derived from summer collections (May-September)—it is assumed that while annual averages are used for consumption rates, most of this consumption occurs during the summer. The exception to this rule is for ice-edge following species that overwinter in the Bering Sea, whose consumption is in wintertime only.

1.2.2 Area description and maps

For analysis with a mass-balance approach, each ecosystem is considered to be a homogenous system in which species mix freely, with the geographic boundaries of the system set large enough so that migration across the model boundaries is minimal, and yet small enough so that processes throughout the ecosystem are relatively uniform.

The three geographically separate food web models, one for each of the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands, were based on the current definitions of these management regions (Fig. 1). This was selected as a primary division so as to model stocks on the same scale as the management of major commercial groundfish species. In general, these divisions correspond with the understood geographic ranges of many stocks. However, within each of these regions are multiple biogeographic subareas delineated by oceanography or bathymetry (e.g., NRC 1996). While a given stock may range across several of these subareas, the critical processes controlling production may vary between the subareas. Therefore, each of the three models was divided into subareas based on RACE survey strata, and the actual geographic area was limited to the continental shelf and slope (<1,000 m depth). Functional groups considered to be “local” are considered to consist of different populations in each modeled subregion. This effectively encodes predator depth and location preferences into the diet matrix; a species consuming copepods in one subregion alone is considered to be limited by the production in that subregion.

On a larger scale, many species, especially marine mammals but also commercial fish such as sablefish, move between regions or spend a significant portion of the year or their life cycle outside of a given model region. For the purposes of mass-balance modeling, rather than explicitly modeling immigration and emigration rates, biomass levels were weighted by the amount of time each such stock spends in each modeled region. Fisheries were included as they occur in the modeled regions. While this accounting is sufficient for building mass-balance models, further specification of imported diet and external fishing (feeding and fishing of species outside the model’s geographic boundaries) will be required for dynamic simulations.

1.2.2.1 Eastern Bering Sea

The mass balance model of the EBS continental shelf system is defined by the North Pacific Fishery Management Council (NPFMC) management areas between 500 and 531 (but does not include area 530), which coincide roughly with International Pacific Halibut Commission (IPHC) management areas 4C-4E (Fig. 1) in the EBS. The continental shelf and slope to approximately 1,000 m are included in the model following AFSC bottom trawl surveys. Unlike in the AI or GOA, nearshore areas of less than 50 m depth are included in the shallowest depth stratum for the EBS. Within the NPFMC management areas listed above, the area of the EBS shelf/slope covered by NMFS trawl surveys is 495,218 km^2 (Table 1). This total shelf area was used to calculate biomass and production per unit area as model inputs.

There are ten spatial strata in the EBS model: six on the EBS shelf, three on the northern Alaska Peninsula (“Horseshoe”), and one along the EBS slope (Fig 2a). The shelf habitat types are defined as “shallowest” habitats from 0-50 m depth, “shallow” habitats from 50-100 m depth, and “middle” habitats from 100-200 m depth. The entire EBS slope habitat ranges from 200-1,000 m depth. Habitats north of the Alaska Peninsula in the Horseshoe area are classified similarly to GOA and AI, with shallow, middle and deep regions referring to the 0-100 m, 100-200 m, and 200-500 m depth layers, respectively.

Table 1. Basic spatial information of the Eastern Bering Sea food-web model. Numbers in parentheses refer to percent of total area; areas as estimated by database manager in square kilometers.

Region	*NorthWest*	*SouthEast*	*Horseshoe*	*Total*
Depth (m)	*Areas 531,524*	*Areas < 520*	*518*	
Shallowest 0-50	41,330 (8.3%)	78,704 (15.9%)	4,026 (0.8%)	120,033 (24.2%)
Shallow 50-100	108,439 (21.9%)	103,920 (21.0%)		216,384 (43.7%)
Middle 100-200	95,218 (19.2%)	38,991 (7.9%)	1,849 (0.4%)	136,057 (27.5%)
Deep 200-500+	21,136 (4.3%)		1,607 (0.3%)	22,743 (4.6%)
	258,063 (52.1%)	229,673 (46.4%)	7,482 (1.5%)	495,218

1.2.2.2 Gulf of Alaska

The mass balance model of the GOA continental shelf system is defined laterally by the North Pacific Fishery Management Council (NPFMC) management areas 610, 620, 630, and 640, which coincide roughly with International Pacific Halibut Commission (IPHC) management areas 3A and 3B (Fig. 1) in the GOA. The continental shelf and slope to approximately 1,000 m are included in the model following AFSC bottom trawl surveys; nearshore areas of less than 50 m depth are not included. Within the NPFMC management areas listed above, the area of the GOA shelf/slope covered by NMFS trawl surveys is 291,840 km^2 (Table 2). This total shelf area was used to calculate biomass and production per unit area as model inputs.

There are nine spatial strata in the GOA model, representing three very general habitat types in each of three geographical sections (Fig 2b). The habitat types are defined as “shelf” habitats from 50-200 m depth, “gully” habitats from 100-200+ m depth, and “slope” habitats from 200-1,000 m depth. The distinction between “gully” and “slope” habitats is defined according to the trawl survey strata; in general, gully habitats are deep areas within the continental shelf surrounded by shallower shelf areas, whereas slope habitats are found at the seaward margin of the continental shelf. Management area 610 (which corresponds to the INPFC “Shumagin” areas and the NMML EAI and WGOA areas) is designated as the “Western GOA” in this model. Management areas 620 and 630 (corresponding to the INPFC “Chirikof” and “Kodiak” areas and the NMML CGOA area) is designated as the “Central GOA” in this model, and NMFS area 640 (INPFC “Yakutat”) is designated the “Eastern GOA” in this model.

Table 2. Basic spatial information of the Gulf of Alaska food-web model. Numbers in parentheses refer to percent of total area; areas as estimated by database manager in square kilometers.

Region *Depth (m)*	*Eastern* *640*	*Central* *630 and 620*	*Western* *610*	*Total*
Shelf 50-100	46,046 (15.8%)	112,721 (38.5)%	49,303 (16.9%)	208,070 (71.3%)
Gully 100-200+	4,150 (1.4%)	38,903 (13.3%)	6,525 (2.2%)	49,578 (17%)
Slope 200-1,000	7,005 (2.4%)	17,925 (6.1%)	9,262 (3.2%)	34,192 (11.7%)
	57,201 (19.6%)	169,549 (58.1%)	65,090 (22.3%)	291,840

1.2.2.3 Aleutian Islands

The AI ecosystem model boundaries are defined laterally by the North Pacific Fishery Management Council (NPFMC) management areas 541, 542 and 543 respectively (Fig. 1). The model covers a total area of 56,936 km^2(Table 3). East to West it extends from 170˚ W to 170˚ E within which three regions are recognized:

Eastern area: from 170˚W to177˚W (roughly from Samalga to Tanaga Pass).

Central area: from 177˚W to 177˚E (roughly from Tanaga Pass to just west of the Rat Islands), and

Western area: from 177˚E to 170˚E (from W of the Rat Islands to Attu Island).

Note that outside a management context, the model covers only those areas generally referred to as central (Samalga to Amchitka Pass) and western Aleutian Islands (Amchitka to Attu Island). The vertical range of the model goes from surface level down to 500 m deep; with shallow, middle and deep regions referring to the 0-100 m, 100-200 m., and 200-500 m depth layers, respectively. Figure 2c shows a map of the geographical extent of the model while Table 3 summarizes area and layers basic statistics. For the halibut fisheries, area 4B as defined by the IPHC was used to estimate catches in the Aleutian Islands.

Table 3. Basic spatial information of the Aleutian Islands food-web model. Numbers in parentheses refer to percent of total area; areas as estimated by database manager in square kilometers.

Region	*Eastern*	*Central*	*Western*	*Total*
Depth (m)	*541*	*542*	*543*	
Shallow	6,848	5,847	4,880	17,575
0-100	(12%)	(10%)	(9%)	(31%)
Middle	7,768	4,606	5,318	17,691
100-200	(14%)	(8%)	(9%)	(31%)
Deep	10,584	6,089	4,996	21,670
200-500	(19%)	(11%)	(9%)	(38%)
	25,200	16,542	15,194	56,936
	(44%)	(29%)	(27%)	

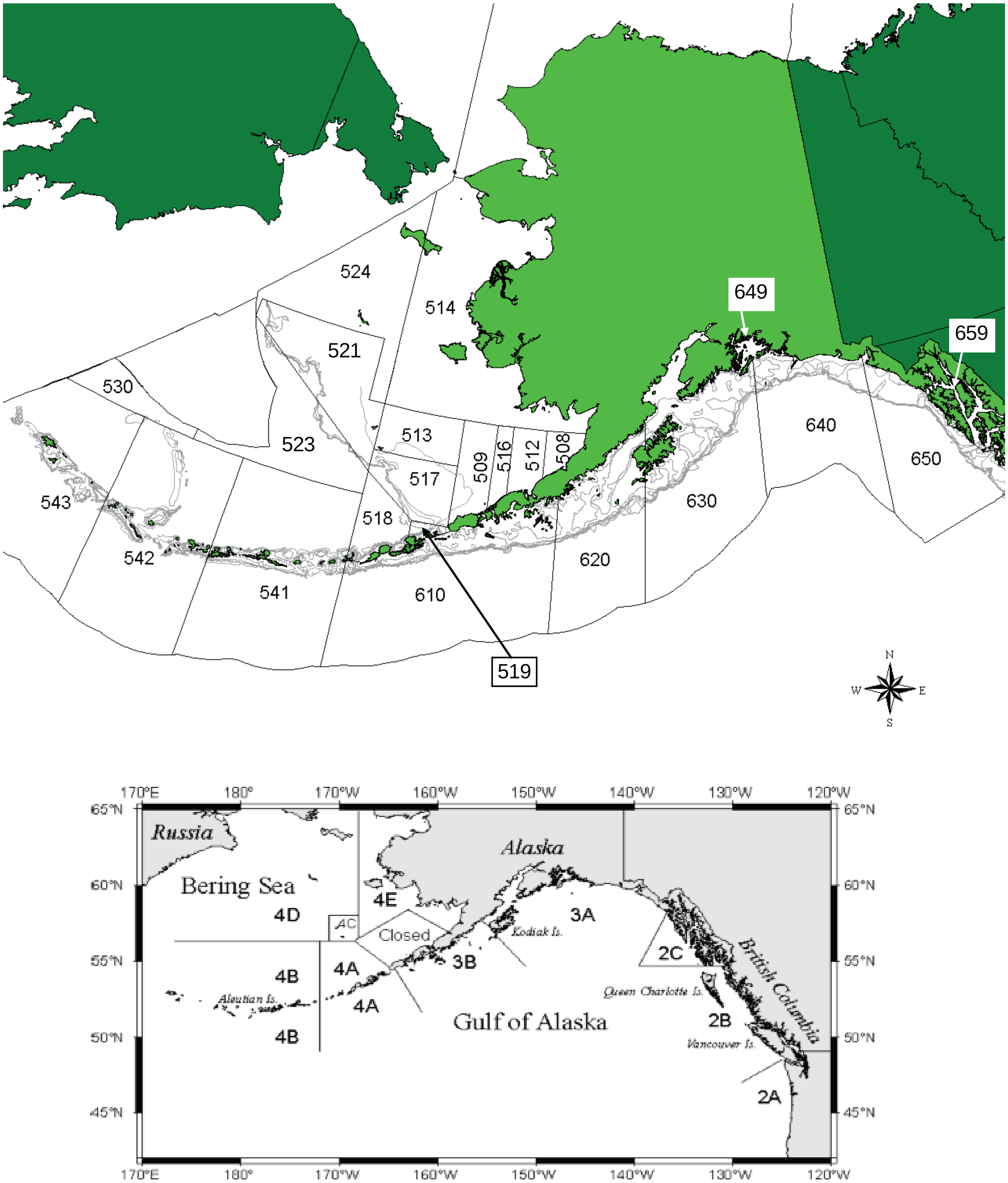


Figure 1. **Management areas included in the ecosystem models for the Eastern Bering Sea (EBS), Gulf of Alaska (GOA) and Aleutian Islands (AI). The maps show North Pacific Fishery Management Council (NPFMC) fishery management areas in Alaska (top) and International Pacific Halibut Commission (IPHC) management areas (bottom) in the North Pacific.**

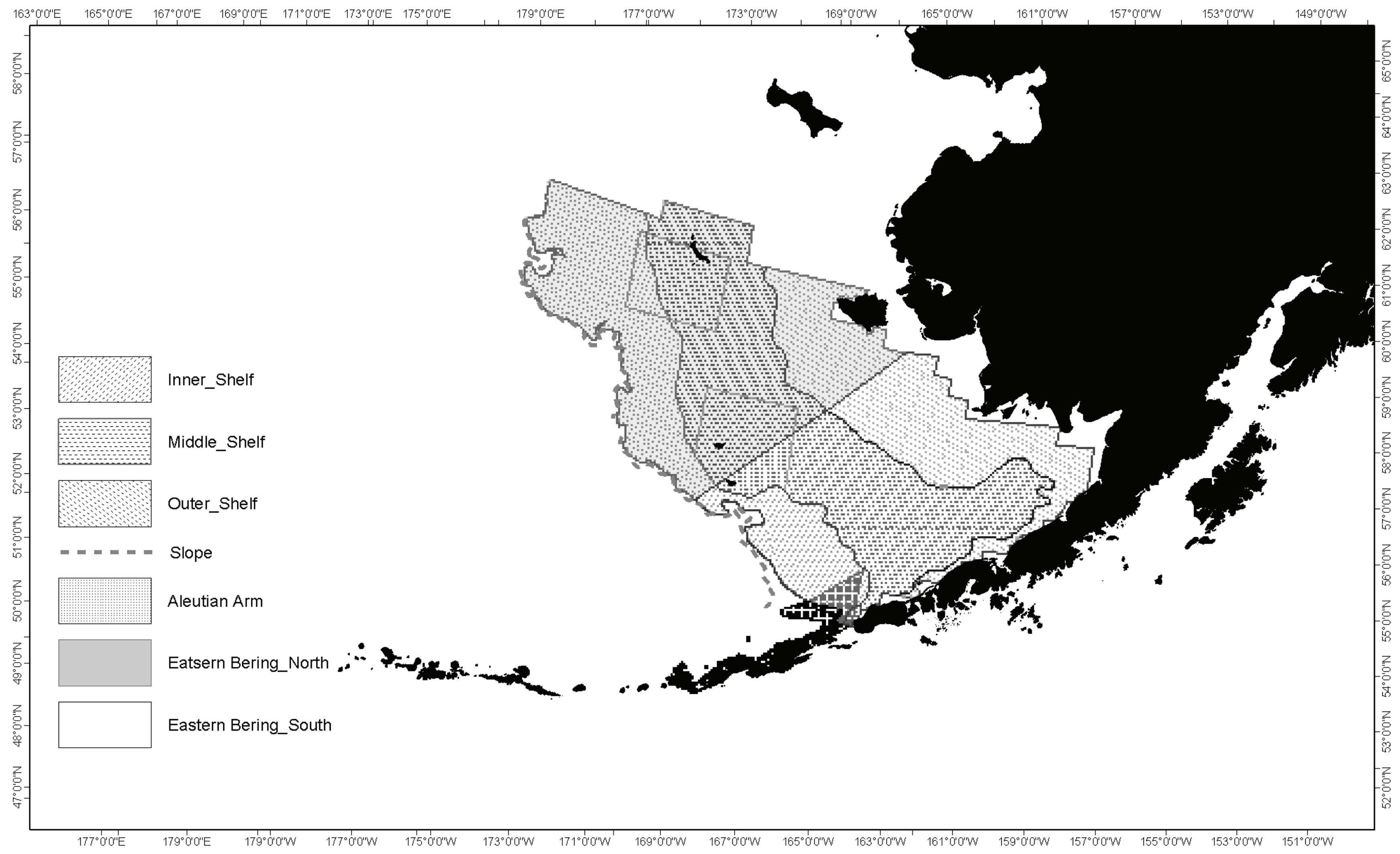


Figure 2a. Eastern Bering Sea model strata

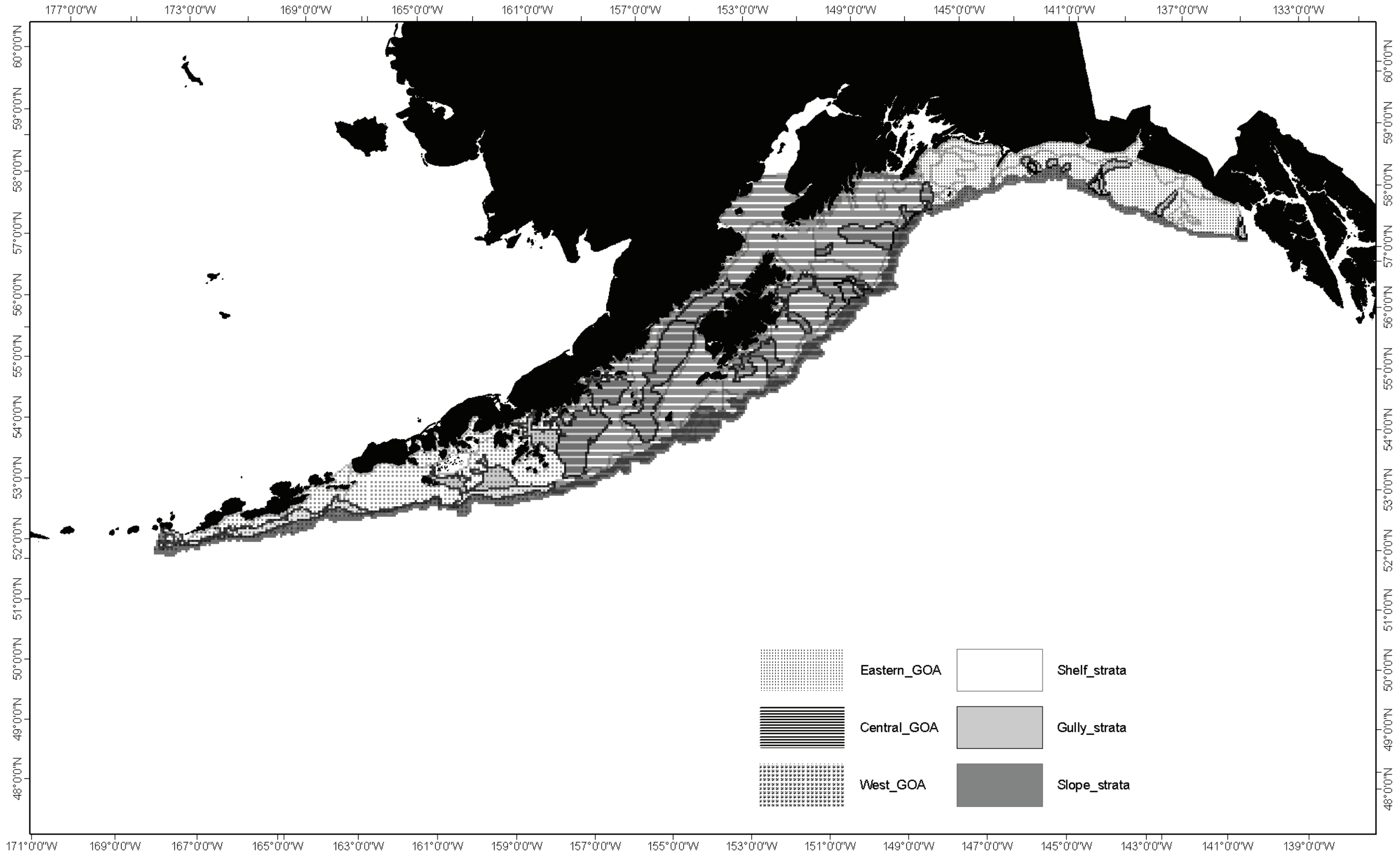


Figure 2b. Gulf of Alaska model strata

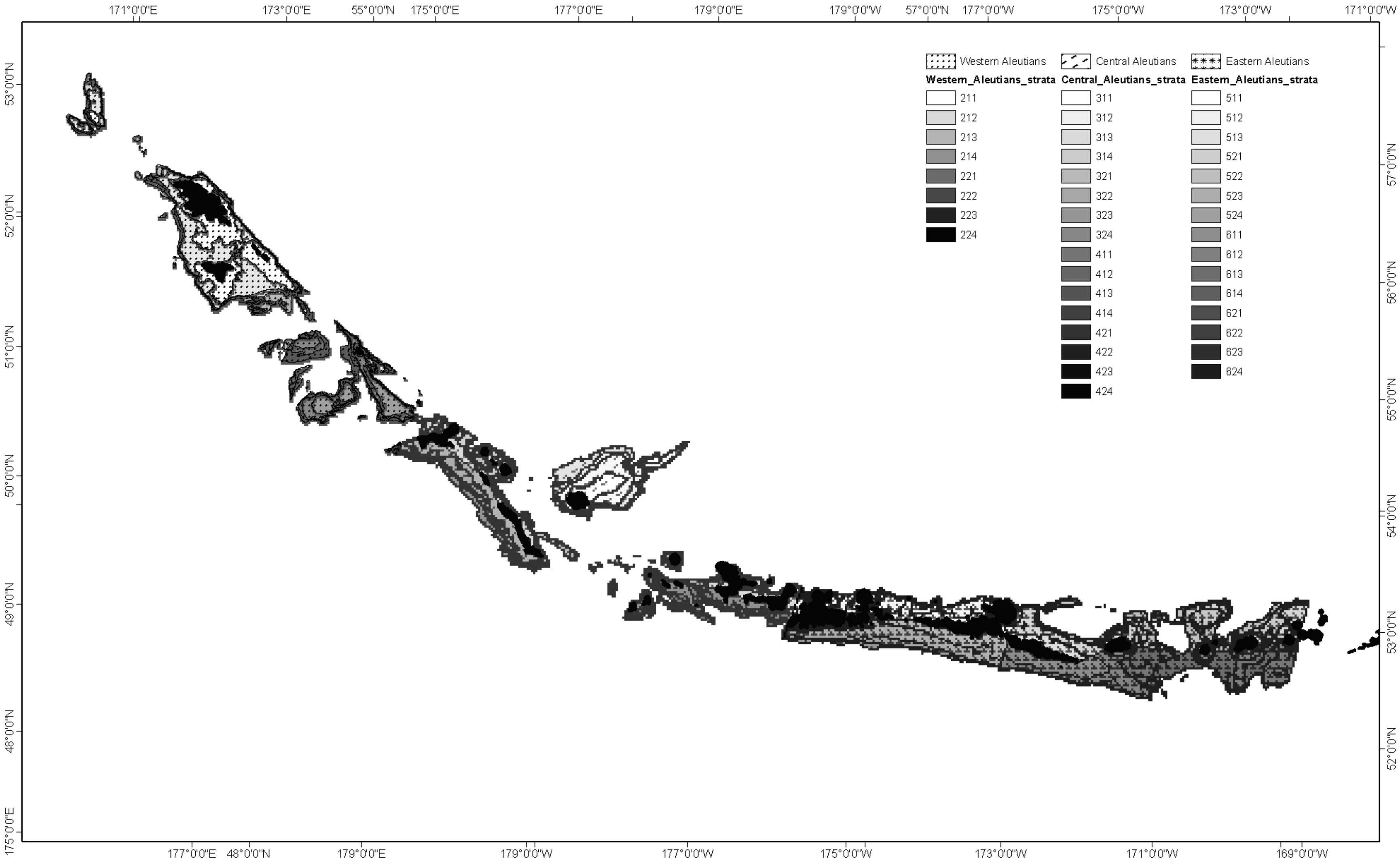


Figure 2c. Aleutian Islands model strata

1.2.3 Species breakdown and scale types

All individually modeled species groups are listed in Table 4. Note that these are the model group names, which do not always correspond to single taxonomic species. Full descriptions of the species included in each of these groups are found in Appendix A. Not all indicated species occur in all modeled regions (also described in detail in Appendix A). Species were categorized as one of either migratory (moving specifically across model boundaries), stock (primarily contained within each model's boundaries), complexes (stocks consisting of multiple species) or local (subpopulation/different species may occur in different subdomains of each of the three models). Further, species were modeled as either biomass pools or aged (initially split into juvenile and adult biomass accounting; this would be elaborated into a fully age-structured model during future dynamic simulations).

Juvenile groups were included to account for ontogenetic diet shifts and to represent age structure for protected pinnipeds and commercially important fish species. See Appendix A for detailed pinniped juvenile definitions. In general, we defined "juveniles" of each major groundfish species to be those individuals less than 20 cm long. This size threshold was based on observations of groundfish predator diets, where fish smaller than 20 cm were much more common in diets than those above 20 cm in length. Using a size threshold to define all juvenile groups means that the age of juveniles may vary by species. The approximate ages corresponding to juvenile groups for each species in these models are discussed in each species group description in Appendix A.

Pacific salmon (*Oncorhynchus* spp.) represent a unique model group, as a large proportion of the critical stages in their life cycle occur outside of modeled areas, and their presence occurs in compressed bursts of migration throughout the year. These bursts represent a large component of both food supply and predation, and yet their temporal compression prevents scaling their brief in-system growth rates to the remainder of their life cycle. Therefore, outmigrating and immigrating salmon are considered to be separate (unlinked) species and treated as an input parameter rather than a state variable for dynamic simulations. The substantial catch of incoming adult salmon is included in the EBS and GOA models, although this fishery operates differently than other modeled fisheries (terminal fishery). The AI model also includes a salmon fishery, although the salmon fisheries there (seine, gillnet and subsistence) are minimal (<24 metric tons (t) caught per year).

Table 4. Model groups.

Category	Group	Juvenile Group?	Model
Toothed Whales	Transient killer whales	no	all
Toothed Whales	Sperm and beaked whales	no	all
Toothed Whales	Resident killer whales	no	all
Toothed Whales	Porpoises	no	all
Toothed Whales	Belugas	no	EBS only
Baleen Whales	Gray whales	no	all
Baleen Whales	Humpback whales	no	all
Baleen Whales	Fin whales	no	all
Baleen Whales	Sei whales	no	all
Baleen Whales	Right whales	no	all
Baleen Whales	Minke whales	no	all
Baleen Whales	Bowhead whales	no	EBS only
Otters and Pinnipeds	Sea otters	no	all
Otters and Pinnipeds	Walrus and bearded seals	no	EBS only
Otters and Pinnipeds	Northern fur seal	yes	all
Otters and Pinnipeds	East Steller sea lion	yes	GOA only
Otters and Pinnipeds	West Steller sea lion	yes	all
Otters and Pinnipeds	Resident seals	no	EBS only
Otters and Pinnipeds	Wintering seals	no	EBS only
Birds	Shearwater	no	all
Birds	Murre	no	all
Birds	Kittiwake	no	all
Birds	Auklet	no	all
Birds	Puffin	no	all
Birds	Fulmar	no	all
Birds	Storm Petrel	no	all
Birds	Cormorants	no	all
Birds	Gulls	no	all
Birds	Albatross and jaeger	no	all
Sharks	Sleeper sharks	no	all
Sharks	Salmon sharks	no	all
Sharks	Dogfish	no	all
Aged Roundfish	Walleye pollock	yes	all
Aged Roundfish	Pacific cod	yes	all
Aged Roundfish	Pacific herring	yes	all
Aged Large Flatfish	Arrowtooth flounder	yes	all
Aged Large Flatfish	Kamchatka flounder	yes	EBS, AI only
Aged Large Flatfish	Greenland turbot	yes	EBS, AI only
Aged Large Flatfish	Pacific halibut	yes	all
Aged Small Flatfish	Yellowfin sole	EBS, AI only	all
Aged Small Flatfish	Flatnead sole	yes	all
Small Flatfish	Northern rock sole	EBS only	all
Small Flatfish	Southern rock sole	no	GOA, AI only
Small Flatfish	Alaska plaice	no	all
Small Flatfish	Dover sole	no	all
Small Flatfish	Rex sole	no	all
Small Flatfish	Miscellaneous flatfish	no	all
Skates	Alaska skate	no	all
Skates	Bering skate	no	all
Skates	Aleutian skate	no	all
Skates	Whiteblotched skate	no	all
Skates	Mud skate	no	all
Skates	Longnose skate	no	all
Skates	Big skate	no	all
Aged Deep Roundfish	Sablefish	yes	all
Deep Roundfish	Eelpouts	no	all
Deep Roundfish	Giant grenadier	no	all
Deep Roundfish	Pacific grenadier	no	all
Deep Roundfish	Other Macrourids	no	all
Deep Roundfish	Miscellaneous deep fish	no	all
Rockfish	Pacific ocean perch	GOA only	all
Rockfish	Sharpchin rockfish	no	all
Rockfish	Northern rockfish	no	all

Table 4. Continued.

Category	Group	Juvenile Group?	Model
Rockfish	Dusky rockfish	no	all
Rockfish	Shortraker rockfish	no	all
Rockfish	Rougheye rockfish	no	all
Rockfish	Shortspine thornyheads	GOA only	all
Rockfish	Other Sebastes	no	all
Aged Shelf Roundfish	Atka mackerel	yes	all
Shelf Roundfish	Greenlings	no	all
Shelf Roundfish	Large sculpins	no	all
Shelf Roundfish	Other sculpins	no	all
Shelf Roundfish	Miscellaneous shallow fish	no	all
Cephalopods	Octopus	no	all
Cephalopods	Squids	no	all
Forage Fish	Salmon returning	no	all
Forage Fish	Salmon outgoing	no	all
Forage Fish	Bathylagidae	no	all
Forage Fish	Myctophidae	no	all
Forage Fish	Capelin	no	all
Forage Fish	Sand lance	no	all
Forage Fish	Eulachon	no	all
Forage Fish	Other managed forage fish	no	all
Forage Fish	Other pelagic smelts	no	all
Shellfish	Tanner crab	EBS only	all
Shellfish	King crab	EBS only	all
Shellfish	Snow crab	EBS only	EBS only
Shellfish	Pandalid shrimp	no	all
Shellfish	Non-pandalid (NP) shrimp	no	all
Motile Benthic Epifauna	Sea star	no	all
Motile Benthic Epifauna	Brittle star	no	all
Motile Benthic Epifauna	Urchins sand dollars and cucumbers	no	all
Motile Benthic Epifauna	Snails	no	all
Motile Benthic Epifauna	Hermit crabs	no	all
Motile Benthic Epifauna	Miscellaneous crabs	no	all
Motile Benthic Epifauna	Miscellaneous Crustaceans	no	all
Motile Benthic Epifauna	Benthic Amphipods	no	all
Sessile Benthic Epifauna	Anemones	no	all
Sessile Benthic Epifauna	Corals	no	all
Sessile Benthic Epifauna	Benthic Hydroids	no	all
Sessile Benthic Epifauna	Benthic Urochordates	no	all
Sessile Benthic Epifauna	Sea pens	no	all
Sessile Benthic Epifauna	Sponges	no	all
Benthic Infauna	Bivalves	no	all
Benthic Infauna	Polychaetes	no	all
Benthic Infauna	Miscellaneous worms	no	all
Pelagic Zooplankton	Scyphoziod jellies	no	all
Pelagic Zooplankton	Fish larvae	no	all
Pelagic Zooplankton	Chaetognaths	no	all
Pelagic Zooplankton	Euphausiids	no	all
Pelagic Zooplankton	Mysids	no	all
Pelagic Zooplankton	Pelagic Amphipods	no	all
Pelagic Zooplankton	Pelagic gelatinous filter feeders	no	all
Pelagic Zooplankton	Pteropods	no	all
Pelagic Zooplankton	Copepods	no	all
Microbial Loop	Benthic bacteria	no	all
Microbial Loop	Microzooplankton	no	all
Primary Producers	Algae	no	all
Primary Producers	Large phytoplankton	no	all
Primary Producers	Small phytoplankton	no	all
Primary Producers	Outside production	no	all
Detritus	Discards	no	all
Detritus	Offal	no	all
Detritus	Pelagic detritus	no	all
Detritus	Benth detritus	no	all
Detritus	Outside detritus	no	all

1.3 New Information and Improvements Over Previous Models

We present the first comprehensive mass balance models for the GOA and AI ecosystems, and the EBS model presented here is substantially different from previously published mass balance models for the EBS (Aydin et al. 2002, Trites et al. 1999). These three models were designed to fully exploit the large amount and high quality of data available for Alaskan fisheries and ecosystems by including biomass pools for juveniles and adults of all major groundfish, for dozens of forage species, birds, and marine mammals, and for many detailed taxonomic categories within benthos and zooplankton. This resulted in models with 124-132 biomass pools, three to four times the typical number modeled in previous work. The detailed Alaskan fisheries catch data was used to define 14-16 fisheries in each model with a full suite of target and incidental species catch, both retained and discarded. This gives us the capability to evaluate ecosystem effects of bycatch mortality on nontarget as well as target species. In previous EBS models, fishing was included only as direct fishing mortality on target species; addressing the ecosystem impacts of a particular fishing fleet was not possible. In the current models, diet information from a wider range of species is included, and diets are weighted by biomass of consumers in survey spatial strata to account for diet differences across the vast areas modeled. We also employed a new method standardizing diet estimation for marine mammals and seabirds from literature sources. Finally, production and consumption parameters for many species were estimated based on detailed biological information including weight at age measured on surveys, rather than on empirical relationships. Finally, low trophic levels and detritus groups were modeled in more detail than in previous models: each Alaskan model has both benthic and pelagic microbial pools as well as benthic and pelagic detritus pools to separate these important processes. In addition, both phytoplankton and zooplankton groups were separated to clarify and test hypotheses regarding energy flow pathways between large and small phytoplankton and copepods, euphausiids, mysids and other pelagic groups.

1.4 Outline of Result Types

We use these three models and comparisons between them to describe and explore key food web relationships and potential fisheries interactions in each ecosystem. In the initial descriptive results, we present alternate ways of visualizing each ecosystem and its key energy flow pathways. Then, we show examples to demonstrate the uses of the food web models to provide single species indicators and statistics as well as ecosystem indicators and statistics. Single species indicators presented explore ecosystem relationships for walleye pollock (*Theragra chalcogramma*) and the pollock fisheries in each ecosystem. Three general types of ecosystem indicators are then presented. In the first, we demonstrate the variability in the ecosystem role of a key fished predator species, Pacific cod (*Gadus macrocephalus*), between the three food webs. In the second, we present differences in the consumption of key forage species between the three food webs. Finally, we present trophodynamic comparisons of biomass, predator consumption and fisheries catch, and the impacts of certain consumers on each ecosystem. Despite the similar modeling framework and construction of the models, the data from each system included in the analysis clearly defines differences in food web structure which may be important considerations for fishery management in Alaskan ecosystems.

2. Methods

2.1 Modeling Framework

2.1.1 Ecopath modeling

Ecopath is a food web analysis tool that has gained broad recognition as a methodology for assembling and exploring data on marine food webs (Polovina 1985, Christensen and Pauly 1992, Christensen et al. 2000). The implementation we used to prepare these models, Ecosense, was written by one of the authors (Aydin) based on Ecopath and Ecosim code provided by V. Christensen (University of British Columbia, pers. comm., 2003). The code was reviewed and modified for formal parameter estimation in Microsoft Excel, Visual Basic, and C++ development environments. The modifications were focused on (1) automating links between AFSC survey and assessment databases to allow consistent updating of the regional submodels on a regular basis; (2) implementing formal parameter estimation procedures (see section 2.2 and Appendix B); (3) appropriate spatial weighting of input biomass and diet data; (4) iterative estimation of diet composition from general “preferences” derived from literature where direct data were unavailable; and (5) incorporation of uncertainty within model outputs. We describe spatial weighting and “preference” diet estimation in Section 2.1.2., and estimation of uncertainty in Section 2.4.

Ecopath is a mass-balance model, built by solving a simple set of linear equations which quantify the amount of material (measured in biomass, energy or tracer elements) moving in and out of each compartment (functional group) in a modeled food web. A single functional group (food web compartment) may be a single species or a set of trophically similar species. The master Ecopath equation is, for each functional group (i) with predators (j):

$$B_i\left(\frac{P}{B}\right)_i * EE_i + IM_i + BA_i = \sum_j \left[B_j * \left(\frac{Q}{B}\right)_j * DC_{ij} \right] + EM_i + C_i \qquad \textbf{(1)}$$

The definition of the parameters in the above equation, and the general methods we used to derive their group specific values, are given in Table 5.

Table 5. Parameters (input data) and parameter calculation methods for the Ecopath master equation.

Parameter	**Abbreviation (units)**	**Parameter source**
Biomass	B (t/km^2)	Data or model estimate: Survey estimates, sampling programs, stock assessments; estimated by fixing EE if no data available
Production/ Biomass	P/B (1/year)	Data: Mortality rates, growth rates, bioenergetics models
Consumption/ Biomass	Q/B (1/year)	Data: Bioenergetics models, gut content analysis
Diet composition	DC (proportion by biomass/wet weight)	Data: Gut content analysis
Fisheries Catch	C (t/km^2)	Data: Fisheries statistics
Biomass Accumulation	BA (t/km^2)	Data: Biomass trend (only used if energetic demand requires it)
Immigration and Emigration	IM and EM (t/km^2)	Data: Used to specify annual net migration imbalance (not used in these models)
Ecotrophic Efficiency	EE (proportion)	Model estimate or assumption: Estimated by Ecopath; if no biomass data are available, EE is fixed at a standard level (0.8 here) to estimate biomass

In general, parameters can be either derived from data or estimated by the model; to solve the set of linear equations in Ecopath, the model will estimate one parameter given the values supplied for the other parameters. The preferred method when using the Ecopath model is to input all parameter values from independent data sources, except for ecotrophic efficiency (EE), for each functional group. Ecotrophic efficiency measures the proportion of a group's total production which is removed by mortality (consumption, fishing) on an annual basis within the ecosystem. Ecopath will estimate a vector EE values by solving the resulting set of linear equations, with EE as the unknown for each functional group, utilizing the generalized inverse method (Mackay 1981) to guarantee a solution. The estimation of EE is the primary tool for data calibration in Ecopath: independent estimates of consumption and production of different species often lead to initial conclusions that species are being preyed upon more than they are produced (EE>1.0), which is impossible under the mass-balance assumption (Christensen et al. 2000).

By using an EE greater than 1.0 as a diagnostic tool for error, it is then possible to assess the relative quality of each piece of input data to adjust inputs to a self-consistent whole. This process is known as "balancing" the model: it does not imply that the true ecosystem is in equilibrium but rather quantifies the uncertainty contained in the estimates of supply and demand present in the system. It should be noted that this is a "one way" criterion. If specified mortality on a species is greater than its production, the species is flagged as containing an error (EE>1.0), while if production is greater than specified mortality this is considered acceptable. This reflects the fact that it is possible and likely, even in a closed system, to have unspecified energy loss from a given compartment (such as due to disease or senescence for top predators) but it should not be assumed that there is unspecified energy gain.

In cases where biomass is unknown for a functional group, the EE for the group may be fixed (usually at a value between 0.8-1.0) and used to estimate the minimum biomass or production rate required to satisfy the consumption rates of the group's predators; this is known as a "top-down" balance. In our study, this "minimum production" method was used only in cases where no reasonable estimate of biomass was available for a group (Appendix A lists these groups in detail). A fixed value of 0.8 was selected for all such species: this value of 0.8 was chosen by trial and error to produce adequate detritus cycling within the models.

The mass-balance constraints of Ecopath do not in themselves require or assume that the modeled ecosystem is in equilibrium, but rather require that any directional component (known increase or decrease of biomass) be included in the mass-balance accounting through the biomass accumulation (BA) term. In our food webs, this term is used only in cases where known historical decreases in the biomass of species are required to provide sufficient energy for measured consumption and fishing in the rest of the ecosystem.

Within a modeled regime, it is assumed that the components of the ecosystem either (a) lie close (within the range of short-term process noise) to an attractive and relatively stable equilibrium for the given biomass levels and mortality rates, or (b) are subject to an explicitly specified directional trend as captured by inclusion of a Biomass Accumulation parameter. For species close to equilibrium, the system is not assumed to exist in this state in any given instant; rather, like a carrying capacity for an individual species, it is the state towards which the ecosystem would tend in the absence of driving perturbations (changes in fishing rates, climate, or other process-related noise). For extensions of these assumptions to non-equilibrium estimation see the section on dynamic modeling, below.

2.1.2 Improvements over standard ecopath models

Traditionally, Ecopath is set up so that there is only one set of input parameters (diet, removals, B, P/B, Q/B, and/or EE) for each functional group. The version used here has an option for intermediate subregional inputs for diet, biomass and/or EE. Depending on data availability for each functional group, the final diet was either as entered (if only regional data was available), or estimated by weighting the subregional diets according to biomass and/or area of the subregion(s). Likewise, biomass values were estimated either at a regional level or as the sum of the subregional values. The subregions used were based on RACE survey strata (Tables 1-3) and include depth (shallow, middle, and deep) and location (eastern, central and western) categories for nine to ten depth/location subregions total, depending on the model. The subregional inputs allow a wider range of data treatments: the traditional method assumes homogenous consumption/ production throughout the ecosystem; the most heterogeneous case considers functional groups as different populations in each modeled subregion, and effectively encodes predator depth and location preferences into the diet matrix, limiting consumption to the production in the subregion where it takes place.

Another difference with the standard Ecopath is the way the diet composition is partitioned among prey items for diets with poor taxonomic resolution. The standard method involves straightforward assignment of a fixed diet proportion to each functional group that was a prey item for any one given predator. This was possible when the diet composition data (regional or subregional) had equal or better taxonomic resolution than the functional groups in the model (e.g. groundfish diets). The second method, called "preference", was used when taxonomic resolution was poor (as for marine mammals and seabirds) and a given prey category could be assigned to several functional groups, giving rise to a "prey cluster" (e.g., the category "cephalopods" can be assigned to functional groups "squids" and "octopus" which together constitute the "cephalopod" prey cluster). The initial step of the preference method was to identify the functional groups that comprise a prey cluster; then the cluster was assigned a fixed proportion of the diet composition; finally, the proportion assigned to the cluster was partitioned among the functional groups based on availability to groundfish. The underlying assumption is that the more abundant prey are also more available for consumption, hence consumption is proportional to abundance.

2.2 Input Data and Parameter Estimation Methods

Input data include group specific values for the primary (and/or alternative) parameters B, PB, QB, (EE), DC, Catch (+ Discards + Offal), (Unassimilated consumption), and (Detritus fate). The modeling framework described below is designed to make use of data collected primarily for the purposes of single-species management, either from fisheries, or from marine mammal, seabird, or lower trophic level monitoring programs. Full details of the references for each parameter for each species are found in Appendix A.

Our intent was to use independent, field-based estimates of biomass for every model group; therefore, we prioritized using survey data over stock assessment model output to the extent possible. Groundfish biomass values are taken from RACE trawl surveys in 1979-2002 and, in the case of roundfish with low catchability to trawls, they are supplemented by stock assessment estimates. A full description of trawl survey methods is presented in Appendix B. Production and consumption rate estimates combine mortality estimates from literature and stock assessments with growth ranges measured from available REFM age-length or age-weight data, as described in Appendix B. Shellfish parameters were estimated from Alaska Department of Fish and Game (ADF&G) records listed in the Appendix A. Bird estimates were derived from colony counts provided by USFWS, with birds not nesting in the region being extrapolated from North Pacific-wide estimations. A full description of these methods by functional group is found in Appendix A.

Marine mammal estimations were performed in conjunction with researchers in the National Marine Mammal Laboratory (NMML) and represent their best current information on stock size and mortality rates for each species as provided by authors N. Friday (NMML) and D. Kinzey (University of Washington). Consumption and growth rates were calculated with a general marine mammal bioenergetics model detailed in the Appendix B; for pinnipeds these models were compared to more recent laboratory investigations.

Lower trophic level biomass and production estimates were primarily derived from literature values (specific to region) and supplemented with plankton models and data provided by AFSC Fisheries Oceanography Coordinated Investigations (FOCI) researchers and the results of several broad research programs as detailed in the Appendix A.

Diet data for groundfish were calculated from a detailed analysis of the REEM food habits database which included bootstrap estimation of diet uncertainty, as outlined in the Appendix B. Pinniped diets were supplied from literature with additional information contributed by E. Sinclair (AFSC, pers. comm., 2003), while cetacean diet estimates were obtained from a NMML review conducted by S. Harkness (AFSC, pers. comm., 2003). Diet for other species was provided from literature values obtained by the authors (Appendix A).

In many cases, especially for birds and mammals, literature diet data was only available to indicate predator preference between broad categories (between “roundfish” and “cephalopods” for example). In these cases, predators were assumed to consume the indicated percentages of each of these broader categories, but with neutral preference within the functional groups (i.e. the total percentage consumed of a broad category was allocated among the functional groups in proportion to their relative biomasses). This method is detailed in the in the preference diet Section 2.2.1 above, and Appendix B.

Fisheries catch and bycatch statistics were primarily derived from the NPFMC Blend database 1991-2002, with supplemental information included from state fisheries records (including indigenous catches), International Pacific Halibut Commission records, and bycatch analysis conducted for NMFS groundfish fisheries in its Final Programmatic Supplemental Environmental Impact Statement (PSEIS; NMFS 2004). A full description of the fisheries data is given in Appendix B.

2.3 Balancing Procedure with Data Quality Evaluation

An ecosystem is never frozen in a true equilibrium. A considerable body of literature suggests that variability in marine fish production and growth is influenced by oceanographic conditions (Francis et al. 1998). When available, the input data for the model includes year-specific estimates of production and recruitment, as measured by retrospective stock assessments and growth studies. As such, the starting conditions of the model, for stocks with good data coverage, are an implicit snapshot of the oceanographic variability and compensatory responses that contributed to each stock’s current biomass within the food web.

Given this background variability, thermodynamic limitations on production require that a mass-balance of materials between ecosystem components exists on some scale. Balancing the model, to ensure that EE values are less than 1.0 for each functional group, provides a powerful method for ensuring that data collected from species in an ecosystem, when assembled into a whole, satisfies fundamental thermodynamic constrains. It may be argued that this procedure requires model developers to force a changing ecosystem into an inappropriate static mould; however, the mass balance food web developed under these conditions is simply a “snapshot” in time. Taken at another time, the static snapshot would be different; this is why using data from the appropriate time period and updating models is necessary.

We performed the model balancing by proceeding from the highest to the lowest EE values that exceeded one; it was not uncommon for the initial estimation to produce EEs of 100 or greater (particularly for those functional groups with poor biomass estimates). If EE values of this range were assumed to represent actual biological shifts, it would imply species being reduced by a factor of 100 or more in a single year, which is biologically unreasonable in most cases.

The full changes made for the purposes of balance are detailed in the Results section below. Much of the initial balancing served to confirm whether sampling methodologies undersampled prey items. Other balancing issues focused on “edge” species, for example Atka mackerel exist in small quantities on the edge of the Bering Sea model region, so in reference to the dominant flows a trace diet consumption of Atka may scale into an “unbalanced” result.

To facilitate decisions on which input data to adjust, a grading scheme was used (Table 6) to rank the quality of the input data for all species groups in all three models. These data quality rankings, or data “pedigrees” for each model parameter, are reported for each species group in Appendix A. For groups with EE estimates exceeding 1.0, parameters with lower data quality rankings were adjusted as necessary (minimized or maximized to balance constraints) before parameters of higher data quality were considered for adjustment.

Table 6. Criteria for grading data quality (pedigree) for Biomass, P/B, Q/B, Catch, and Diet input parameters.

Rank and corresponding data characteristics	
1. Data is established and substantial, includes more than one independent method (from which best method is selected) with resolution on multiple spatial scales.	
2. Data is direct estimate but with limited coverage/corroboration, or established regional estimate is available while subregional resolution is poor.	
3. Data is proxy, proxy may have known but consistent bias.	
4. Direct estimate or proxy with high variation/limited confidence or incomplete coverage.	
Biomass and Catch	**PB, QB, and Diet**
5. Estimate requires inclusion of highly uncertain scaling factors or extrapolation.	5. Estimation based on same species but in “historical” time period, or a general model specific to the area.
6. Historical and/or single study only, not overlapping in area or time.	6. For PB or QB, general life-history proxies; For diets, same species in neighboring region, or similar species in same region.
7. Requires selection between multiple incomplete sources with wide range.	7. General literature review from wide range of species, or outside of region.
8. No estimate available (estimated by Ecopath)	8. Functional group represents multiple species with diverse life history traits.

After these corrections, only a few unbalanced functional groups remained in each system which could not be explained by poor data quality; in these cases a decline in these species over time had been noted from the data and was included as a Biomass Accumulation term.

When run as a dynamic model, Ecosim and Ecosense (described below) contain built-in compensatory density-dependent responses in recruitment and production. These responses may be fit with time series data, and Ecosense will allow for formal model selection between alternate density-dependent formulations. External variability, such as oceanographic change, will not be explicitly modeled in the initial formulation. However, hypotheses of external control mechanisms derived from other sources may be explicitly included for exploration or by examining the residuals of these responses.

2.4 The Ecosense Routines: Estimating Uncertainty

The “Ecosense” method is used to convey an appropriate level of uncertainty in presenting model results to managers; even if uncertainty is high, qualitative results can be clearly conveyed from a quantitative model using this method. At its basis, the method relies on this principle:

although much information is required to build a food web model and some of that information is uncertain, food web models must obey certain thermodynamic principles. For example, production at low trophic levels ultimately limits production at high trophic levels, and energy is always lost within and between trophic levels by respiration and incomplete assimilation; therefore an extremely high biomass of top predators in a system with low primary production is not possible. These thermodynamic requirements constrain the parameters used to describe the whole model within certain bounds; therefore, this "thermodynamic bounding" provides insights into the realistic range of values for uncertain parameters.

To incorporate both the information and uncertainty in the input data (initial model state and parameters) and the information gained by thermodynamic bounding within the food web model, we used a simplified Bayesian Synthesis approach (Aydin et al. 2003). Bayesian synthesis provides "a framework for combining evidence about both [model] inputs and outputs while reflecting the uncertainty about each (Givens et al. 1993)." While Givens et al. (1993) fit their population model to time series data, and compared resulting model outputs with informative prior information on the model outputs as well as the inputs, here we simply employ the information gained by thermodynamically enforced food web model structure in combination with informative prior distributions on input parameters. This method has the flexibility to include fitting to time series in future experiments, or to include independent information on model outputs should any become available.

To apply the Bayesian synthesis procedure, we followed four steps. First, we developed prior distributions on the model inputs and built 20,000 alternative realizations of the EBS, GOA, and AI ecosystems by sampling from these prior distributions. Second, we applied thermodynamic bounding to the alternative ecosystems using a persistence criterion to eliminate "impossible" ecosystems. Third, we used the remaining set of "possible" ecosystems to establish a range of baseline conditions within each of the EBS GOA, and AI ecosystems, incorporating both the uncertainty in the input parameters and the thermodynamic bounding. Finally, we perturbed the same set of "possible" ecosystems to establish a range of reactions to the perturbations which also incorporate both the uncertainty in input parameters and thermodynamic bounding. The steps are detailed below.

1. Prior distributions on model inputs

For each of the EBS, GOA, and AI, 20,000 simulated ecosystems were created using the following Monte Carlo process. Within the original models, the uncertainty in each of the static input parameters (B, P/B, Q/B, DC, and fisheries catch) for each functional group was assessed by a data grading procedure which gave each parameter an index of error between +/-10% (low uncertainty) and +/-90% (high uncertainty). This data grading procedure was consistent between regional models as it was the result of consensus between the authors (as described above). The 20,000 model dynamic ecosystems for each of the EBS and the GOA were alternative realizations of the original models created by drawing from distributions to select alternative parameters and then integrating these parameters within the EwE model equations. The parameters drawn were picked based on which dynamic parameters might be expected to be relatively independent within a single functional group. For each predator:

a) P/B (start) was selected from a Uniform distribution in the P/B error range;
b) Growth efficiency (GE, equal to P/B divided by Q/B) was estimated via Q/B selection from a Uniform distribution in the Q/B error range;
c) Each element of the predator's diet composition was selected from a Uniform distribution in the DC error range and re-normalized (giving each diet component a normal distribution);
d) Since the above three parameters are multiplied to determine the starting M2 for the predator's prey, the M2 component had a resulting log-normal distribution deemed appropriate for variable consumption/feeding data;
e) M0 was chosen from a uniform distribution around its original ECOPATH value using the P/B error range. Since ECOPATH sets M0 from EE to "balance" the dynamic equations, at the mean value for all input parameters, the system is in the original ECOPATH equilibrium; however by selecting M0 independently the system begins away from equilibrium;
f) The initial biomass of each functional group was chosen from a Uniform distribution with the B error range. Initial fishing rate F was not changed for any species in this experiment;
g) Parameters governing the recruitment interactions for groups with separate adult and juvenile pools (Appendix B, Table 7) were not perturbed for this experiment. For analyses presented here, we used standard Ecosim "split pool"recruitment dynamics for adults and juveniles (see Christensen et al. 2000 for details). While we do not plan to use this simplistic form of age structure for future dynamic simulations, we retained it here for comparison with previous modeling efforts which did employ split pools. Further, including rudimentary recruitment dynamics allowed us to examine the trophic impacts of our perturbations including a minimally realistic wide range of recruitment uncertainty for these commercially important groups.
h) Parameters for the Ecosim dynamic predator/prey functional response (vulnerability, passive respiration rate, foraging time; see Christensen et al. 2000 for details) were set to constant default values because independent sources of information are not available to assess appropriate error ranges, and we were interested in analyzing mainly the mass balance parameters for the purposes of this report. In these simulations, we set vulnerability = 2; foraging adjust rate = 0 (no foraging adjust); passive respiration rate = 0; handling time importance parameter = 0 (handling time unimportant).

2. Application of thermodynamic bounding

Each generated alternative ecosystem was tested for relative thermodynamic consistency to discard "impossible" states, such as excessive predator biomass without adequate supporting prey production. To achieve this, we assumed that an equilibrium state was likely to exist where all functional groups currently in the ecosystem persist with positive biomass, but without explicitly specifying the equilibrium as in EwE. Each generated alternative ecosystem model was run forward in time for 50 years using the dynamic equations of Ecosim (described in detail in Walters et al. 1997). The models began out of equilibrium, and 50 years was generally sufficient for transient effects to damp out and for models to approach within 10% of each model's unique equilibrium state. For each functional group, the year-50 biomass was examined relative to the starting value for each of the 20,000 alternative ecosystems. Investigation of the distribution of all 20,000 year-50 biomass values relative to starting biomass by functional group indicated that most functional groups had a bi-modal distribution of year-50 biomass, with one mode centered near the original (Ecopath) equilibrium biomass levels and a second, larger mode at zero. In other words, for a given functional group, a large subset of ecosystems no longer contained that functional group because it had “died out” of those ecosystems over 50 years. Examination of multiple functional groups across the whole set of ecosystems revealed that most of these extinctions resulted from the dying out of complete trophic levels. In other words, the lack, in most models, of an equilibrium state in which all functional groups had a positive biomass was not due to an ecological effect such as competitive exclusion within trophic levels resulting in “winners” and “losers.” Rather, it was due to drawing sets of parameters that were thermodynamically inconsistent, in that they represented evolutionarily unrealistic over-consumption of entire sections of the food web.

Based on this observation, an entire generated model was rejected if, after running forward for 50 years, at least one functional group had decreased to 1/1,000 of its original Ecopath biomass, or increased to 1,000 times its original Ecopath biomass. These criteria rejected over 90% of generated ecosystems from consideration and eliminated the lower (zero-centered) peak from all distributions of year-50 biomass. Rejecting such inconsistent models was seen to represent the addition of a thermodynamic constraint; this allowed the exploration of non-equilibrium initial states while guaranteeing that the model allowed the broad functional groups that existed in the original EBS and GOA models to persist over time. Thus, thermodynamic bounding eliminated over 90% of the 20,000 generated alternative ecosystems, leaving on the order of 900-1000 “possible” ecosystems for the EBS, GOA, and AI. These were deemed sufficient numbers of ecosystems for experimental baseline delineation and perturbations.

3. Baseline condition incorporating input uncertainty and thermodynamic bounding

Each of the “possible” ecosystems was run for 50 years (with time step of one year) with no perturbations to give a “baseline” distribution for each functional group’s output values of interest. In analyses presented here, total annual consumption (Q) was estimated for each predator and prey in the ecosystem. We averaged the last 10 years of output for the run for each ecosystem to smooth out the effects of oscillating species trajectories. The distribution of these 10 year average endpoints was then used to generate the “baseline” median and 95% confidence interval for each functional group in the EBS and GOA. These runs (and those below) were automated within Ecosense.

4. Perturbations incorporating input uncertainty and thermodynamic bounding

To determine the role of Pacific cod within each ecosystem we employed a perturbation which reduced cod survival to determine the effect on all other groups, then employed a perturbation which reduced all other group survival to determine the effect on cod. The difference between the perturbation and the baseline observed in each of the set of “possible” ecosystems (step 3 above) gives a distribution of perturbation results. The median of this distribution and the 95% confidence interval are reported.

For the forage fish comparison example, perturbations involved systematically increasing the production of a single functional group by 10% (via a 10% decrease in total mortality) in each “possible” ecosystem. The increased production remained in place for the entire 50 year run, during which time all other functional groups in the ecosystem were allowed to adjust to the perturbation. Therefore, there were as many perturbations as there were functional groups in each system: 135 in the EBS and 129 in the GOA. The results reported are the differences, for each functional group within each “possible” ecosystem, between the non-perturbed ecosystem average production over years 40-50 and the perturbed ecosystem average production over years

40-50. The difference between the perturbation and the baseline observed in each of the set of "possible" ecosystems (step 3 above) gives a distribution of perturbation results. The median of this distribution and the 95% confidence interval are reported.

2.5 Analysis of Mass-balanced Models

2.5.1 Visualizing and comparing ecosystem structure

Full food webs for each ecosystem were visualized using software developed by K. Aydin. (These visualizations are intended to show food web structure qualitatively but they do not incorporate uncertainty from the Ecosense routines.) We visualized benthic and pelagic energy pathways by aggregating the 140+ model groups into 30 common categories, of which 8 represent the main commercially important single species across each ecosystem; the other 22 categories are multispecies groups. The eight single species represented in aggregated visualizations were pollock, Pacific cod, Atka mackerel (*Pleurogrammus monopterygius*), Pacific ocean perch (POP, *Sebastes alutus*), yellowfin sole (*Limanda aspera*), snow crab (*Chionoecetes opilio*), arrowtooth flounder (*Atheresthes stomias*), and Pacific halibut (*Hippoglossus stenolepis*). The remaining categories are fisheries, pinnipeds, toothed whales, sharks, skates, large flatfish, piscivorous seabirds, baleen whales, planktonic seabirds, pelagics, small flatfish, sea otters, rockfish and deep fish, crabs, shrimp, benthic invertebrates, zooplankton, benthic microbes, benthic detritus, pelagic detritus, pelagic microbes, benthic algae, and phytoplankton.

The diet compositions were further aggregated to compare the relative importance of the main pathways across the Alaskan ecosystems. Prey items in the diet matrix were assigned to one of the following four categories: fish (includes all fish, marine mammals, seabirds and cephalopods), crabs and invertebrates (includes decapods and benthic invertebrates), plankton (includes jellyfish, zooplankton, phytoplankton and algae) and detritus (includes benthic bacteria, discards, offal, pelagic and benthic detritus, and outside detritus). These main categories were used to characterize the feeding habits of a species, the total consumption in the ecosystem and to classify the species themselves according to their diet. To classify feeding habits, for each species the diet was collapsed into each of the four categories mentioned above. The proportion of each category was multiplied by the total biomass of said species. Therefore, the biomass of one species is summarized as percent piscivorous, percent crabivorous, percent planktivorous, and percent detritivorous. To examine consumption, the diet for each species was collapsed into each of the four categories mentioned above, and the proportion of each category was multiplied by that species total consumption (biomass times Q/B). The total consumption of the species is thus summarized as percent fish, percent crab and other invertebrates, percent plankton, percent detritus. Species were classified into piscivorous, crabivorous, planktivorous or detritivorous according to the dominant (highest) prey category.

2.5.2 Ecosystem indicators and statistics

1. Ecosystem models for single species indicators and statistics, with cross system comparisons

We first present the relationships visually within the food web by highlighting a fishery or species group and each of its direct predators and prey, as well as the strength of the interaction.

We use the results of the static food web model to evaluate the trophic level (TL) and role of the species to place it within the continuum of apex predator to low trophic level prey. Then, we use the food web model to partition sources of mortality for a single species group. In this way, we evaluate fishing mortality relative to predation mortality and the remaining mortality not explained by the food web model to determine the extent of potential control of mortality by fishery managers. Sources of mortality are evaluated in terms of both proportion of total mortality for each group and in estimated annual tonnages consumed by other predators. We also evaluate the diet compositions of each group proportionally and in estimated tonnages of species consumed by that group. Uncertainty in these annual estimates of consumption was incorporated using the Sense routines described above. We use pollock as an example to demonstrate uses of ecosystem models to generate single species indicators and statistics, and compare these results across the AI, EBS, and GOA ecosystems. Detailed species group comparisons by ecosystem are also included along with the species group descriptions and data sources in Appendix A.

2. Ecosystem level indicators and comparative statistics

We also evaluate how sensitive each ecosystem is to changes in key species or species groups using the food web models, and how the AI, EBS, and GOA compare in terms of biomass and consumption characteristics. Pacific cod are used to illustrate the different ecosystem roles a single species can play, with different ecosystem implications arising from the same manipulation (an increase in mortality). Then, the three ecosystems are compared with respect to consumption of forage species, which illustrates important energy pathways present in each system. Finally, we look at a wide range of groups to compare general characteristics of biomass and consumption by trophic level across the three ecosystems. Trophic level (TL) for a given group is calculated as 1.0 plus the average of a group’s preys’ trophic levels, where primary producers and detritus groups have a TL = 1.0 (Aydin et al. 2002).

3. Results and Discussion

3.1 Quantitative Results, Model Balance, and Food Webs

Quantitative results of all three models are summarized in Appendix tables for easy comparisons. Results for the Biomass, EE, P/B, QB , and TL estimates are shown in Tables C1-C2 in Appendix C. Retained and discarded catch of each model group is shown in Table C3. Diet results are shown in Tables C4-C26 of Appendix C. Data quality ratings ("pedigrees") for each model parameter are shown in Tables C27-C29 of Appendix C. A detailed narration of parameter sources and data pedigrees, as well as brief overviews of comparative results for each species group is found in Appendix A.

3.1.1 Reconciling data sources to achieve balanced models

Our approach to balancing these food web models was to alter input data as little as possible. While many groups required no changes to input data, there were several balancing issues common to all three models. The biggest issue was one of inadequate survey biomass data, which was addressed by substituting either stock assessment biomass estimates, or a top-down balance for survey biomass estimates for unassessed species where it was clear that groundfish surveys would not adequately sample non-groundfish species. In general, top-down balance was applied to benthic invertebrates and pelagic forage species across the board. There were groundfish species which also appeared to have survey biomass estimates inadequate to supply consumption demand, and these were several rockfish species and pollock in all systems. The steps taken to address these inconsistencies are detailed below. Additionally, about 5-10 of the juvenile compartments used to model age-structured species were balanced in this manner as well. To prevent this top-down method from merely creating sufficient supply in the model to satisfy any indicated demand within the food web, microzooplankton and phytoplankton in the EBS and GOA, respectively, were modeled with direct production estimates. Lack of information prevented this for the AI model.

The top-down balance necessitated by current data limitations may create a bias in the models for forage fish and juvenile production estimates, specifically with respect to species such as sand lance, capelin, and myctophidae, and some crab and flatfish juveniles. While the constraints placed on the lowest trophic levels ultimately limit overall biomass estimates at mid-trophic levels, even those achieved by top down balance, we note that the resulting modeled biomass of each of these forage and juvenile groups represents the minimum amount required to sustainably satisfy the predators' demand for these species. This result does not in itself guarantee that such biomass levels exist in the system.

3.1.1.1 Model-specific balancing details: EBS

The EBS model has the highest quantity and quality of information of the three models due to extensive long term scientific study of this ecosystem. Fishery catch data in this ecosystem are of the highest quality because most large scale fisheries have 100% observer coverage in the EBS. Production and consumption parameter estimates were generally available from direct measurements or peer-reviewed literature for all groups. Diet information collected aboard NMFS surveys and from fishery observers is most extensive in the EBS. Two classes of groups were apparent in this and the other two systems; those with adequate biomass data from surveys or assessments, and those with inadequate biomass data. Of the 140 groups in the EBS model, 88 had adequate data to specify all parameters, resulting in “balanced” biomass pools. Of these 88, three groups (adult walleye pollock, adult Pacific cod, and adult Pacific herring) had inadequate raw survey biomass, but adequate stock assessment-estimated biomass to supply ecosystem consumption needs. We felt using the assessment biomass rather than the survey biomass was justified for these species in particular. For pollock and herring, the assessment incorporates hydroacoustic or aerial estimates and therefore is a better reflection of the substantial portion of fish that are distributed off the bottom. For cod, the difference between the survey biomass and the assessment due to catchability of the bottom trawl has long been noted and is a subject of ongoing investigation (e.g., Thompson et al. 2006). Of the remaining groups, 48 had inadequate survey or other independent information to determine biomass. These groups are either not sampled or are generally thought to be poorly sampled by NMFS trawl surveys, and include juvenile fish, cephalopods, forage fish, and benthic invertebrates. These groups with inadequate biomass data were “top-down balanced”; in other words, we estimated the minimum biomass necessary to supply the consumption requirements of all groups in the ecosystem by assuming that 80% of the production of each group is consumed. In all of these cases, the information derived from groundfish and marine mammal diets constituted the “best available data” on biomass for these poorly sampled model groups.

In general, NMFS trawl surveys were not expected to provide realistic biomass estimates for juvenile groundfish, cephalopods, forage fish, or benthic invertebrates. These surveys were not designed to sample small animals in any habitat or pelagic species; they were designed to sample the larger demersal groundfish managed by NMFS. However, there were a few cases where survey biomass estimates for minor managed groundfish groups were far too low to support ecosystem consumption demand and top down balance was required. In the EBS, these groups included sharpchin and northern rockfish, and the multispecies complex Other Sebastes. Rockfish occur in extremely small portions of the overall habitat of the EBS shelf and slope, and these habitats tend to be “untrawlable” by the NMFS survey gear, so trawl survey biomass estimates for these groups are generally thought to be underestimates of rockfish biomass.

The remaining four groups which had problematic data included dusky rockfish, juvenile Atka mackerel, adult Atka mackerel, and the multispecies group Miscellaneous flatfish. Miscellaneous flatfish include both groups that are well surveyed and other flatfish species that are not well sampled by the NMFS bottom trawl survey because they are distributed nearshore. Therefore, this entire group was top-down balanced, primarily because cod predation caused ecosystem demand to exceed supply based only on trawl survey biomass. Dusky rockfish have similar survey biomass problems as other rockfish in the EBS ecosystem, but top-down balance was considered undesirable for this species which has more fishing mortality than natural mortality due to a relatively small amount of fishery bycatch. No stock assessment estimate of EBS dusky rockfish biomass is available, but this species is assessed in the GOA. Therefore, the EBS survey biomass estimate for dusky rockfish was scaled up by the ratio of stock assessment estimated biomass to survey biomass for GOA dusky rockfish (1.6), based on the assumption that an assessment in the EBS might compensate for bottom trawl survey biases similarly. Adult Atka mackerel biomass in the EBS was also based on the stock assessment for another area, in this case the entire BSAI management area. The Atka mackerel assessment biomass for the BSAI was scaled down to reflect the percent of Atka mackerel occupying EBS model strata using the survey biomass in each stratum. Since there is little information on the biomass of juvenile Atka mackerel in either system, we assumed that juvenile biomass would be 10% of adult biomass in the EBS. This assumption could be addressed in the future if further information on Atka mackerel in the EBS becomes available.

3.1.1.2 Model-specific balancing details: GOA

Of the 132 biomass pools in the GOA model, unmodified input data resulted in “balanced” biomass pools (where consumption and fishery removals did not exceed production) for 80 of them, over 60% of model biomass pools. Of the 52 groups which did not immediately balance, 47 had inadequate survey information to determine biomass. These groups shared the characteristics with those in the EBS model in that they are either not sampled or are generally thought to be poorly sampled by NMFS trawl surveys. They are the same groups in both models: juvenile fish, cephalopods, forage fish, and benthic invertebrates, and they had the same assumptions for top down balance applied as in the EBS. However, as in the EBS model, there were a few cases in the GOA where survey biomass estimates for minor managed groundfish groups were far too low to support ecosystem consumption demand and top down balance was required. These groups included the single species group sharpchin rockfish, and the multispecies complexes Other Sebastes and Small sculpins. All of these fish either live in habitat which may not be sampled by a bottom trawl survey (e.g., rocky) or are too small to be retained by survey net mesh (small sculpins), or both.

The remaining five groups which did not immediately balance included spiny dogfish, adult walleye pollock, adult Pacific herring, the aggregate group Greenlings, and the detritus group Fishery Offal. In each of these cases the weight of evidence regarding reliability of each source of data was considered so that the least reliable data could be identified. In two of these cases (dogfish and offal), diet information of major predators of the group was considered unreliable and so was modified to achieve balance for the group. In three of these cases (pollock, herring, and greenlings), no clear source of poor data could be identified, so the model was balanced by incorporating observed negative biomass trends for these three groups. Information on biomass trends was derived either from stock assessments (pollock and herring) or from surveys (greenlings). Inclusion of biomass trends for pollock, herring, and greenlings are described in detail in each of their sections in Appendix A. The two groups requiring diet information modification for balance are discussed below.

NMFS trawl survey biomass estimates for spiny dogfish are considered fairly reliable. The majority of spiny dogfish mortality came from salmon shark predation when data were unmodified. Because salmon shark diet information came from a sample of only 11 animals caught within Prince William Sound, this diet information was considered less reliable than dogfish survey biomass data when applied Gulfwide. Therefore, the percent of spiny dogfish in the salmon shark diet was reduced from the original 7% to 1% to reflect the lower Gulfwide density of dogfish relative to high density areas such as Prince William Sound, and the percentage of squid in the salmon shark diet was increased from 1% to 7% which also reflects increased density of squid in the open Gulf relative to within the Sound. Ideally, salmon shark diet studies should be conducted outside Prince William Sound to determine whether this change was appropriate.

The maximum amount of fishery offal entering the ecosystem can be estimated using catch data and product recovery rates, so a consumption-based estimate for this biomass pool would be completely inappropriate. The major consumers of fishery offal in the GOA during the early

1990s, according to food habits data, were Pacific cod and sablefish. Sablefish diet information from the early 1990s was very sparse in several model strata where fishery offal consumption was also estimated to be very high, which resulted in offal comprising an apparent 25% of sablefish diet overall. Cod had better sample sizes for food habits in all GOA strata during the early 1990s, but in two of these strata the percentage offal was estimated to be anomalously high compared with other strata, comprising as much as 9-13% of cod diets in the central gully and central slope areas. For sablefish, more widely distributed field observations from the 2001 GOA trawl survey were consulted to determine a more realistic diet proportion of fishery offal, as well as a better estimate of gelatinous prey which can be difficult to evaluate in preserved food habits samples (T. Buckley, AFSC pers. comm., 2003). Based on this additional information, sablefish diets were adjusted so that fishery offal comprised 5% of diet, with higher diet percentages allocated to deeper water prey such as squids, jellyfish, and gelatinous filter feeders. For cod, we hypothesized that these high-offal diet samples collected in the central gully and slope strata might have coincided with areas with non-representative high concentrations of offal from offshore dumping of plant processing waste around Kodiak. Therefore, the percentage of offal in cod diets for these strata was lowered to reflect percentages observed in other model strata, resulting in a Gulfwide cod diet proportion of 3% fishery offal. While it is true that processing waste from Kodiak plants was dumped offshore during the early 1990s, we have no way to verify whether food habits sampling may have accidentally preferentially sampled cod foraging in these areas. However, these adjustments preserve the original trend in the unmodified food habits data which suggest that sablefish and cod are the primary consumers of fishery offal in the GOA. In the balanced model, offal is consumed about equally at 33% each by sablefish and cod, with lower consumption by halibut, pollock, Tanner crab, and arrowtooth flounder.

3.1.1.3 Model-specific balancing details: AI

The Aleutian Islands is perhaps the most data poor of the three ecosystems modeled, and required more adjustments to existing data than the EBS or GOA. Despite this, almost no diets were modified for balancing the AI model, but some biomass estimates were adjusted to balance groups where the main sources of mortality were reliable estimates of predation or directed fishing. The main source for biomass estimates were the bottom trawl survey data for 1991-1994 in the Aleutian Islands, followed by available databases and published data. For several of the functional groups which are distributed in far deeper waters, the 500 m depth limit of the trawl surveys only captures the upper portion of their habitat. For example, giant grenadier biomass was increased by an order of magnitude from the 1991-94 survey data based on the estimate from 1996 when deeper waters were included in the survey. Likewise, sablefish biomass in the eastern Aleutians was increased according to the biomass proportions in the catches, since sablefish are not caught in the eastern Aleutians during the surveys. Similar to both the EBS and GOA models, survey biomass of walleye pollock was inadequate to supply demand from predators and fisheries. As with sablefish, the AI bottom trawl survey estimates do not include the area where the pollock fishery takes place; therefore biomass estimates from the stock assessment for AI pollock were used. Finally, both salmon shark and dogfish biomasses were increased from their survey levels. Salmon sharks are rarely caught during survey trawls, thus their estimated bycatch far exceeds survey estimates. An independent regional population estimate for the North Pacific (Nagasawa 1998) was proportioned to the Aleutians to provide a more accurate estimate. The dogfish estimate was derived from a combined “shark” survey biomass estimate which was thought to include 3.6% dogfish and 96.4% sleeper sharks. There was no independent estimate of biomass for dogfish in the AI, so the original dogfish biomass based on the combined shark survey biomass was doubled, resulting in a minimal absolute biomass change but one sufficient to supply the relatively small predation and fishery demand in the AI.

In several cases where fishery bycatch initially resulted in excessive demand on certain groups, bycatch data was implicated as most uncertain because these bycatch estimates were extrapolated from more recent years than the model baseline. Such was the case for skates, where survey biomass had doubled from 1991-1994 to 1997-2000 (the years of the bycatch estimates). Bycatch estimates for mud, whiteblotched, Aleutian and Alaska skates were therefore cut by half to reflect a potentially lower population during the early 1990s. Corals were also initially out of balance due to bycatch. There is no biomass estimate for corals in the Aleutian Islands, so an estimate from the Gulf of Alaska had been used as a surrogate. Given the distribution of corals between the two ecosystems, this estimate turned out to be too low, and so it was increased by a factor of 8, the same factor by which coral bycatch in the Aleutians exceeds that in the Gulf of Alaska. Finally, top down balance was used for a similar set of groups in the Aleutians as in the EBS and GOA: poorly sampled benthic and pelagic fish groups, including Other macrouids, Miscellaneous deep fish, Miscellaneous shallow fish, Other Sebastes, rex sole, Miscellaneous flatfish, sharpchin rockfish, Other sculpins, octopus and squids.

Scyphozoid jellyfish were the only group where an initial imbalance was corrected by changing diets. Jellyfish make up a large proportion of the prowfish diet, and prowfish are the only source of information for the feeding habits of the entire miscellaneous shallow fish group. Because the diet of prowfish likely contains a higher proportion of jellyfish than all other members of this group, jellyfish were reduced in the overall diet. Furthermore, it was noted that the distinction between gelatinous plankton and jellyfish was not obvious when analyzing stomach contents. Hence, all instances where jellyfish were present in a diet, the percentage was reproportioned 50-50 between jellyfish and Pelagic gelatinous filter feeders. The combined effect of these changes brought the jellyfish back into balance.

3.1.2 Visualizing the food webs and primary energy flows

The EBS food web (Fig. 3a) quantifies biomass flow over 3,230 pathways between each of its 148 groups (including fisheries). In each of these plots, box size is proportional to biomass density and line width is proportional to energy flow between boxes. Groups are arranged in roughly the same locations for each ecosystem to facilitate comparisons. Trophic levels calculated within the food web model for each group, including fisheries, indicate that the halibut longline fishery is the highest “predator” in the EBS with a trophic level (TL) of 5.5. The indigenous mammal harvest and several other longline fisheries, including the rockfish longline, turbot longline, and sablefish longline, also occupy apex predator positions in the EBS food web with TLs over 5.4. The GOA food web (Fig. 3b) quantifies biomass flow over 2,969 pathways between its 138 total groups. Trophic levels calculated within the food web model indicate that the halibut longline fishery is the highest “predator” in the GOA with a trophic level (TL) of 5.4, with no other fisheries or predators approaching this trophic level. The AI food web (Fig. 3c) quantifies biomass flow over 2,676 pathways between its 140 total groups. As in the other two ecosystems, the halibut longline fishery is the apex predator in the AI with a TL of 5.4; the AI turbot trawl fishery has a similar TL. All food webs were visualized using the same plotting parameters, so the higher number of larger boxes in the AI web relative to the EBS and GOA webs indicates that there is less contrast in biomass density between the larger and intermediate groups. In the EBS, there is the greatest contrast between groups in biomass density, with fewer dense groups and many rarer groups. The GOA is intermediate, with a range of densities from large to small.

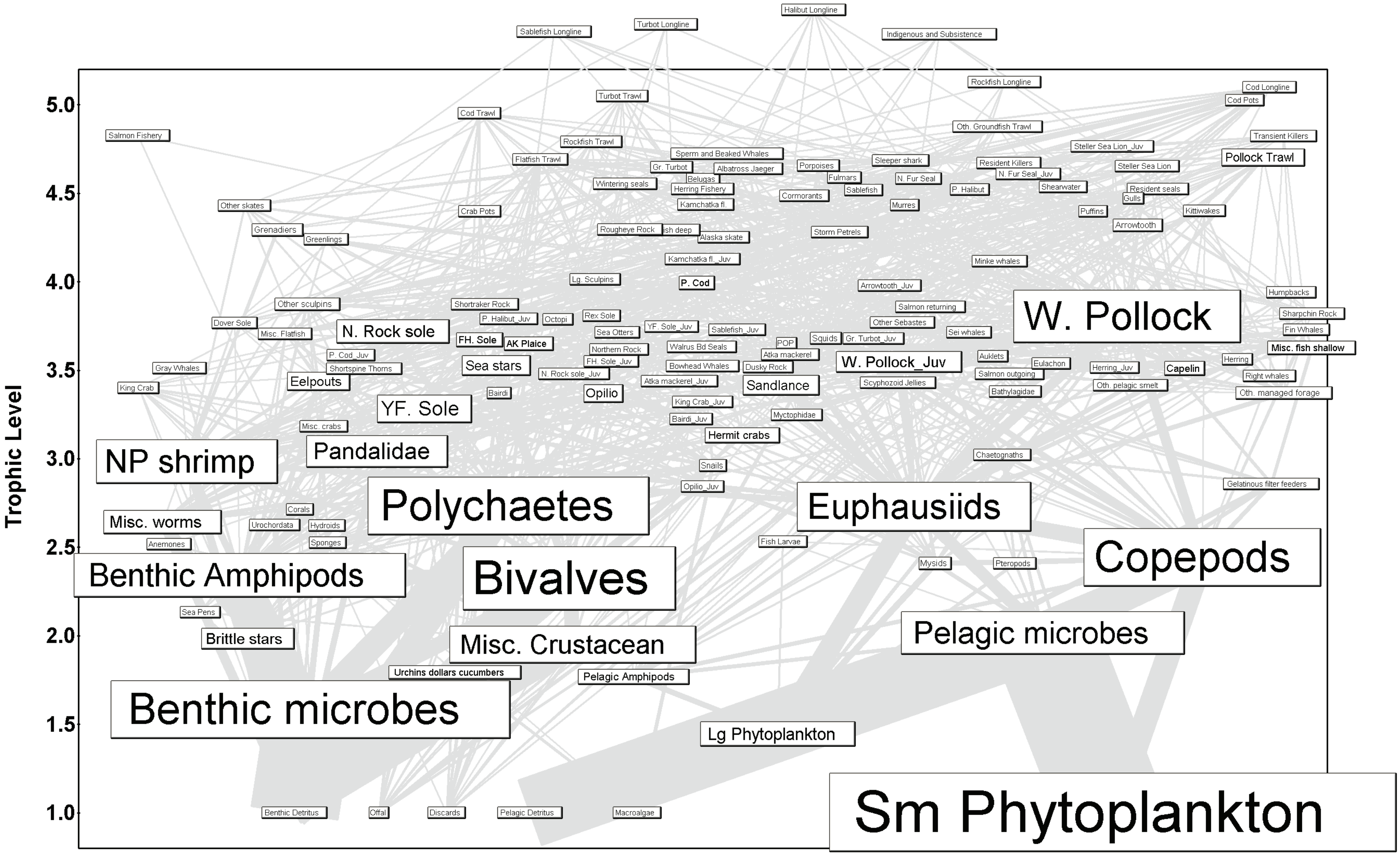


Figure 3a. Eastern Bering Sea food web.

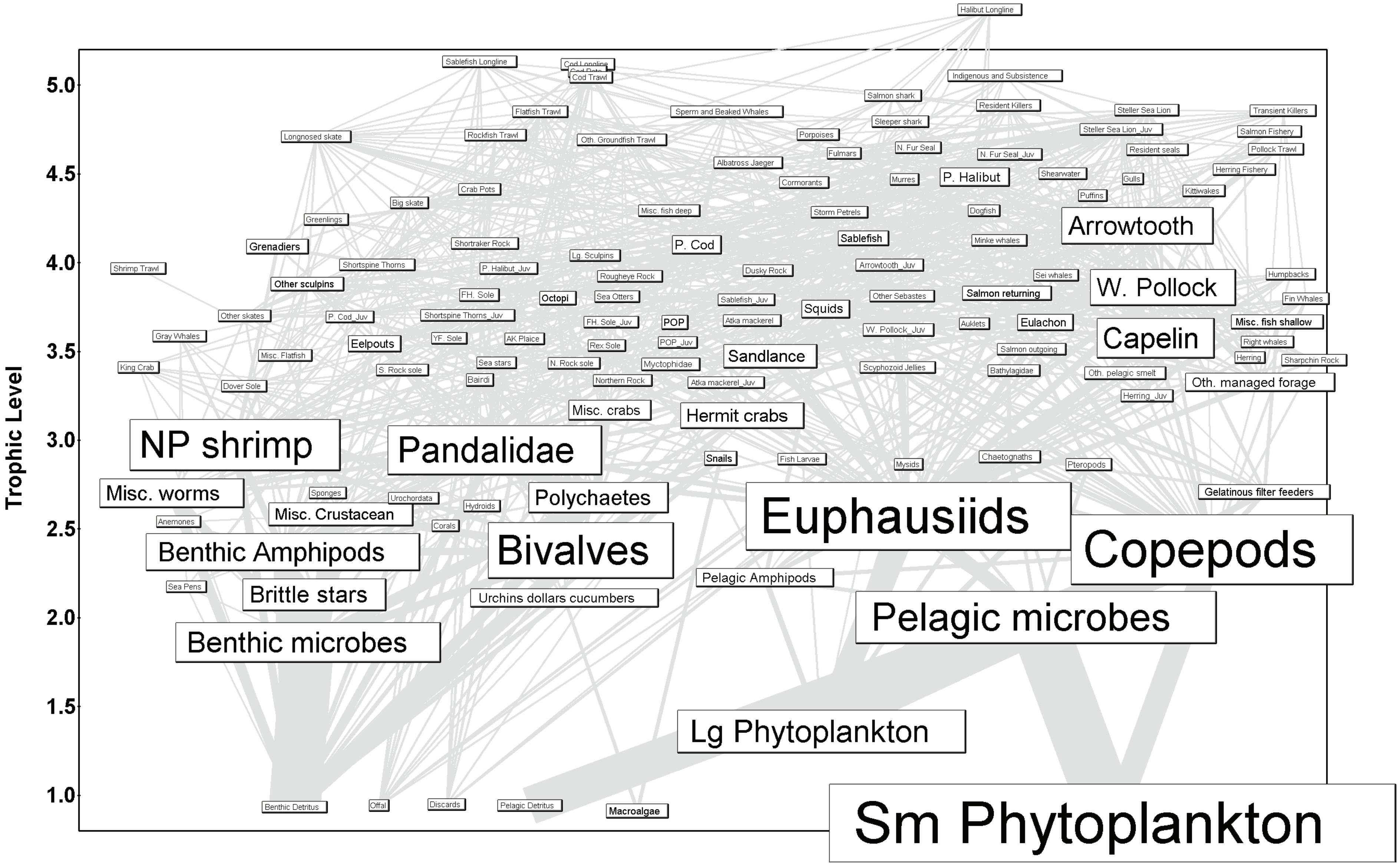


Figure 3b. Gulf of Alaska food web.

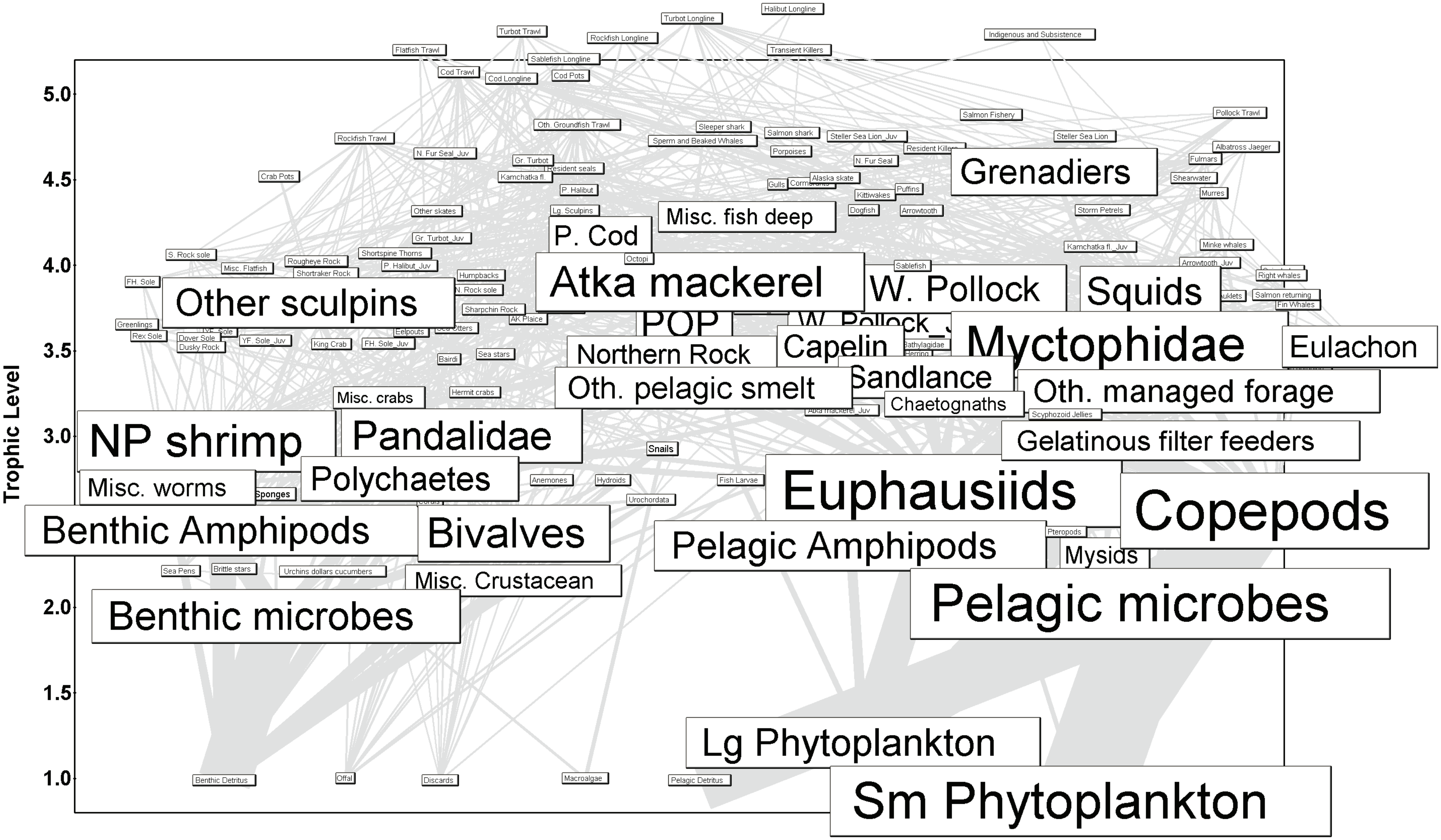


Figure 3c. Aleutian Islands food web.

Aggregating food webs by combining groups makes differences between the modeled ecosystems clearer. For this comparison, we aggregated the large models shown above into 22 functional groups plus the eight biomass dominant single groundfish species across the three ecosystems. The color blending in these figures shows the extent to which pelagic (blue) or benthic (red) energy flows into different biomass pools (Fig. 4 a, b, and c). Comparing these aggregated food webs, it is apparent that the EBS (Fig. 4a) has a much larger benthic influence in its food web than either the GOA (Fig. 4b) or the AI (Fig. 4c). The groundfish groups "small flats" and yellowfin sole, along with crabs and pollock, are dominant in the EBS. Conversely, the AI has the strongest pelagic influence in its food web relative to the two other systems. Notice in particular the aggregated "Rock/deep fish" group, which contains rockfish and grenadiers; in the EBS this group is mostly red, feeding in the benthic pathway, while in the AI this group is mostly blue, feeding in the pelagic pathway. Dominant groundfish in the AI occupy the pelagic pathway: Atka mackerel, and Pacific ocean perch (POP). The GOA appears balanced between benthic and pelagic pathways, but is notable in having a relatively smaller "biomass" of fisheries (catch) relative to the two other systems, and a high biomass of fish predators above TL 4, arrowtooth flounder and halibut.

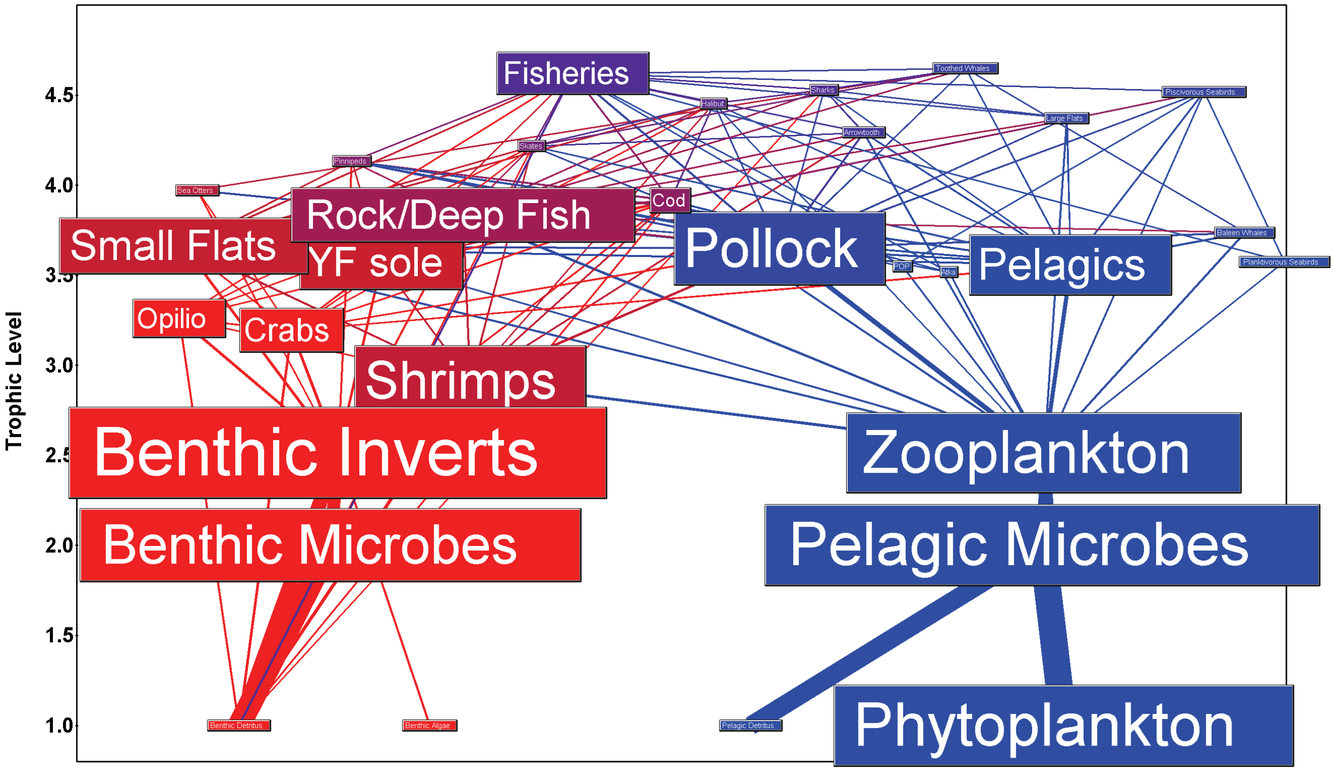


Figure 4a. Eastern Bering Sea aggregated food web benthic (red) and pelagic (blue) pathways.

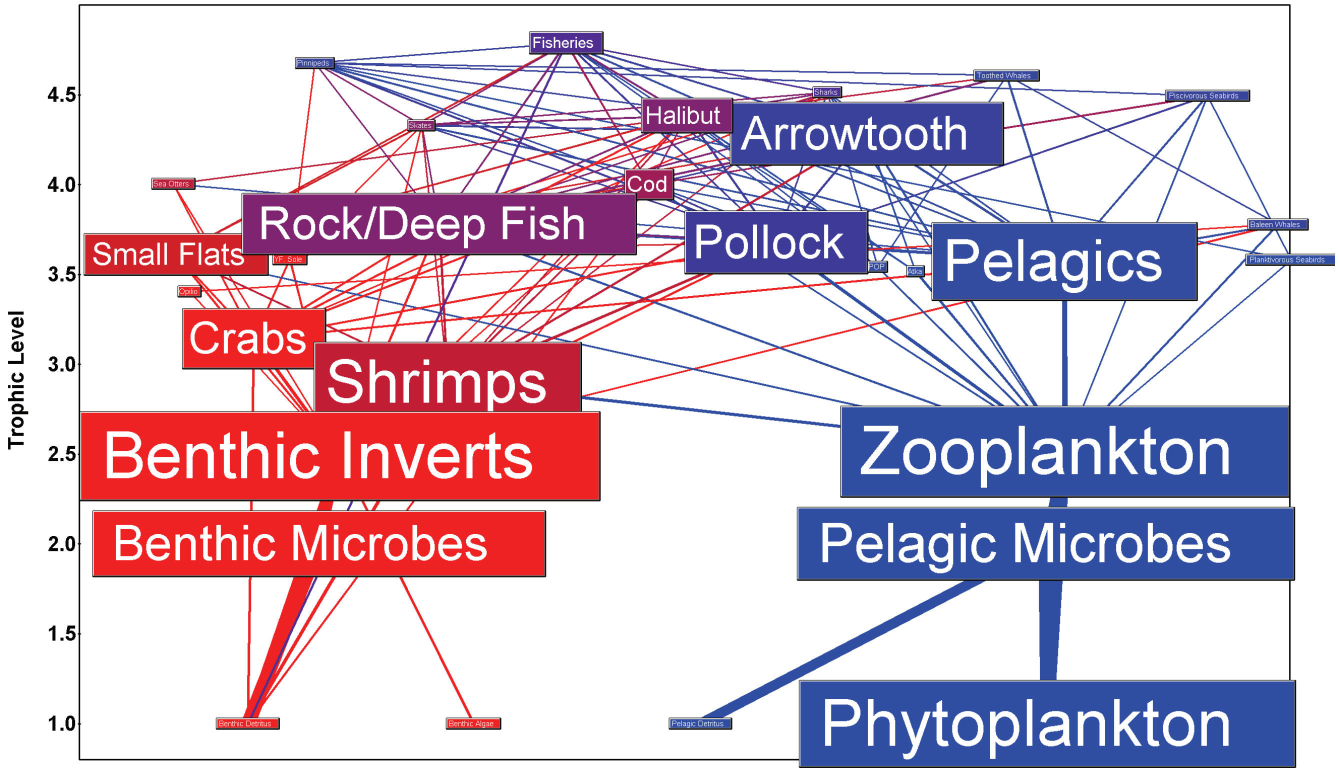


Figure 4b. **Gulf of Alaska aggregated food web benthic (red) and pelagic (blue) pathways.**

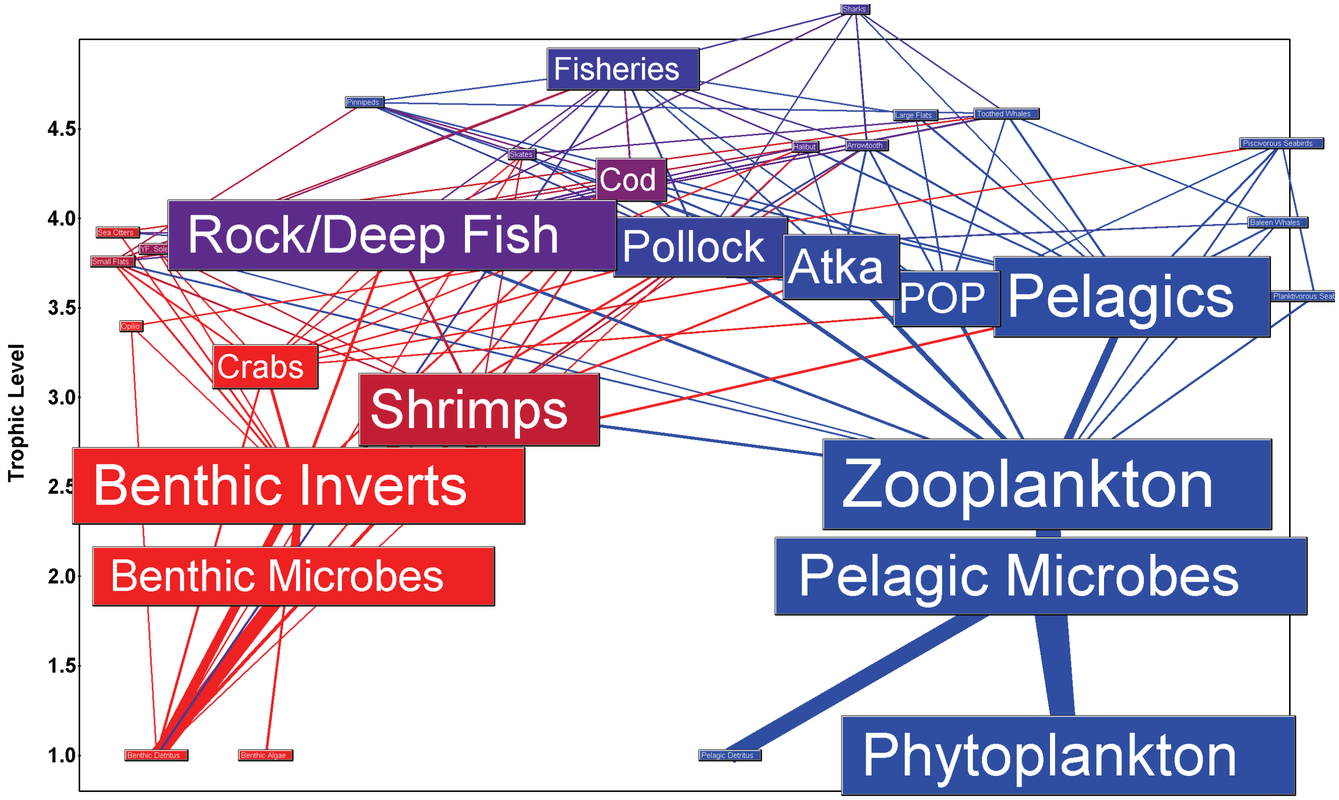


Figure 4c. **Aleutian Islands aggregated food web benthic (red) and pelagic (blue) pathways.**

By aggregating the groups further, the difference between systems is even more apparent. Consumption of major groups by prey category is shown in Figure 5. In the EBS, the consumption of detritus represents the largest portion of consumption, due to the strong benthic energy flow pathway in this system. In the GOA, consumption of plankton and detritus are nearly balanced, while in the AI, consumption of plankton is dominant due to the strong pelagic energy flow pathway. Although there are large biomasses of both piscivorous and invertivorous animals in each ecosystem, overall consumption of fish and large invertebrates amounts to less than 5% of the total in each ecosystem. Consumption of crabs and invertebrates differs by system as well, with the GOA highest at 3%, the EBS next at 2%, and the AI lowest at 1%. Piscivory is a small proportion of total ecosystem consumption in all three ecosystems, but is the highest proportion of the total in the AI (0.7%), followed by the GOA (0.5%), and then the EBS (0.2%).

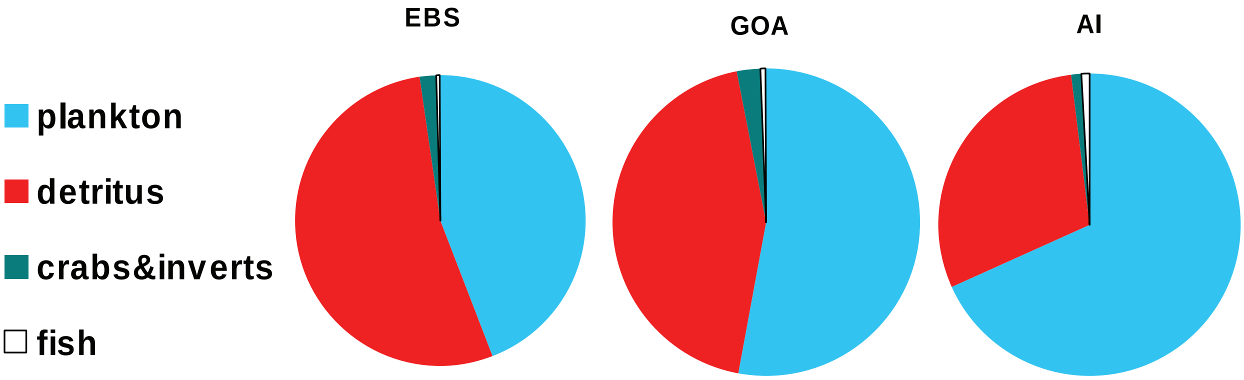


Figure 5. Proportion of total ecosystem consumption by prey classes in the Eastern Bering Sea (EBS), Gulf of Alaska (GOA) and Aleutian Islands (AI).

3.2 Single Species Indicators and Statistics

The food web models of each system allow comparisons of single species interactions across ecosystems. Here, we use walleye pollock (*Theragra chalcogramma*) to provide a detailed example of single species results, because it is a commercially important prey species in all three ecosystems. Using the web-accessible food web models, similar comparisons could be made for any group in the models. Brief examples of these comparisons by group are given in Appendix A following the species group descriptions.

In partitioning the mortality sources for each case study species between fishing and predation mortality, the food web model suggests a relationship between the relative importance of fishing mortality and trophic level (TL). High TL predators such as halibut experience the majority of their mortality from fishing (Fig. 6, left panel). In contrast, the lower TL pollock experience much larger predation mortality than halibut. In the EBS and GOA, predation mortality exceeds fishing mortality for pollock, even though pollock are a commercially exploited species (Fig. 6, right panel). Pollock experience so much predation mortality in the GOA that an “accumulation” term representing a declining biomass pool for the group must be included to account for the estimated consumption by pollock’s many predators.

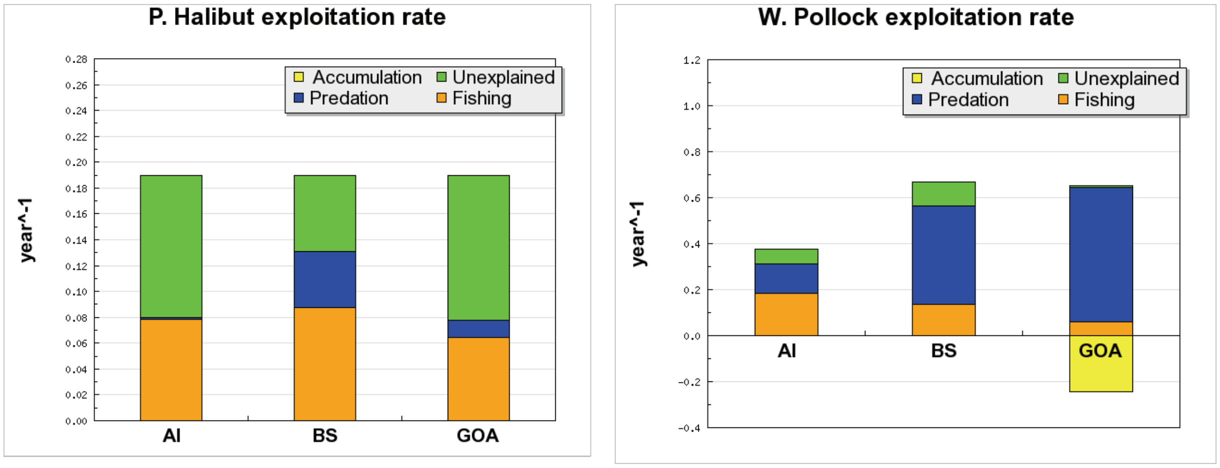


Figure 6. **Comparison of mortality sources by ecosystem: a high trophic level predator, Pacific halibut (left) and a mid-trophic level species, walleye pollock (right).**

When viewed within the food webs, the pollock trawl fishery (in red) is a relatively high TL predator which interacts mostly with adult pollock, but also with many other species (in green; Fig. 7a-c.). The diverse pollock fishery bycatch ranges from high TL predators such as salmon sharks, sleeper sharks, and arrowtooth flounder, to mid-TL pelagic forage fish and squid, to low TL benthic invertebrates such as crabs and shrimp in all three ecosystems, but all of these catches represent extremely small flows. Because the pollock trawl fishery contributes significant fishery offal and discards back into each ecosystem, these flows to fishery detritus groups are represented as the only “predator consumption” flows from the fishery; the biomass of retained catch represents a permanent removal from the system.

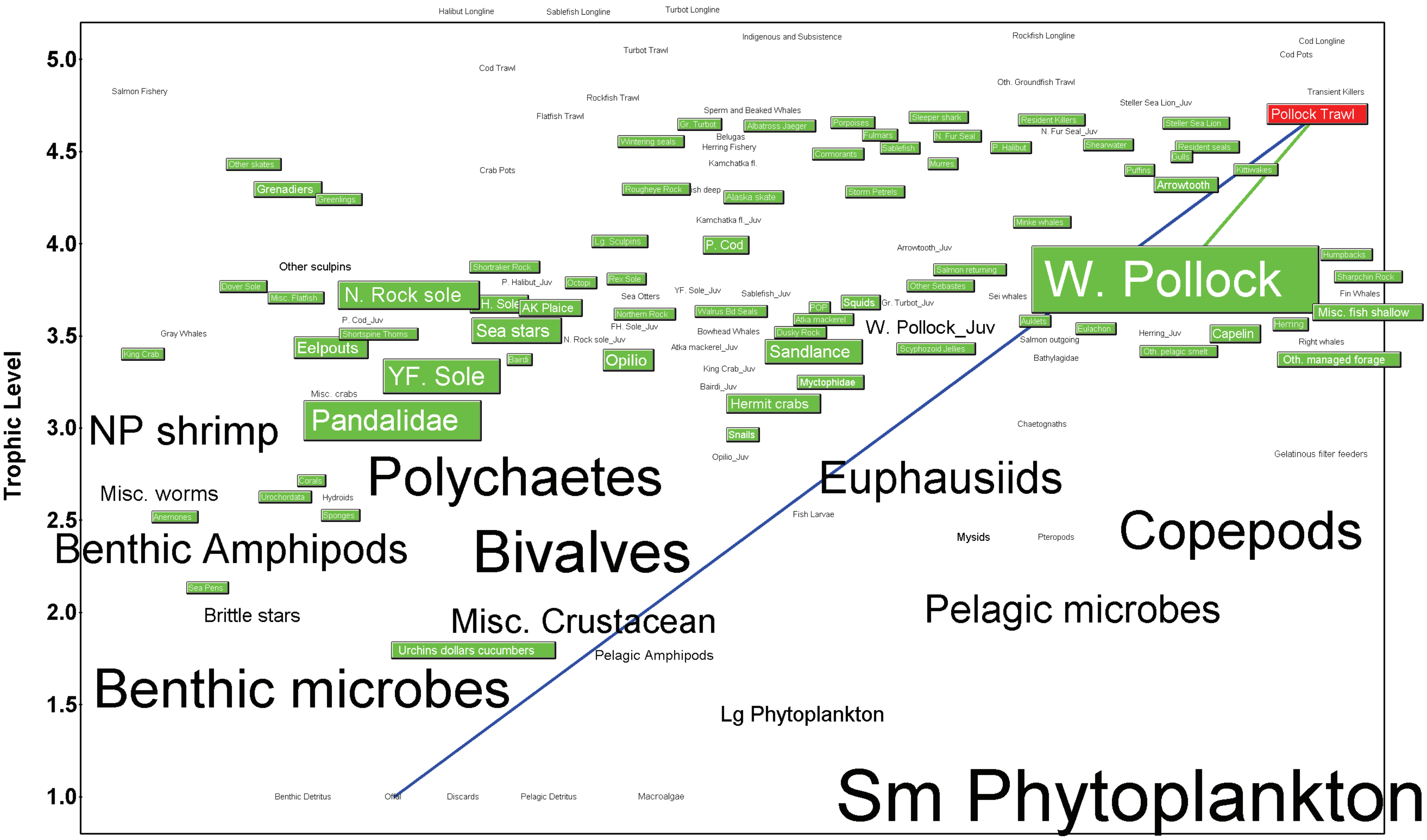


Figure 7a. Pollock trawl fishery in the Eastern Bering Sea food web.

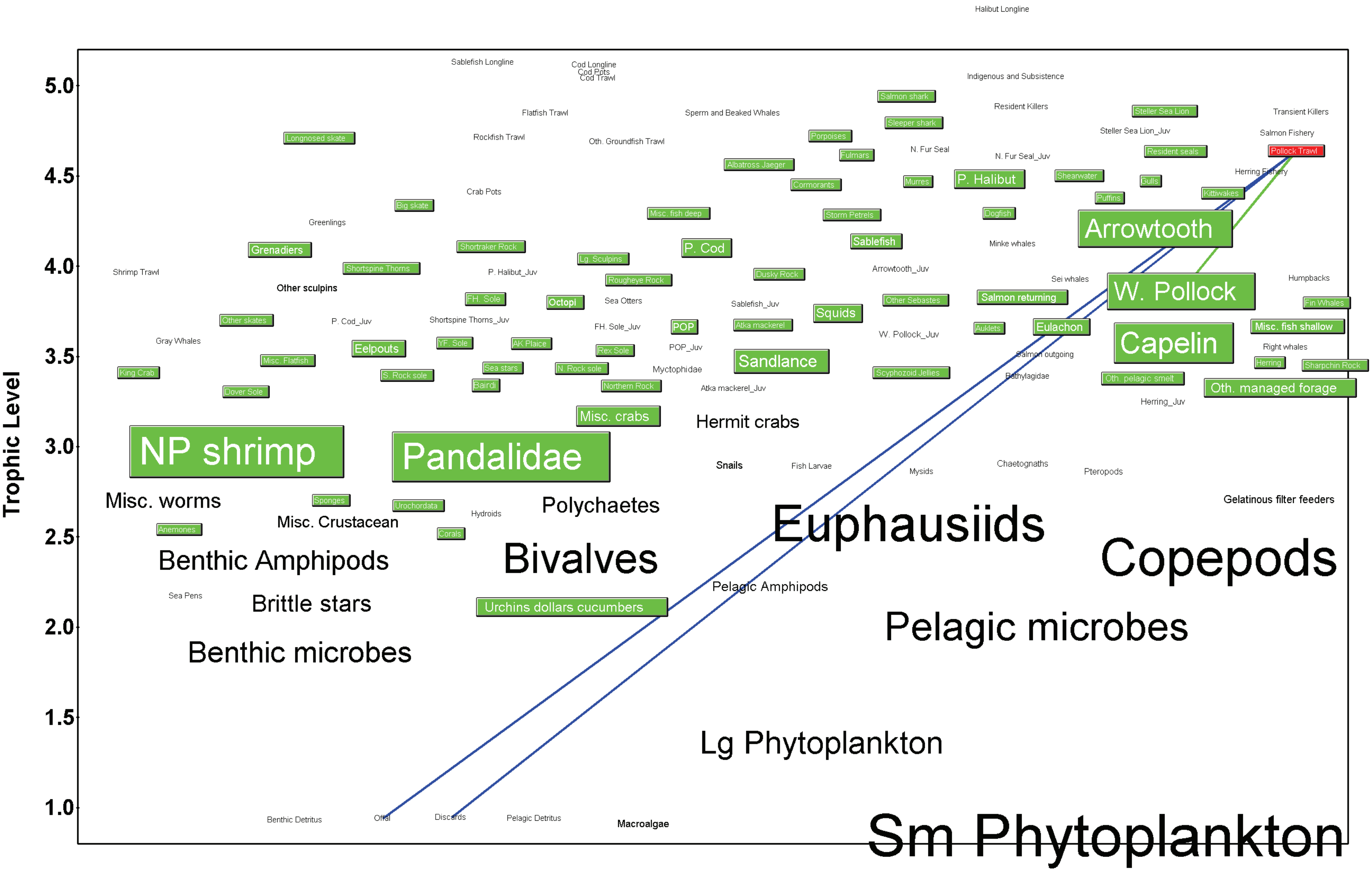


Figure 7b. Pollock trawl fishery in the Gulf of Alaska food web.

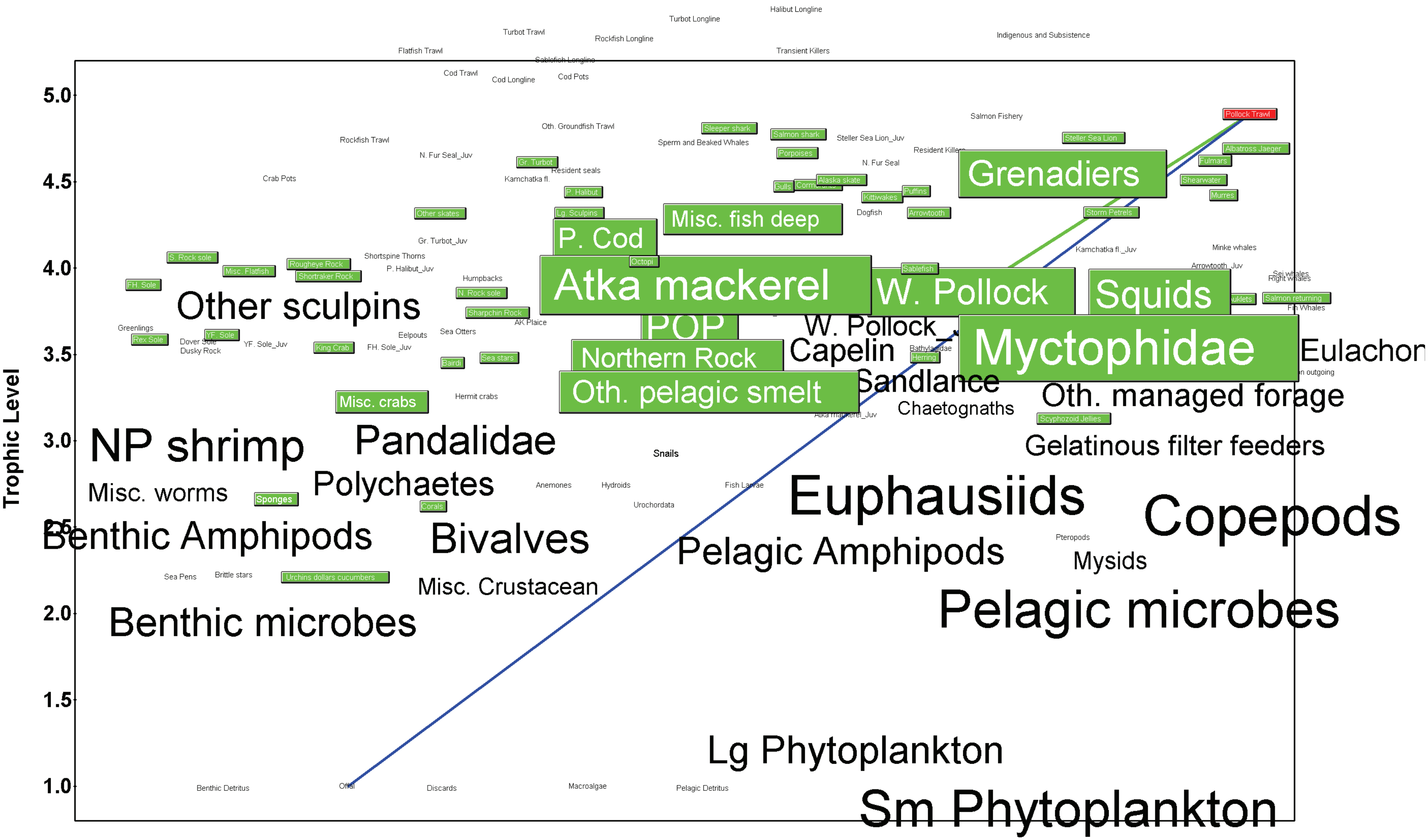


Figure 7c. Pollock trawl fishery in the Aleutian Islands food web.

In this set of models, we included detailed information on bycatch for each fishery. This data shows that the pollock trawl fishery is extremely species-specific in all three ecosystems, with pollock representing over 90% of its total catch by weight (Fig. 8 a-c). Other species caught in the GOA pollock trawl fishery include arrowtooth flounder and Pacific cod which account for 2% of total catch each. The remaining GOA pollock fishery bycatch consists of various flatfish and roundfish. In the EBS and AI, the pollock fishery catches an even higher proportion of pollock, with no single bycatch species accounting for more than 1% of the catch. Although these catches are small in terms of percentage, the high volume pollock fisheries still account for the majority of bycatch of pelagic species in the BSAI and GOA management areas, including smelts, salmon sharks, and squids (Gaichas et al. 1999, Gaichas et al. 2006).

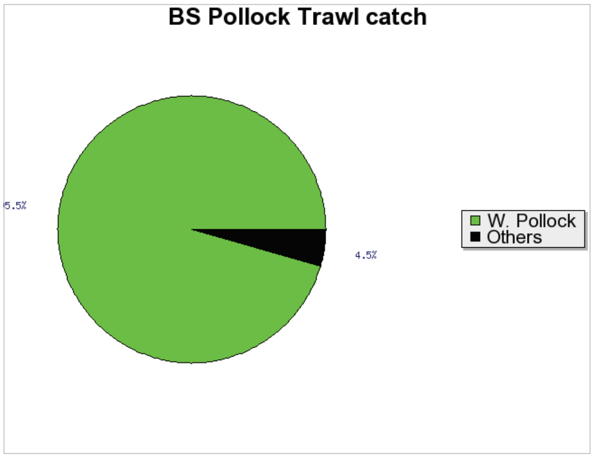


Figure 8a. Catch composition of pollock trawl fishery, Eastern Bering Sea.

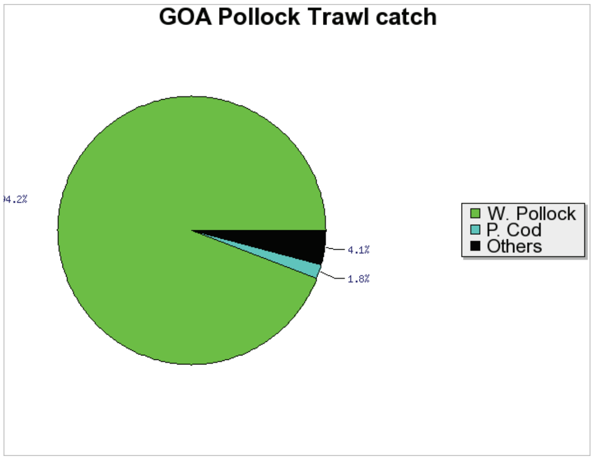


Figure 8b. Catch composition of pollock trawl fishery, Gulf of Alaska.

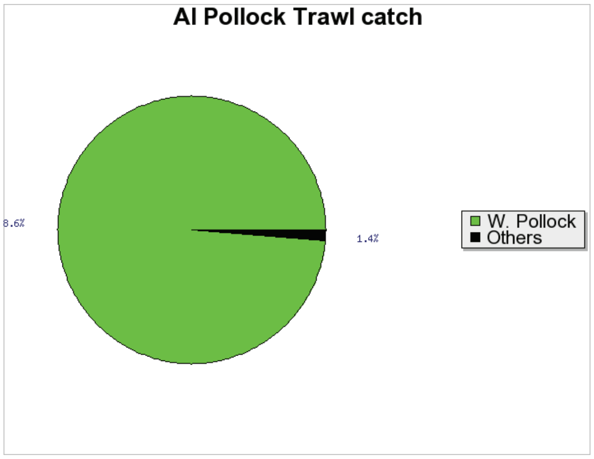


Figure 8c. Catch composition of pollock trawl fishery, Aleutian Islands,

The intended prey of the pollock trawl fishery is also a very important prey species in the wider EBS, GOA, and AI food webs. When both adult and juvenile pollock food web relationships are included, over two-thirds of all species groups turn out to be directly linked to pollock either as predators or prey in the food web model (Fig. 9a-c). In the GOA, the significant predators of pollock (blue boxes joined by blue lines) include arrowtooth flounder, halibut, cod, sablefish, Steller sea lions, humpback whales, and the pollock trawl fishery. Arrowtooth flounder, adult pollock, seabirds such as murres and puffins, and cod are significant predators of juvenile pollock. Significant prey of pollock (green boxes joined by green lines) are euphausiids, copepods, benthic shrimps, and amphipods, with juveniles preying on the euphausiids and copepods.

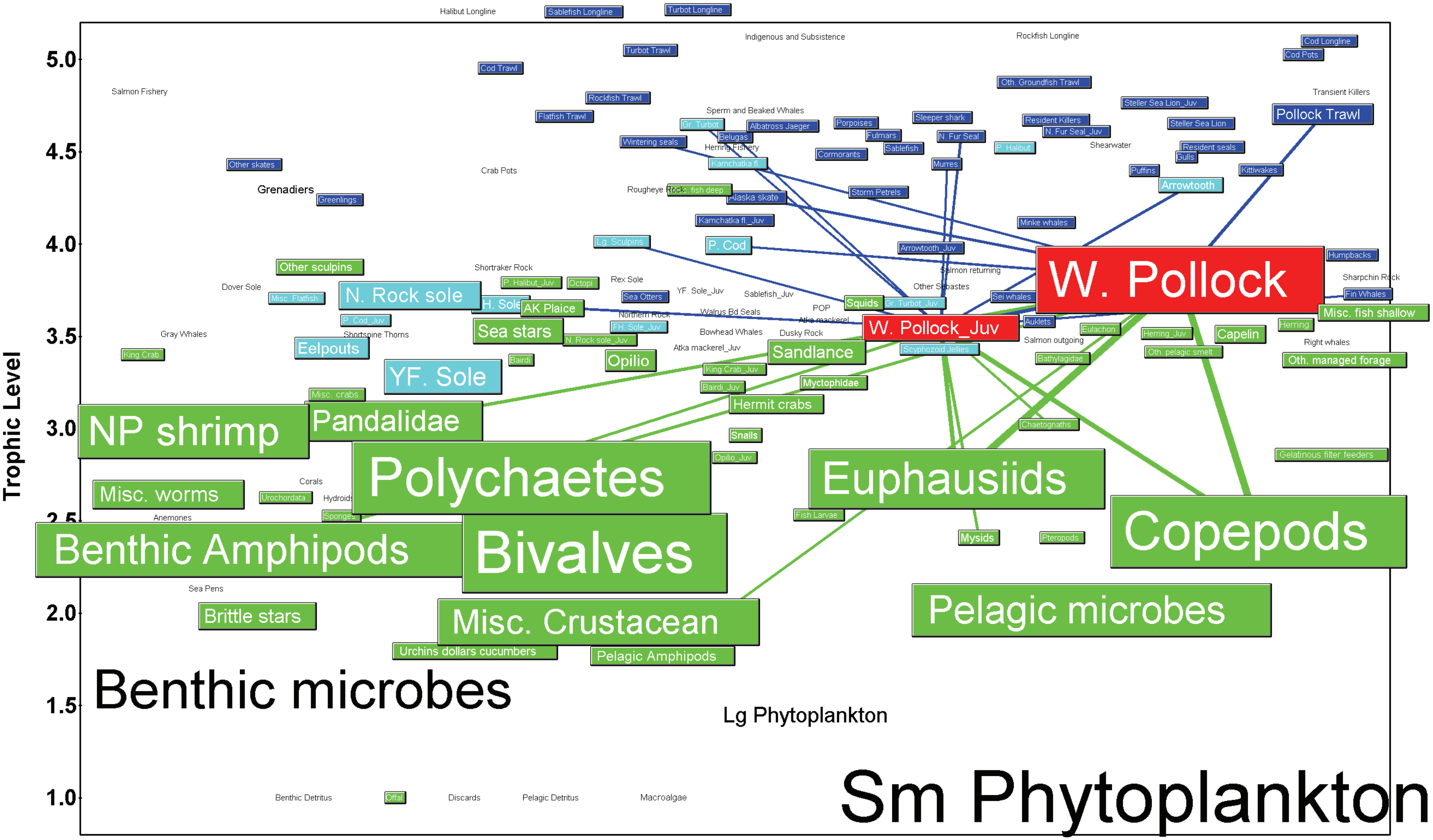


Figure 9a. Adult and juvenile pollock predators and prey in the Eastern Bering Sea food web.

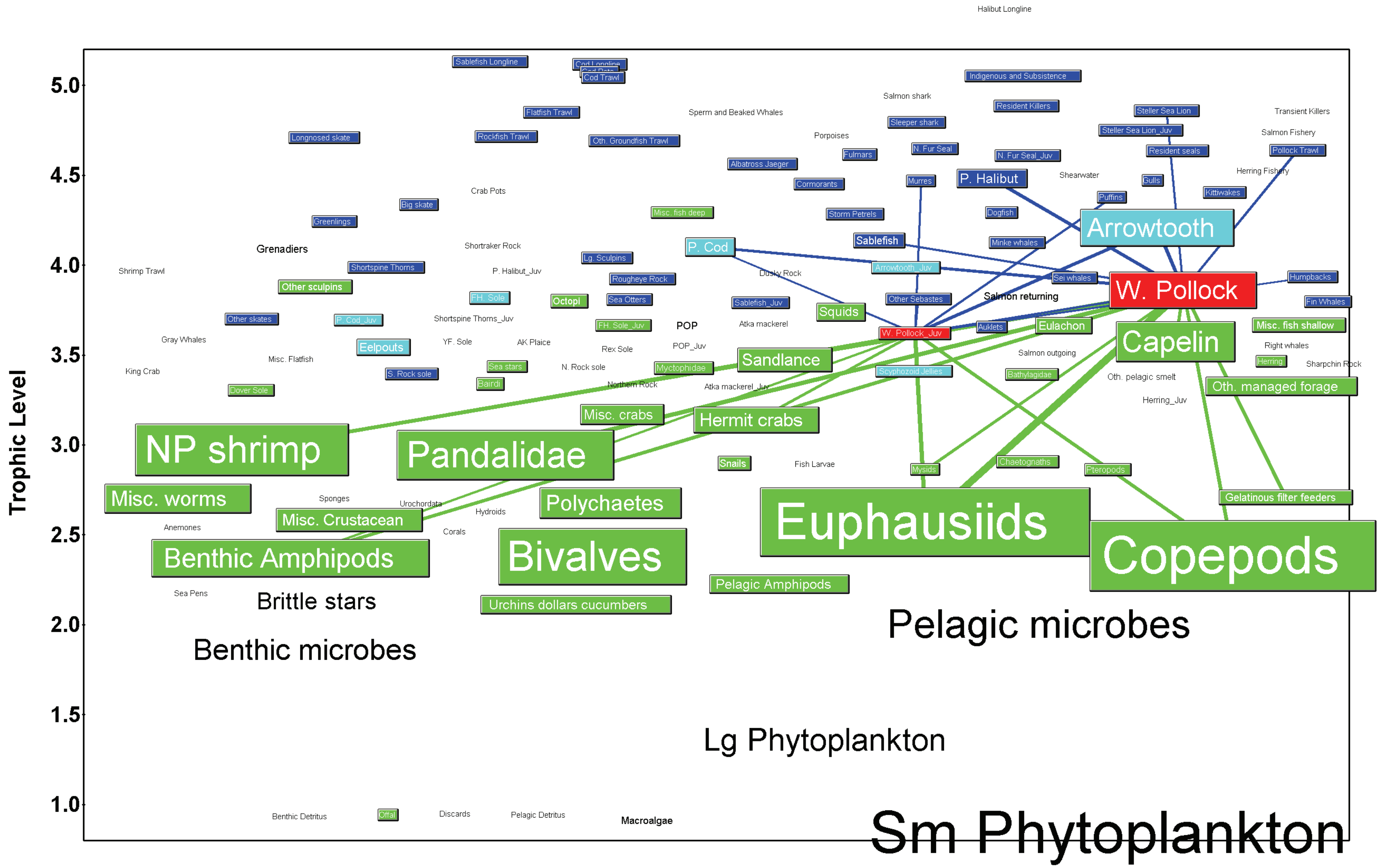


Figure 9b. Adult and juvenile pollock predators and prey in the Gulf of Alaska food web.

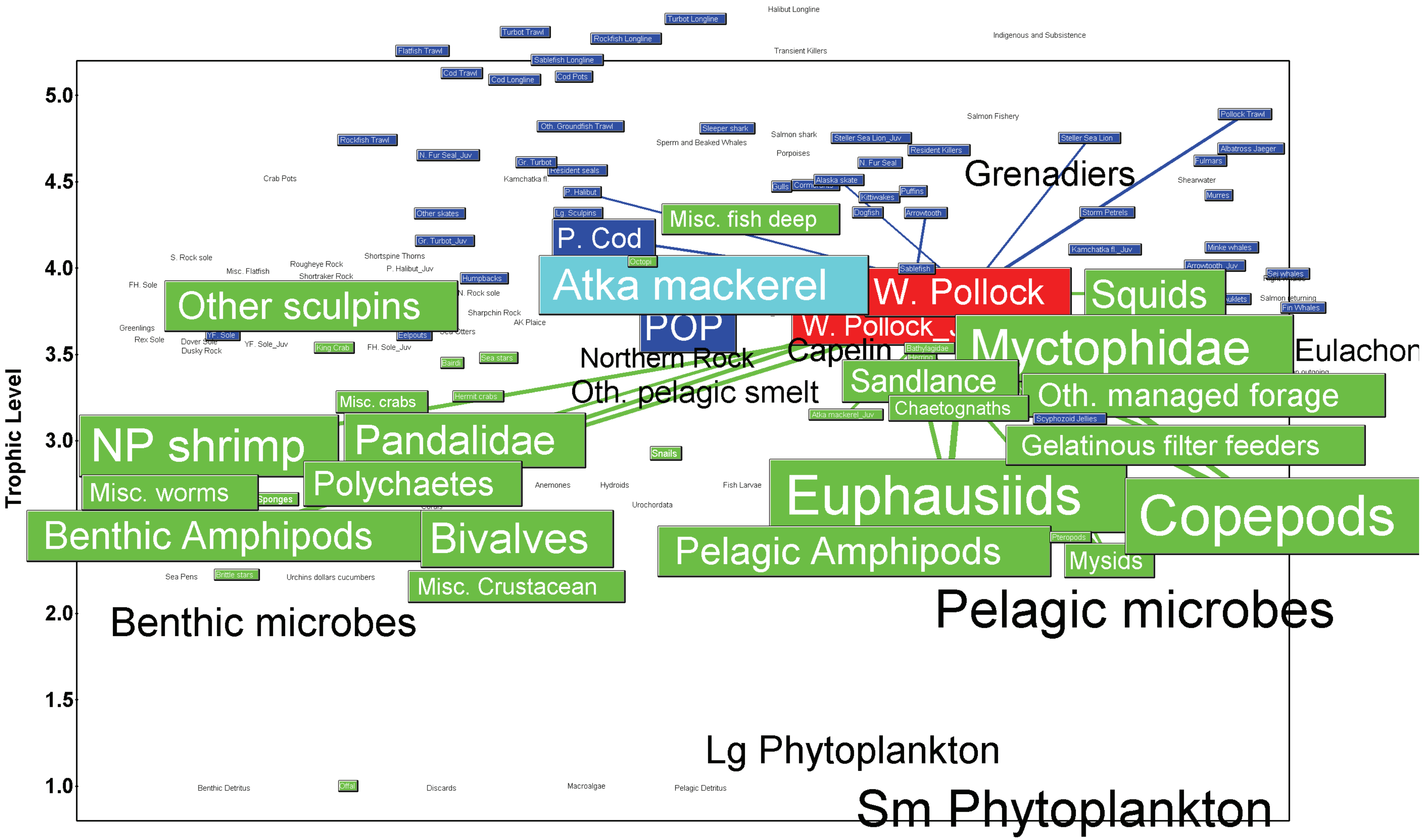


Figure 9c. Adult and juvenile pollock predators and prey in the Aleutian Islands food web.

As indicated above in Figure 6, food web modeling suggests that the majority of adult pollock mortality during the early 1990s was caused by predation in the EBS and GOA, but not in the AI. In each ecosystem, food web modeling reveals that a different set of predators cause the majority of predation mortality on pollock. In the EBS, most adult and juvenile pollock mortality is caused by pollock themselves (40%; Fig. 10a, left panels). The second largest source of adult pollock mortality in the EBS is the pollock fishery (19%), followed by the predators Pacific cod, Alaska skates, wintering seals, and arrowtooth flounder, which together account for 20% of pollock mortality. After adult pollock cannibalism (40%), juvenile pollock mortality is caused by flatfish, marine mammal and bird predation. Using the Sense routines described in Section 2.4, we can estimate ranges of total consumption of adult and juvenile pollock in the EBS ecosystem based on the food web model parameters and their associated uncertainty. Adult pollock were estimated to consume 2 to 3 million t of adult pollock and another 750,000 to 2 million t of juvenile pollock annually due to cannibalism, by far the largest consumption of pollock in the EBS (Fig. 10a, right panels).

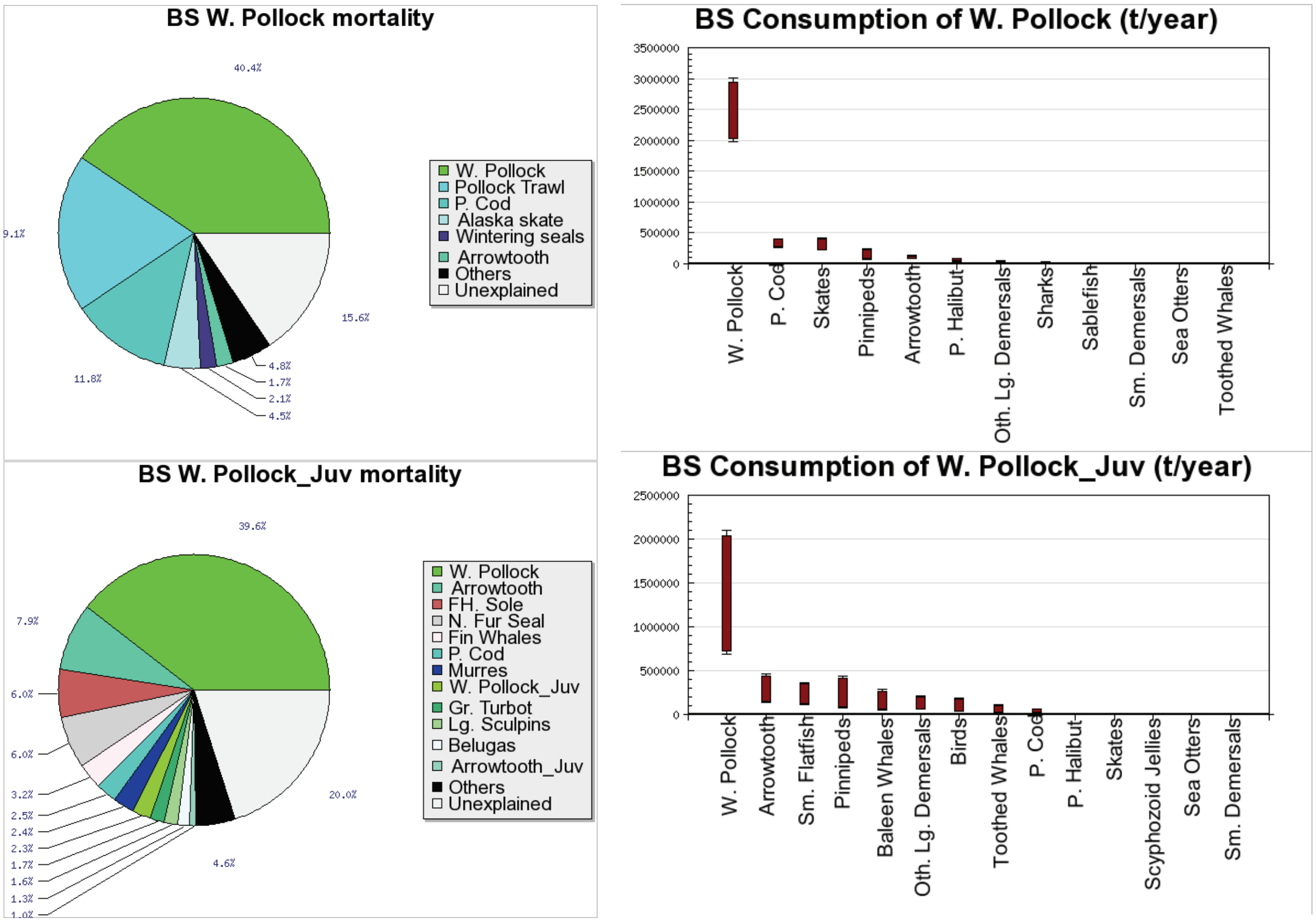


Figure 10a. Mortality sources (left) and estimated consumption by predators (right) of Eastern Bering Sea adult (top) and juvenile (bottom) pollock.

In the GOA, the vast majority of early 1990s adult pollock predation mortality was caused by three groundfish predators: arrowtooth flounder (32% of total mortality), halibut (22%), and cod (15%; Fig. 10b, upper left panel) according to the food web model. The pollock trawl fishery causes 8.7% of adult pollock mortality, which is slightly larger in magnitude to that caused by sablefish, Steller sea lions (adults and juveniles combined), and by adult pollock cannibalism. Consumption of pollock by arrowtooth flounder alone as estimated by the food web model ranges from 280 thousand to 400 thousand t annually, plus another 100-400 thousand t of juvenile pollock (Fig. 10b, right panels). The majority (47%) of mortality on juvenile pollock is also caused by arrowtooth flounder, followed by adult pollock cannibalism (11%; Figure 10b, lower left panel). Seabirds are estimated to cause substantial juvenile pollock mortality (9% by murres, puffins, and kittiwakes combined), as are whales and groundfish. Halibut consume the second highest annual tonnage of pollock.

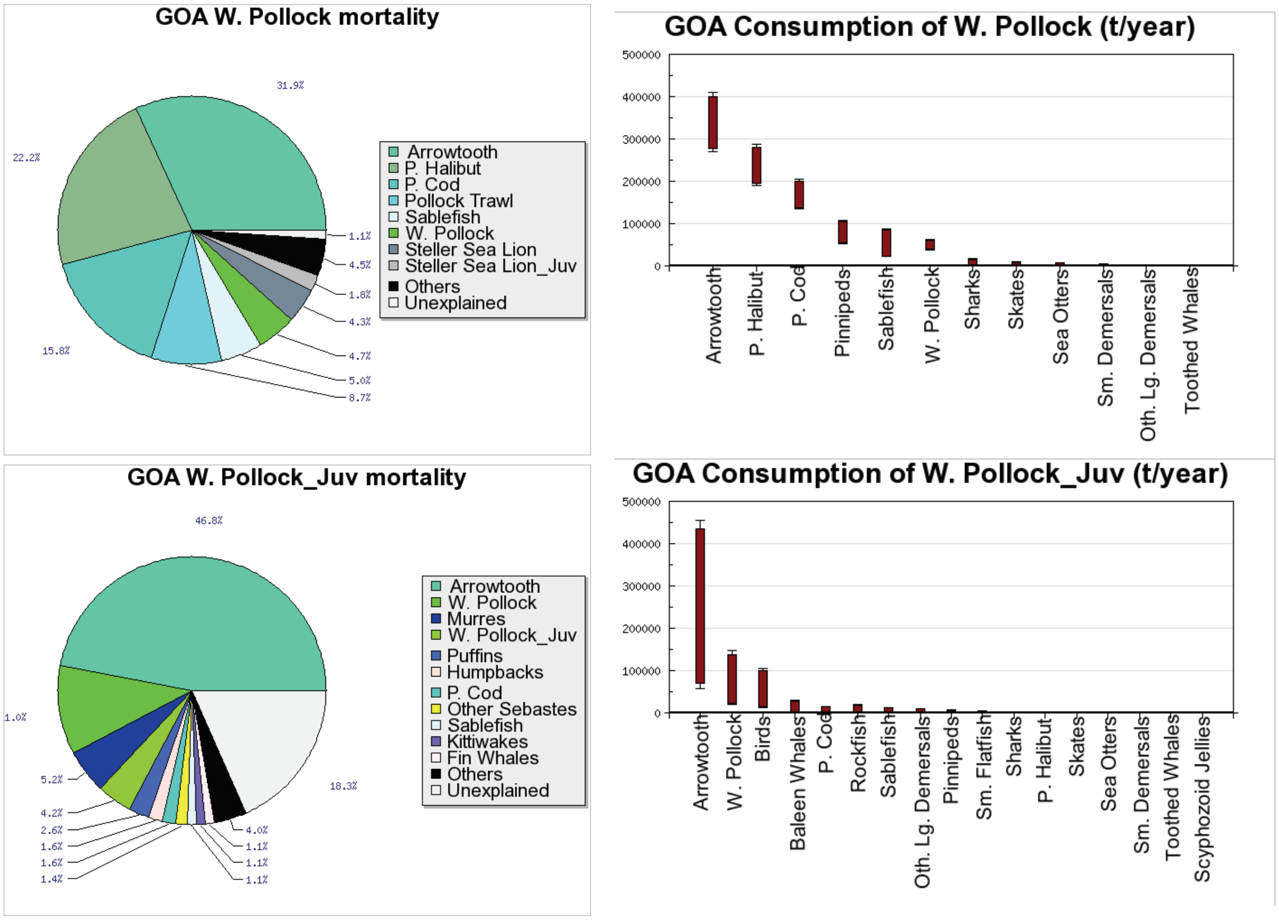


Figure 10b. Mortality sources (left) and estimated consumption by predators (right) of Gulf of Alaska adult (top) and juvenile (bottom) pollock.

In the AI, food web modeling suggests that most adult pollock mortality was caused by the pollock trawl fishery during the early 1990s (48%; Fig. 10c). (Fishery catch of pollock in the AI has subsequently declined to less than half the early 1990s catch by the late 1990s, and the directed fishery was closed in 1999 (Ianelli et al. 2005). Therefore, AI pollock likely now experience predation mortality exceeding fishing mortality as in the other two ecosystems.) The major predators of AI adult pollock are Pacific cod, Steller sea lions, pollock themselves, halibut, and skates. In the AI food web model, juvenile pollock have a very different set of predators from adult pollock; Atka mackerel cause most juvenile pollock mortality (71%). Estimates of adult pollock consumption from the Sense routines range from 8 to 27 thousand t consumed by cod annually, while Atka mackerel are estimated to consume between 75 and 410 thousand t of juvenile pollock annually in the AI ecosystem (Fig. 10c, left panels).

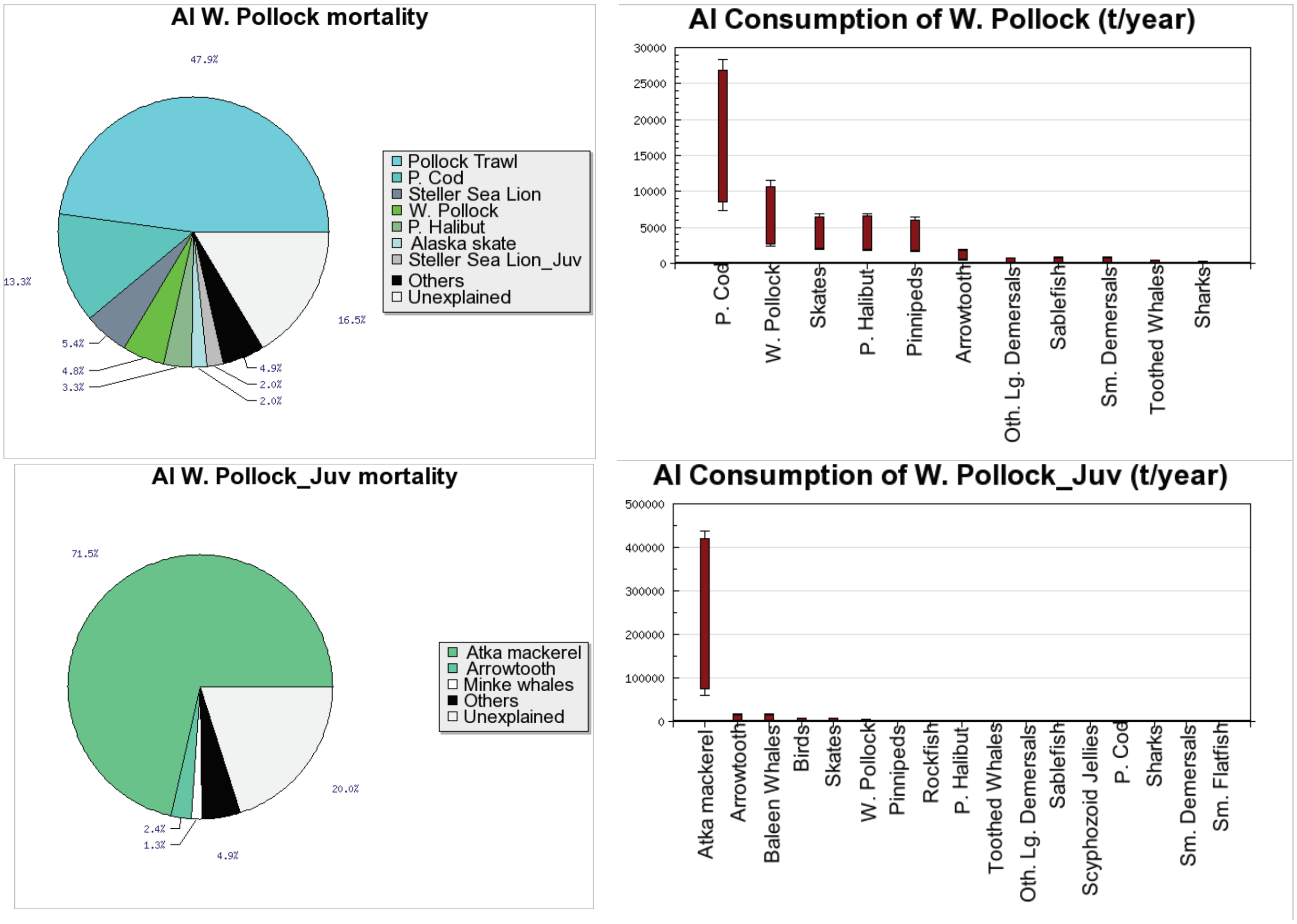


Figure 10c. Mortality sources (left) and estimated consumption by predators (right) of Aleutian Islands adult (top) and juvenile (bottom) pollock.

While pollock mortality sources are different between the EBS, GOA, and AI, general pollock diets are similar between systems. However, the proportions of species in pollock diets differs between the EBS, GOA, and AI, and a key difference in pollock diets between ecosystems was already demonstrated from the mortality results: the amount of pollock cannibalism. These differences in pollock diet compositions are independent of food web model assumptions because they arise directly from the extensive database of food habits information collected in the EBS, GOA, and AI on NMFS trawl surveys.

In the EBS, pollock diet data from the early 1990s shows that both adult and juvenile pollock consumed primarily copepods and euphausiids. Adult EBS pollock consumed equal proportions of these large zooplankton (36% and 35%), while juvenile EBS pollock consumed more copepods (42%) than euphausiids (32%; Fig. 11a, left panels). The next most important prey item for adult EBS pollock is EBS pollock; cannibalism on both adults and juveniles accounts for 12.9% of adult EBS pollock diet. Shrimp, amphipods, and other zooplankton round out the adult EBS pollock diet. Juvenile EBS pollock prey mainly on zooplankton, with smaller amounts of benthic amphipods and miscellaneous crustaceans accounting for less than 8% of their diet.

Combining these diet compositions with consumption to biomass ratios and biomass estimates for EBS pollock within the food web model Sense routines, we estimate that adult EBS pollock consume between 3 million and 18 million t each of euphausiids and copepods annually, with juvenile EBS pollock consuming another half million to 6 million t of each group annually (Fig. 11a, right panels). Clearly, EBS pollock account for an enormous energy transfer from pelagic zooplankton to higher TL predators (including humans) within the EBS ecosystem.

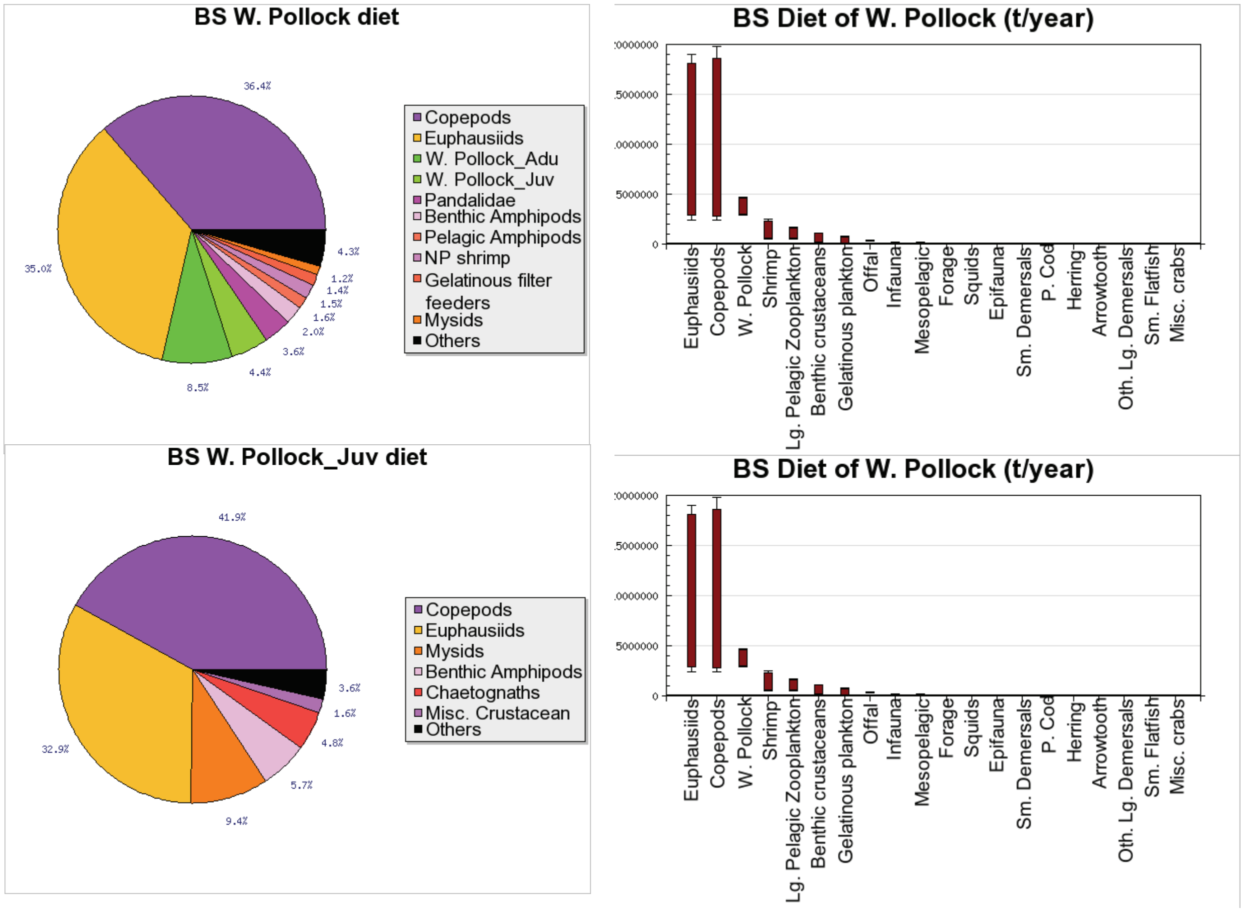


Figure 11a. Diet composition (left) and estimated consumption of prey (right) by Eastern Bering Sea adult (top) and juvenile (bottom) pollock.

In the GOA, pollock feed on similar prey as in the EBS, but in different proportions. Early 1990s GOA diet data indicate that both adult and juvenile pollock feed primarily on pelagic zooplankton, with euphausiids comprising 50% of the adult pollock diet and 45% of the juvenile pollock diet (Fig. 11b, left panels). While adult and juvenile pollock diets are similar, adult pollock prey more on pandalid and non-pandalid (NP) shrimp (18% of diet), and juvenile pollock prey more on copepods (26% of diet). As in the EBS but on a smaller scale, the combination of this diet composition along with the high biomass of pollock within the system and the relatively high production rate of pollock results in high estimated flows from pelagic zooplankton and benthic shrimp to pollock from the Sense routine. Based on this information, adult and juvenile pollock combined consume an estimated 1.6 to 6.7 million t of euphausiids annually, as well as over 1 million t each of shrimp and copepods in the GOA (Fig. 11b, right panels).

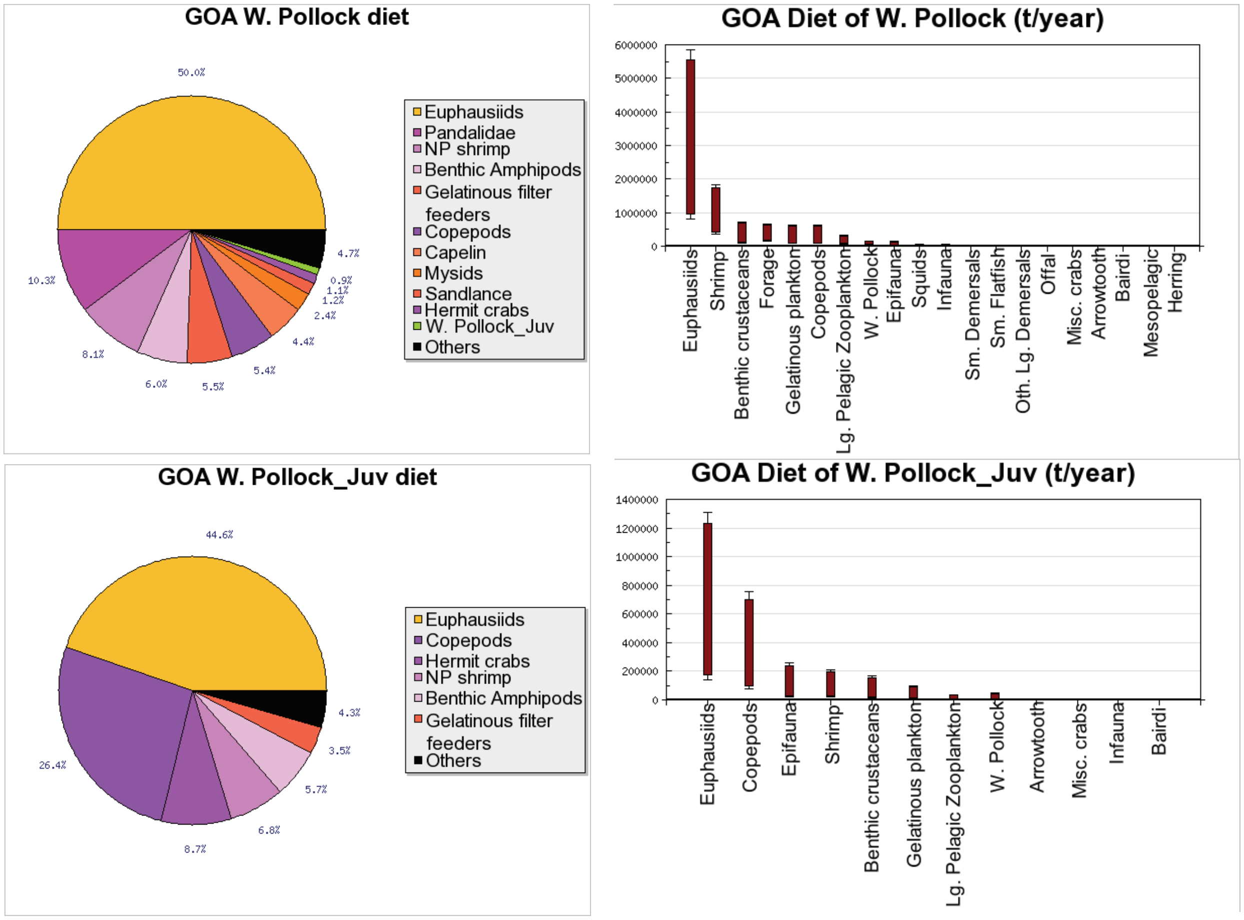


Figure 11b. Diet composition (left) and estimated consumption of prey (right) by Gulf of Alaska adult (top) and juvenile (bottom) pollock.

In the AI, pollock diet data reflects a closer connection with open oceanic environments than in either the EBS or the GOA. Similar to the other ecosystems, euphausiids and copepods together make up the largest proportion of AI adult pollock diet (29% and 19%, respectively); however, it is only in the AI that adult pollock rely on mesopelagic forage fish in the family Myctophidae for 24% of their diet, and AI juvenile pollock have a lower proportion of euphausiids and a higher proportion of gelatinous filter feeders than in the other ecosystems (Fig. 11c, right panels). As estimated by the food web model Sense routine, AI adult pollock consume between 100 and 900 thousand t of euphausiids annually, with similar ranges of myctophid and copepod consumption. Juvenile AI pollock consume an additional estimated 100 to 900 thousand t of copepods per year (Fig. 11c, right panels). The consumption estimates for AI pollock are an order of magnitude lower than those for EBS pollock, reflecting the lower pollock biomass in the AI relative to the EBS. However, it is important to note that the relatively lower early 1990s pollock biomass in the AI is concentrated in a smaller area of continental shelf and slope than in the EBS and GOA, which means that early 1990s pollock density in the AI is equivalent to the GOA for adult pollock, and greater than the GOA or the EBS density for juveniles (Fig. 12).

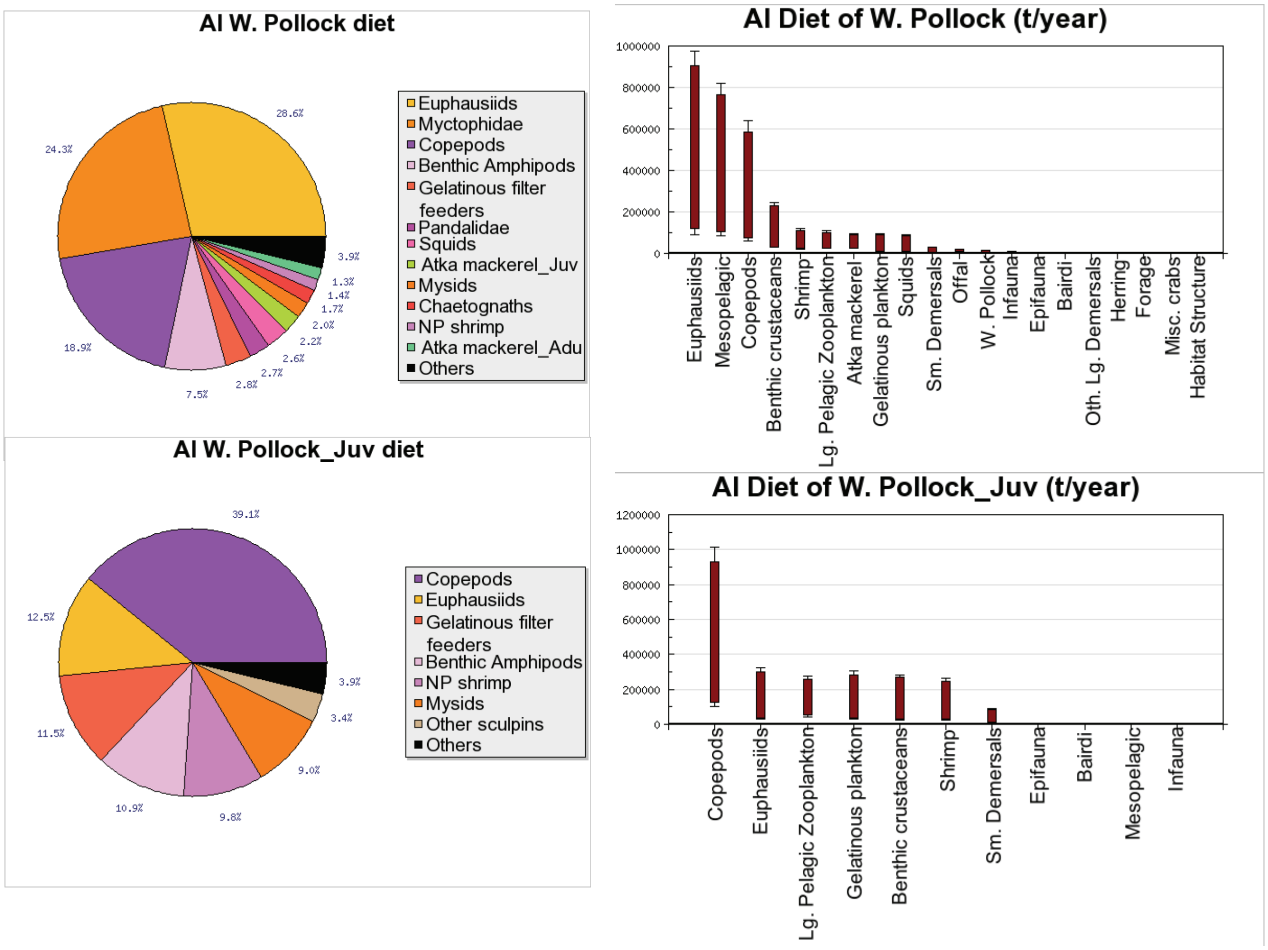


Figure 11c. **Diet composition (left) and estimated consumption of prey (right) by Aleutian Islands adult (top) and juvenile (bottom) pollock.**

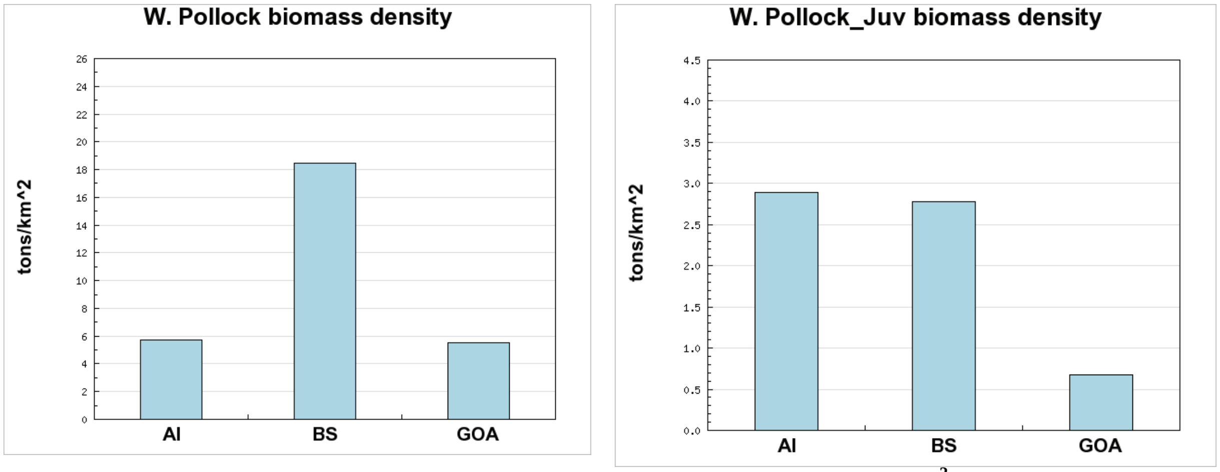


Figure 12. **Comparison of adult (left) and juvenile (right) pollock density in t/km^2 between ecosystems in the early 1990s in the Aleutian Islands, eastern Bering Sea, and Gulf of Alaska.**

Comparing the food web model results for a single species, pollock, in the EBS, GOA, and AI demonstrates the utility of food web modeling for supplementing traditional single species models for commercially fished species. Viewing fisheries within the context of predator-prey relationships provides a comprehensive view of fishing impacts beyond target species which is not possible within the current single target species context. Evaluating the predator prey relationships for commercially important species such as pollock improves fishery sustainability through a fuller accounting of mortality sources and prey species contributing to production which are not considered in traditional single species models. In addition, strong relationships between fished species identified by food web modeling may imply that separately managed species might benefit from more coordinated management. All of these insights contribute an ecosystem based fishery management objective of maintaining the relationships in a marine ecosystem, including the economic relationships based on present and future commercial species sustainability.

For fished prey species such as pollock, food web modeling suggests that different assessment or management strategies might be considered for the same species in different ecosystems. The AI food web model shows that in the early 1990s, fishing mortality was a larger proportion of total mortality for pollock than predation mortality. This suggests that fishery managers had control over the dominant source of AI pollock mortality. This was not the case in the EBS and the GOA, where predation mortality estimated to be greater than fishing mortality in food web models. The key difference between the EBS and GOA is that the dominant pollock predation mortality came from different sources. In the EBS, pollock cannibalism is the dominant source of pollock mortality; this sets up a potentially complex interaction between fishing mortality on adult pollock and its affects on pollock cannibalism, which is addressed to some extent in the single species stock assessment for EBS pollock through the use of the Ricker stock recruitment curve (Ianelli et al. 2005).

In contrast with EBS and AI pollock, the GOA food web model shows that the overwhelming majority of explained pollock mortality is from predation by arrowtooth flounder, cod, and halibut, rather than pollock cannibalism or fishing. This suggests that for GOA pollock, reducing fishing mortality may have little impact on their population trajectory, contrary to conventional fishing theory. However, lack of control does not imply lack of responsibility. It also suggests that increased fishing mortality might have a greater than expected effect if the population collapses under the combined effects of high predation mortality and increased fishing mortality. A further implication of the GOA food web model is that if pollock’s predator populations change substantially, then predation mortality would likely change with them; in other words, the single species stock assessment assumption of constant natural mortality for pollock is not supported by food web modeling. This was initially addressed in Hollowed et al. (2000b), but that work has not been formally incorporated to date within the pollock assessment used to establish annual quotas. Finally, in the GOA pollock are strongly linked through predation mortality to other managed species, in particular halibut and cod. Halibut and cod differ from pollock in that fishing accounts for the majority of explained mortality for both species (Fig. 6 and Fig. 13 below), suggesting that management actions affecting fishing mortality for halibut and cod may in turn affect pollock mortality in the GOA. Overall, food web modeling indicates where commercially important species might benefit from some coordination of management.

3.3 Ecosystem Indicators and Statistics

In this section, we transition from food web model results comparing a single species across ecosystems to results comparing ecosystem characteristics from single and multispecies perspectives. In the first example, we examine the different ecosystem roles of a single influential commercially fished predator species, Pacific cod (*Gadus morhua*). In the second example, we demonstrate how the food web model can be used to estimate the relative importance of different forage species in each ecosystem, and provide estimates of biomass based on predator consumption as alternatives to our current relatively poor survey biomass estimates for selected forage fish and epibenthic prey. The third section compares standard indicators of ecosystem condition and function.

3.3.1 Different ecosystem roles of Pacific cod

Pacific cod are commercially important in all three ecosystems, and are also important predators in the EBS, GOA, and AI. While they are managed similarly in all three ecosystems, food web modeling suggests key differences in cod's ecosystem role in the AI, BS, and GOA. The first key difference between ecosystems relates to cod's relative density in its continental shelf habitats in each system: because the AI has a much smaller area of shelf relative to the GOA and BS, the smaller absolute biomass of cod in this area translates into a higher density in t/km^2 relative to the density in the BS and GOA (Fig. 13, left panel). Although the density of cod differs between systems, the food web model estimates that the relative effects of fishing and predation mortality are similar between the AI, EBS, and GOA: cod have relatively more fishing mortality than predation mortality in all three ecosystems (Fig. 13, right panel). This suggests that changing fishing mortality is likely to affect cod population trajectories; therefore, we may ask what ecosystem effects changes in cod mortality might cause in each ecosystem.

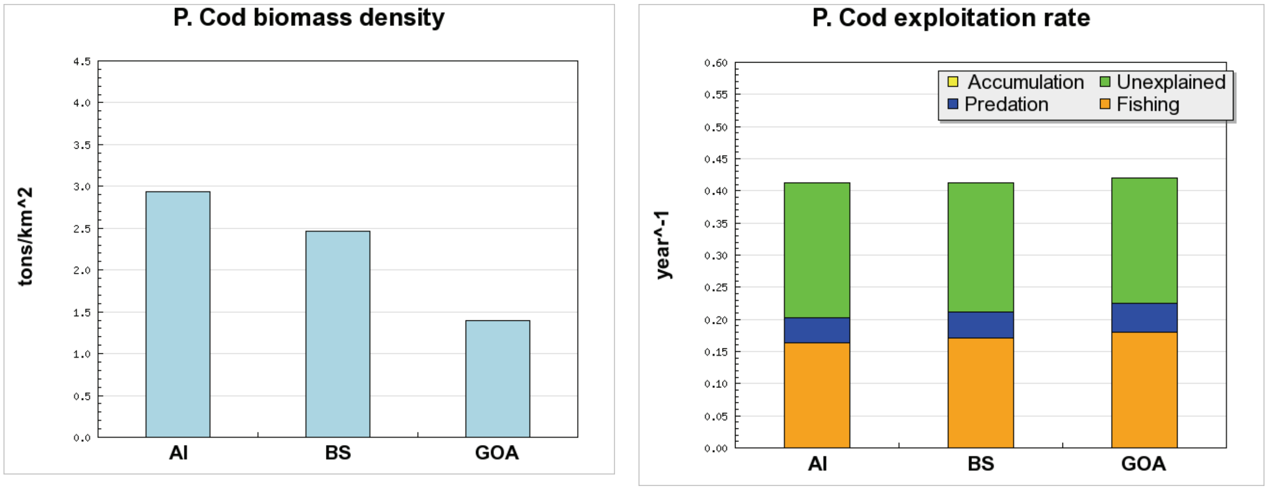


Figure 13. Comparative biomass density (left) and mortality sources (right) for Pacific cod in the Aleutian Islands, eastern Bering Sea, and Gulf of Alaska ecosystems.

To determine the potential ecosystem effects of changing total cod mortality, we first examine the diet data collected for cod and mortality estimates resulting from each food web model. Pacific cod have an extremely varied diet in all three ecosystems (Fig. 14, left panels). In both the EBS and GOA, pollock are a major diet item for cod (26% and 19% of diet, respectively), but in the AI Atka mackerel and sculpins are the predominant fish prey for cod (15% of diet each), with pollock comprising less than 5% of the diet. In all three ecosystems, Pandalid and non-Pandalid shrimp and various crabs are important prey, but other major prey items differ by ecosystem and seem to relate to the relative importance of benthic and pelagic pathways in each ecosystem as discussed above in section 3.1.3. Commerically important crab species such as snow crab (*C. opilio*) and Tanner crab (*C. bairdi*) make up 9% of cod diets in the EBS and GOA, but less than 3% in the AI, reflecting the stronger benthic energy flow in the EBS and GOA. In contrast, squids make up over 6% of cod diets in the AI, but are very small proportions of diets in the EBS and GOA, reflecting the stronger pelagic energy flow in the AI. Myctophids are also found in cod diets only in the AI, reflecting the oceanic nature of the food web there. Cod are clearly opportunistic predators in all three ecosystems, feeding on a variety of fish and invertebrates, and scavenging as well. Fishery offal makes up 3-7% of cod diets in all systems, indicating that while fishing causes cod mortality, it also contributes to cod production (although much fishery offal comes from fisheries directed at pollock, not cod).

Mortality sources estimated by the food web models for cod are similar when comparing fisheries, but different when comparing predators between the EBS, GOA, and AI. In all three ecosystems, the trawl and longline fisheries for cod were the largest mortality sources for cod in the early 1990s (Fig. 14, right panels). The next largest source of cod mortality is the pollock trawl fishery in the EBS, the cod pot fishery in the GOA, and the directed Atka mackerel ("Other groundfish") fishery in the AI, which retains incidentally caught cod. In the EBS and GOA, pollock and halibut predation rank next, and in the AI, adult and juvenile Steller sea lion predation represents the largest single source of predation mortality for cod. Cod cannibalism is a significant source of cod mortality only in the EBS, and flatfish trawl fisheries, halibut predation and skate predation round out the large cod mortality sources in that ecosystem. In the GOA, sperm whales, sea lions, and dogfish, along with flatfish and halibut fisheries, account for most remaining cod mortality. Therefore, we see groundfish-dominated predation mortality sources for cod in the EBS, sea-lion dominated predation mortality in the AI, and a mixture of groundfish and marine mammal predation on cod in the GOA.

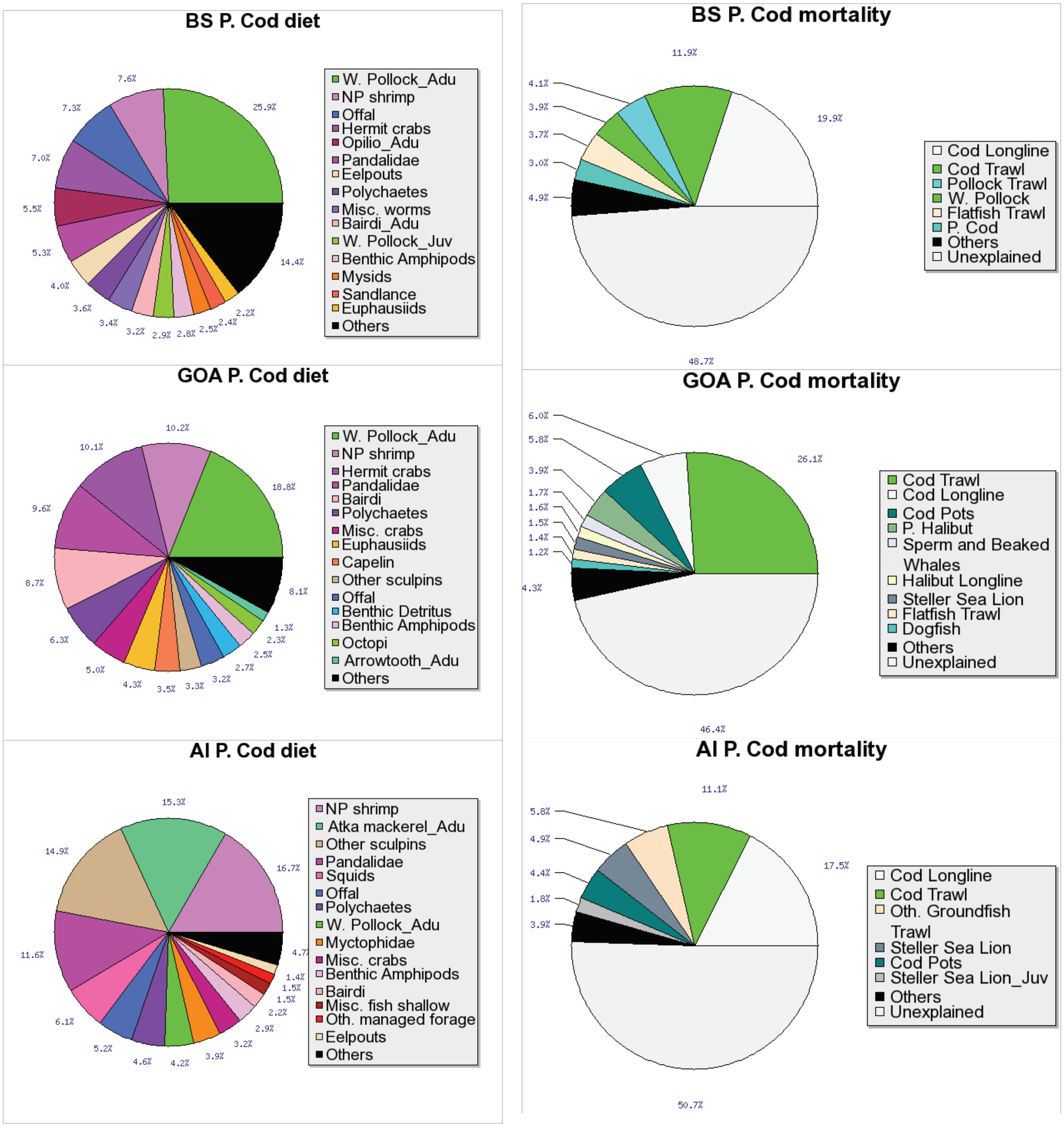


Figure 14. Comparison of Pacific cod diet (left) and mortality sources (right) for the Eastern Bering Sea (top), Gulf of Alaska (center) and Aleutian Islands (bottom) ecosystems.

After comparing the different diet compositions and predators of cod in each ecosystem, we can integrate these results with information on uncertainty in the food web using the Sense routines and a perturbation analysis with each model food web. Two questions are important in determining the ecosystem role of cod: who are cod important to, and who are important to cod?

First, the importance of cod to other groups within the EBS, GOA, and AI ecosystems was assessed using a model simulation analysis where cod survival was decreased (mortality was increased) by a small amount, 10%, over 50 years to determine the potential effects on other living groups. This analysis also incorporated the uncertainty in model parameters using the Sense routines, resulting in ranges of possible outcomes which are portrayed as 50% confidence intervals (boxes in Fig. 15) and 95% confidence intervals (error bars in Fig. 15). Species showing the largest median changes from baseline conditions are presented in descending order from left to right. Therefore, the largest change resulting from a 10% decrease in cod survival in all ecosystems is a decrease in adult cod biomass, as might have been expected from such a perturbation. However, the decrease in biomass resulting from the same perturbation is different between the EBS, GOA, and AI: the 50% intervals range from a 7-11% decrease in the AI, to a 7-17% decrease in the EBS, to a 6-27% decrease in the GOA (Fig. 15). This suggests that in addition to the differences between the three ecosystems in terms of cod diets and mortality sources, there are differences in uncertainty between systems, with the GOA having the highest uncertainty in the outcome of the cod manipulation.

The simulated decrease in cod survival affects the fisheries for cod similarly in the three ecosystems. After the decreased adult cod biomass, the next largest effect of the perturbation predicted by the models is a decrease in the “biomass” (catch) of the pot, longline, and trawl fisheries targeting adult cod in the EBS and GOA ecosystems (Fig. 15, top and center panels). In the AI ecosystem model, adult sablefish are predicted to have a larger change from the cod manipulation than the fisheries, although the predicted increase in sablefish biomass is much more uncertain than the predicted decrease in fishery catch in the AI (bottom panel, Fig. 15). We discuss the sablefish result in detail below; for this discussion, we note that the cod fisheries in the AI are behaving similarly to the cod fisheries in the EBS and GOA after the simulated decrease in cod survival. Since cod fisheries are extremely specialized predators of cod, it makes sense that they are most sensitive to changes in the survival of cod in each ecosystem. It is notable that none of the other predators of cod showed a significant sensitivity to a 10% decrease in cod survival. Pollock, halibut, and sea lions ranked highest as non-fishery mortality sources of cod in the EBS, GOA, and AI, respectively, but none of these species were predicted to have significant changes in biomass in any ecosystem in this analysis: the 50% interval for change in halibut in the EBS and GOA includes zero change, and neither EBS pollock nor AI sea lions showed enough change from the baseline condition to be included in the plots. While these predators may cause significant cod mortality in each system, this analysis suggests that none of them are dependent on cod to the extent that small changes in cod survival affect their biomass in a predictable manner. It may be that these predator species would react more strongly to larger changes in cod survival; this could be further analyzed with different perturbation analyses.

In contrast with the predators of cod, a 10% decrease in cod survival is predicted to change the biomass of some cod prey, and even some species not directly connected to cod. In the EBS, greenling biomass is predicted to increase as a result of the perturbation, as is Tanner and king crab biomass, albeit with less certainty (Fig. 15, top panel). In the GOA all results are less certain, but Tanner crab and sculpin biomass are predicted to increase with decreased cod survival. In the AI, a larger set of species appear to react more strongly to increases in cod mortality than in the other two systems: sablefish, rex sole, arrowtooth flounder, and sleeper sharks are all predicted to increase in biomass in addition to greenlings and small sculpins (Fig. 15). Of these, only rex sole, greenlings and other sculpins are direct cod prey; the change in adult sablefish and adult arrowtooth biomass apparently arises from reduced cod predation mortality on the juveniles of each species in the AI ecosystem model: cod cause 80% of juvenile sablefish and juvenile arrowtooth mortality in the AI model. Sleeper sharks are neither predators nor prey of cod in the AI, suggesting that decreased cod survival has strong indirect effects in this ecosystem. Some of these differences in species sensitivity to cod mortality arise from the differences in cod diet in each system, but it seems likely that the higher sensitivity of multiple species to cod in the AI may also be due to cod's high biomass per unit area there relative to the EBS and GOA. This in turn suggests that in the AI there may be stronger potential ecosystem effects of cod fishing than in the other two systems.

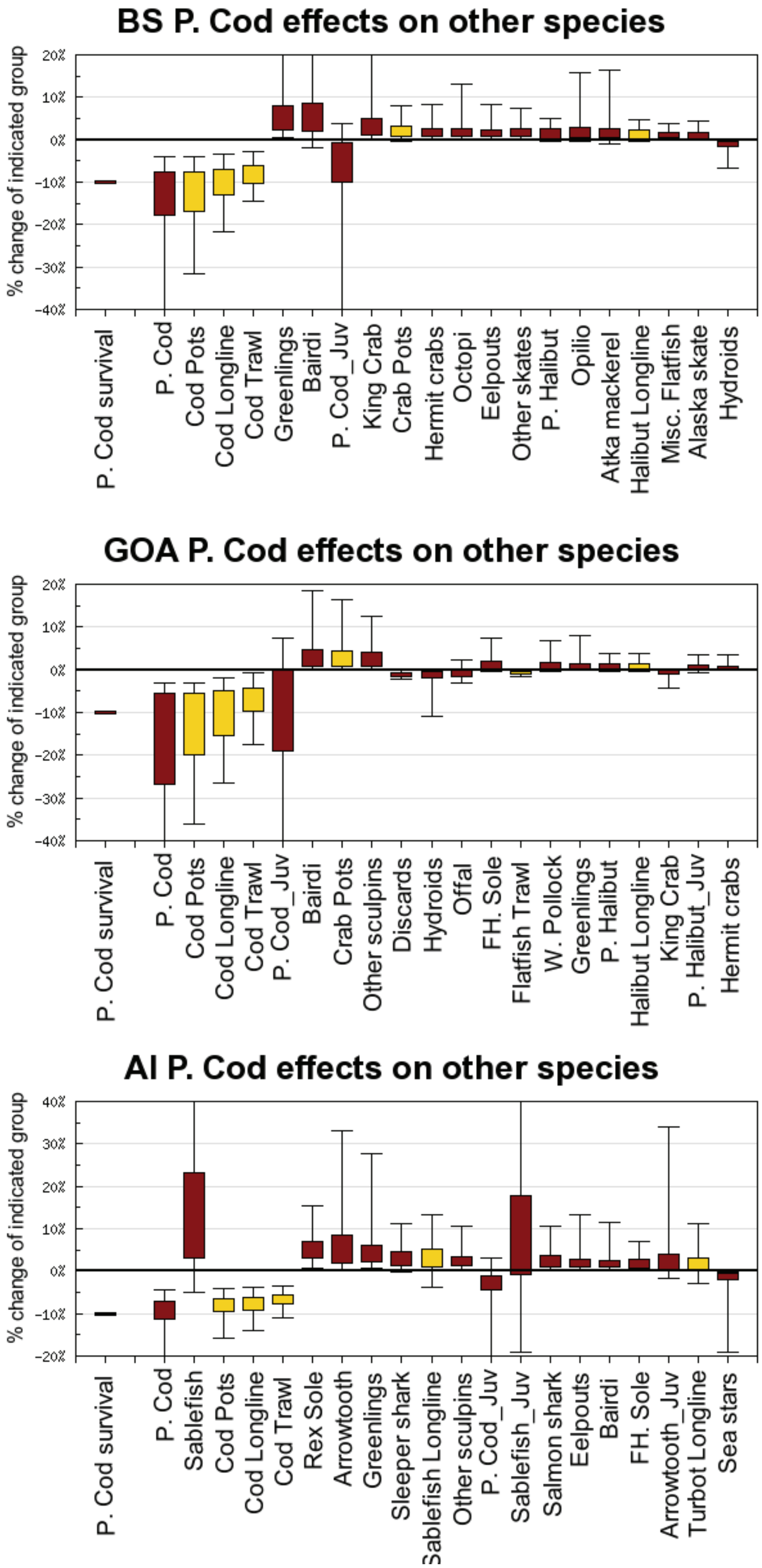


Figure 15. Effect of cod on other species: eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom).

To determine which groups were most important to cod in each ecosystem, we conducted the inverse of the analysis presented above. In this simulation, each species group in the ecosystem had survival reduced by 10% and the system was allowed to adjust over 30 years. The strongest median effects on EBS, GOA, and AI adult cod are presented in Figure 16. The largest effect on adult cod was the reduction in biomass resulting from the reduced survival of juvenile cod, followed by the expected direct effect, reduced biomass of adult cod in response to reduced survival of adult cod, in all three ecosystems (Fig. 16). Beyond these direct single species effects, cod appear most sensitive in all ecosystems to bottom up effects from both pelagic and benthic production pathways (small phytoplankton and benthic detritus). However, the bottom up effect is most pronounced in the AI, where the upper 95% intervals for the percent change of cod indicate that cod biomass will almost certainly decrease as a result of decreased survival of small phytoplankton, benthic detritus, and large phytoplankton (Fig. 16). In contrast, the EBS model prediction is that cod biomass is likely to decrease from decreased survival of small phytoplankton and benthic detritus, but the detritus 95% intervals cross the x-axis indicating that no change is also a possible outcome. In the GOA, there is considerable uncertainty in the effect of reduced small phytoplankton and benthic detritus survival on cod biomass, with 95% intervals both above and below the “no change” x-axis (Fig. 16).

In addition to increased uncertainty in the GOA, complex species interactions are more apparent than in the EBS and AI in this analysis. Reduced survival of juvenile and adult arrowtooth flounder in the GOA appear likely to have positive effects on cod biomass. Adult arrowtooth are only minor predators of adult cod, but cause an estimated 19% of the mortality on juvenile cod in the GOA (Fig. 17). In addition, arrowtooth cause the majority of pollock mortality (Fig. 10b), which is the major prey of cod in the GOA (Fig. 14, center left). Arrowtooth are also estimated to cause the majority of capelin mortality (Fig. 18) and a substantial amount of the mortality for pandalid shrimp (Fig.19), also cod prey in the GOA. It is difficult to determine whether the simulated reduced arrowtooth survival benefits cod more by releasing predation on juvenile cod, by releasing predation on cod’s major prey, or through a combination of effects.

Aside from arrowtooth flounder in the GOA, there are few groups in the ecosystem which appear to benefit cod through reduced survival. In general, reduced “survival” (lower catch) of fisheries means more cod in the EBS, GOA, and AI. In the EBS and GOA, reduced survival of other sculpins may increase cod biomass to some extent (Fig. 16), which may seem counterintuitive given that reduced cod survival appeared to increase other sculpin biomass in the GOA and AI (Fig. 15). While adult cod eat other sculpins, other sculpins in turn eat juvenile cod in both the EBS and GOA (Fig. 17), likely accounting for the results shown in Figure 16.

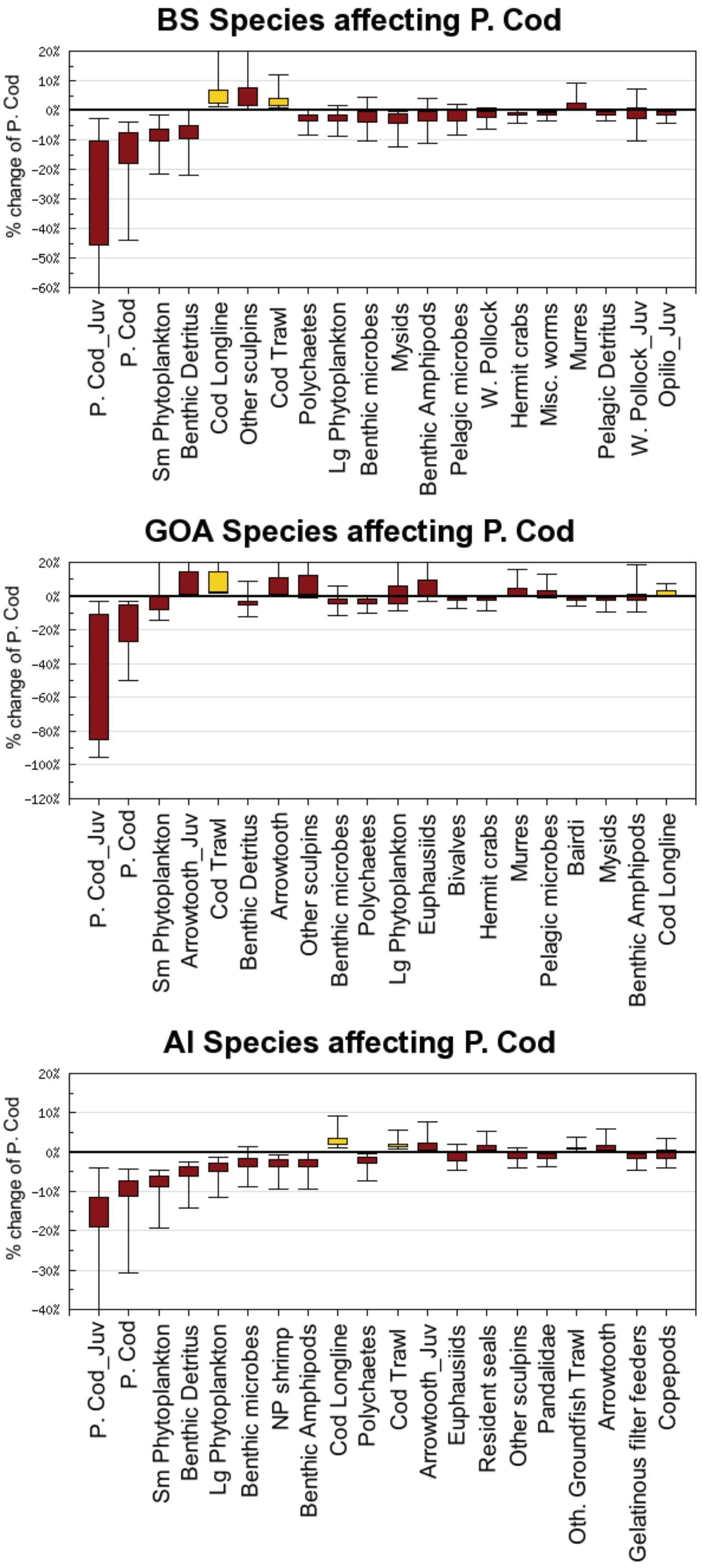


Figure 16. **Species important to cod: eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom).**

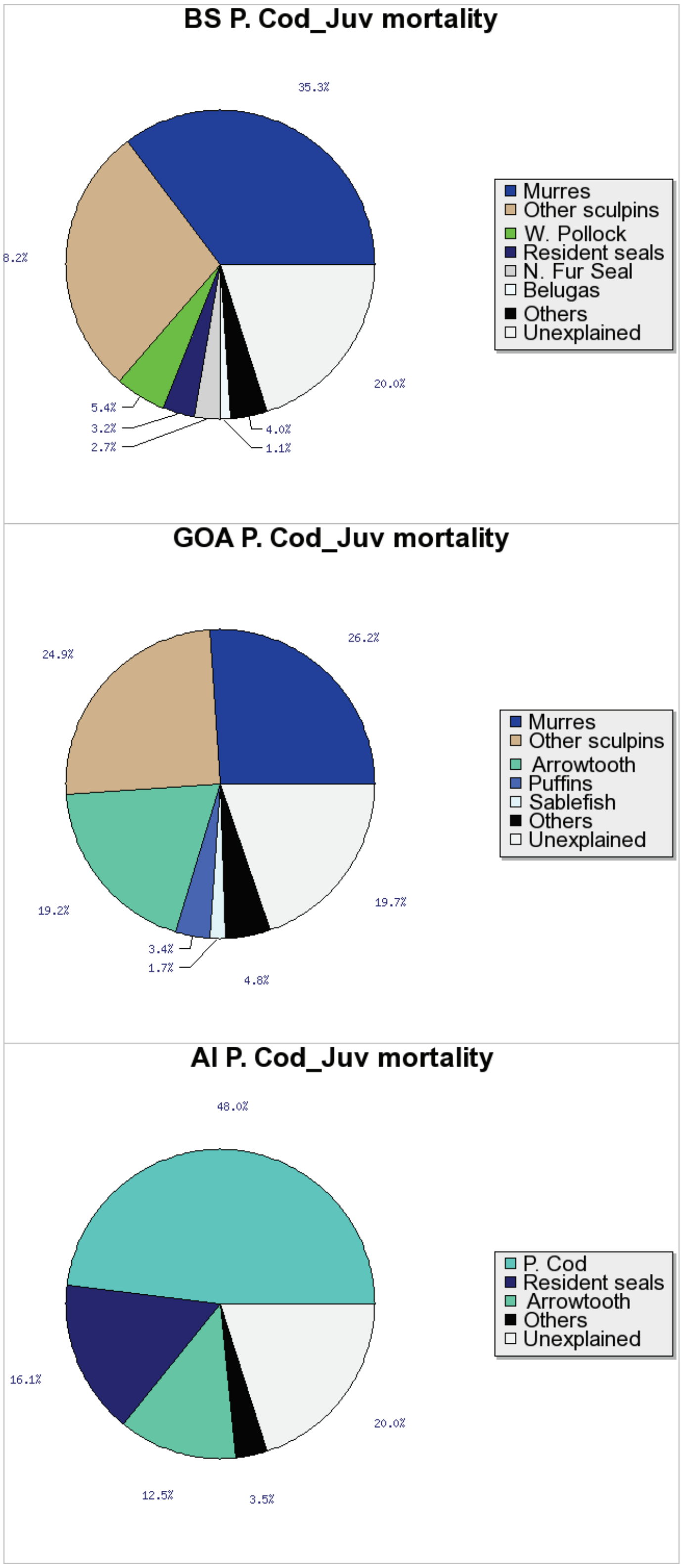


Figure 17. **Juvenile cod mortality sources: Eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom).**

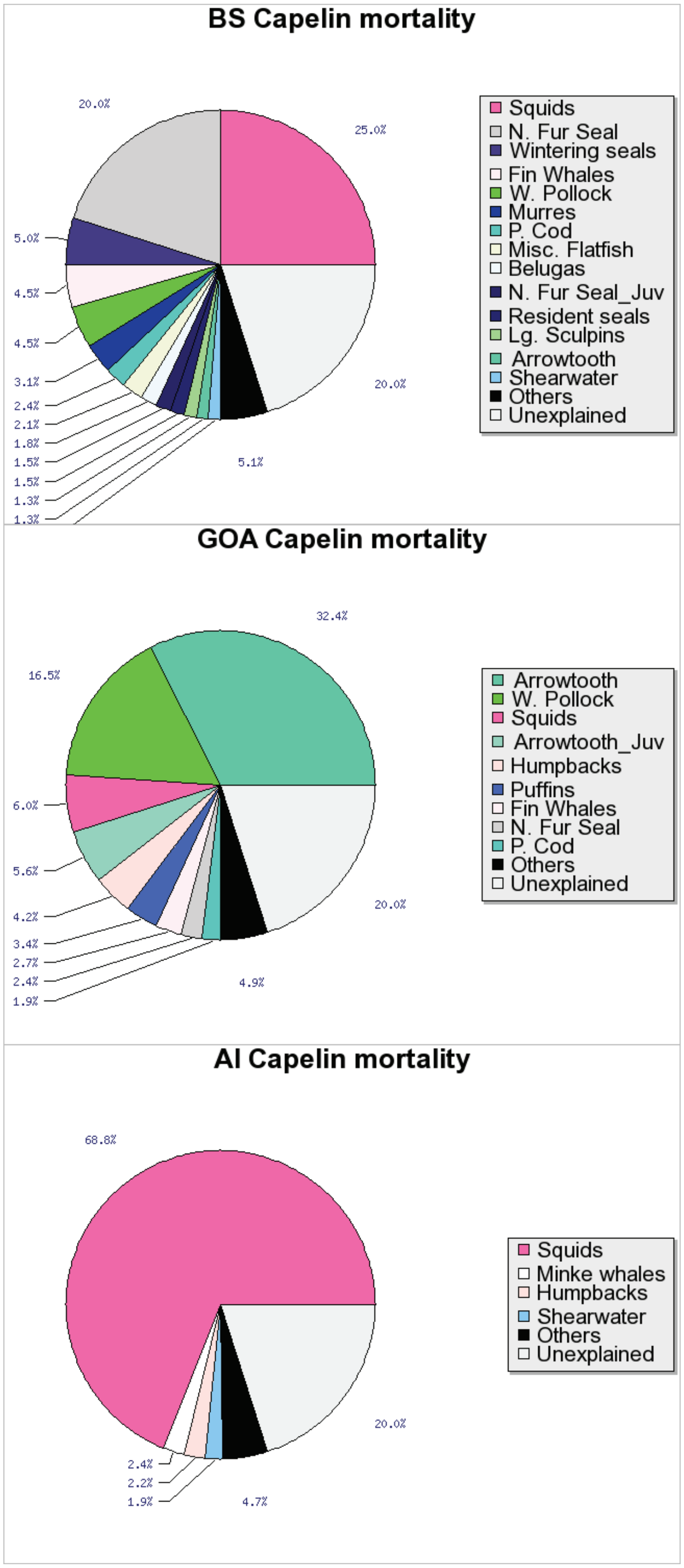


Figure 18. Capelin mortality sources: Eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom).

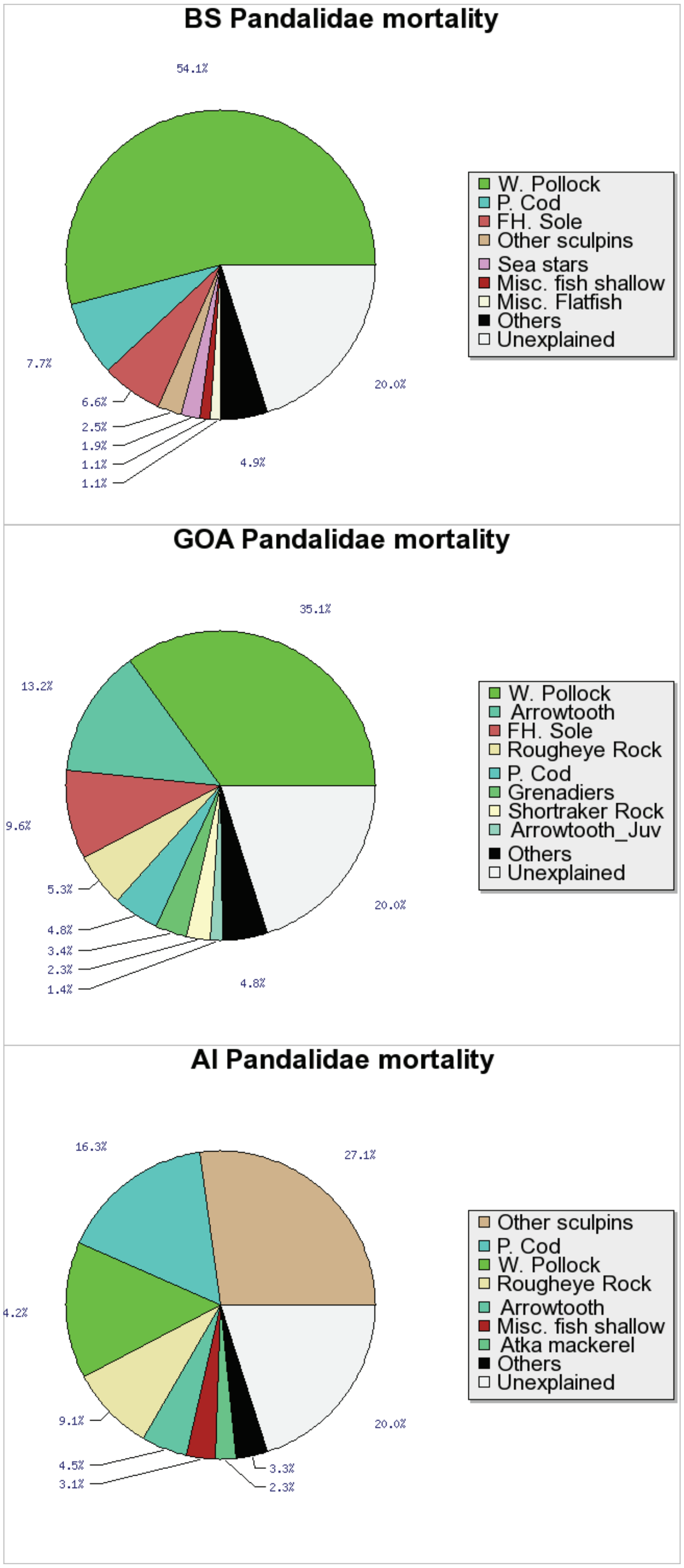


Figure 19. Pandalid mortality sources: Eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom).

The results of these perturbation analyses suggest that the regional level of management applied to Pacific cod should be modified to account for differences between ecosystems. As a commercially important species, Pacific cod are studied and assessed separately between the GOA and BSAI areas, but with similar management objectives. The food web relationships of cod are demonstrably different between the EBS, GOA, and AI ecosystems, with perhaps the largest contrast between the EBS and AI, where they are currently assessed and managed identically. The impacts of changing cod survival (and by extension, fishing mortality) differ by ecosystem as well, with the impacts felt most strongly and with highest certainty in the AI ecosystem according to this analysis. Therefore, it seems that the cod fishery in the AI should be managed separately from that in the EBS to ensure that any potential ecosystem effects of changing fishing mortality might be monitored at the appropriate scale.

3.3.2 Consumption differences between ecosystems: forage base

In our second example of ecosystem indicators derived from the food web models, we compare estimated consumption of forage species by predators in the EBS, GOA, and AI ecosystems. In comparing consumption of forage species, we see key differences between ecosystems in energy flow supporting the predator species, including the groundfish which are targets of commercial fisheries. For some forage species we have some knowledge of biomass in each system, while for others these consumption estimates represent the best available information on their potential abundance in the ecosystem. Species groups at each trophic level were designed to be comparable across ecosystems, and data poor groups had similar assumptions applied, so differences in consumption of these species groups are attributable primarily to the diet data collected for the data rich predators in the ecosystems.

First we compare consumption of forage species at trophic level (TL) 2.5; these groups feed on primary producers, detritus, and microbes. While all of our TL consumption comparisons reflect the relative strength of benthic and pelagic energy pathways discussed in Section 3.1.3, consumption of TL 2.5 groups in particular reflects the major differences between ecosystems. Figure 20 shows that in the EBS, consumption of TL 2.5 groups has the highest proportion of benthic forage species groups of any system: benthic amphipods, bivalves, crustaceans, miscellaneous worms and polychaetes account for half of all consumed species groups at TL 2.5 in the EBS. In contrast, the AI consumption of TL 2.5 groups is 87% pelagic forage; primarily copepods (49%) and euphausiids (33%). The relative consumption from benthic and pelagic pathways in the GOA is intermediate between the benthic EBS and the pelagic AI; 26% benthic and 74% pelagic forage consumed from TL 2.5 in the GOA (Fig. 20).

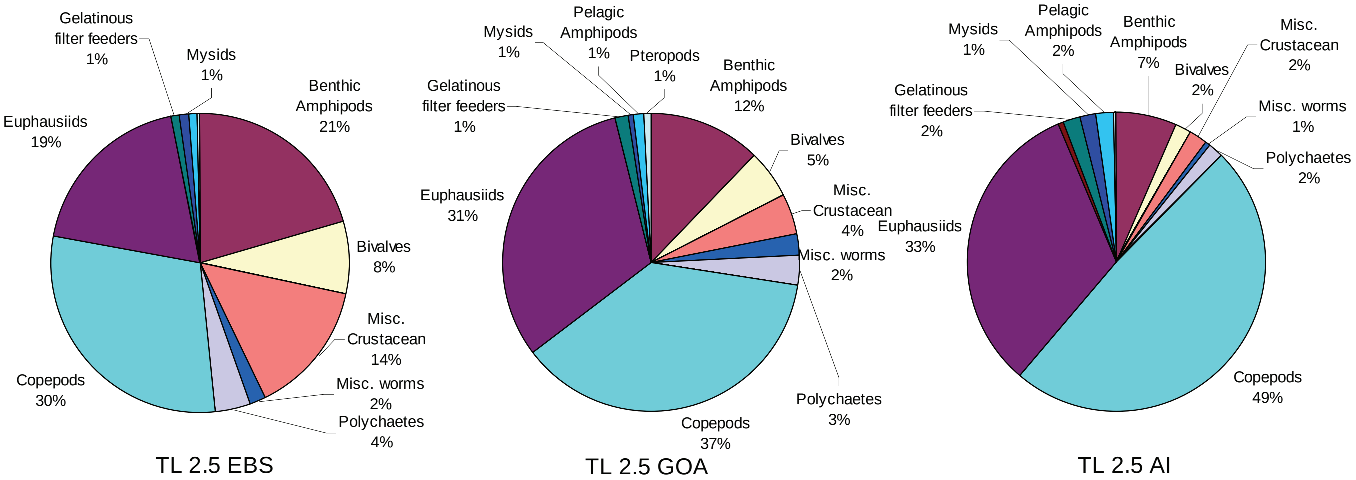


Figure 20. Consumption of groups at TL 2.5 by predators in the Eastern Bering Sea (left), Gulf of Alaska (center), and Aleutian Islands (right).

In all three ecosystems, historical or current field survey data were available to estimate biomass for 5 of the 18 TL 2.5 groups: anemones, corals, sea pens, sponges, and benthic urochordates (see Appendix A for details). In the EBS, additional data were available to estimate the biomass of bivalves and polychaetes. For all other groups, the consumption estimate converts to a biomass estimate when divided by each group's P/B times the assumed EE of 0.80. These consumption-based biomass estimates were generally orders of magnitude higher than estimates derived from trawl surveys (Table 27). We note, however, that the groundfish trawl surveys were not designed to provide estimates of biomass for invertebrates or forage fish, and that food web model based biomass estimates for TL 2.5 groups are still highly uncertain. As TL of forage groups increases, the certainty of food-web model consumption based biomass estimates may increase with the reliability of diet information for data-rich groundfish species (see below).

Table 27. Comparison of food web model consumption-based biomass estimates with early 1990s trawl survey biomass estimates for selected forage species in the GOA, EBS, and AI. Italicized numbers for three EBS groups are provided for comparison only; the model t were based on survey t for EBS Bivalves, Polychaetes, and *C. bairdi* crabs.

Group	TL	EBS model tons	EBS survey tons	GOA model tons	GOA survey tons	AI model tons	AI survey tons
Benthic Invertebrates							
Benthic Amphipods	2.5	6,258,080	n/a	1,712,771	n/a	423,494	n/a
Bivalves	2.5	*30,640,658*	*30,640,658*	4,042,562	1,515	631,581	
Hydroids	2.5	128,643	n/a	30,664	n/a	2,115	n/a
Misc. Crustacean	2.5	4,378,827		618,785	926	118,646	
Misc. worms	2.5	1,839,532		1,070,408	1	137,023	
Polychaetes	2.5	*10,739,981*	*10,739,981*	1,144,973	717	250,948	
NP shrimp	2.9	6,349,705		3,368,271	143	889,636	
Pandalidae	2.9	3,331,307		3,118,909	7,932	471,782	
Snails	2.9	407,168	315,625	252,115	1,409	64,534	
Hermit crabs	3.1	884,053	441,021	830,565	541	33,417	
Misc. crabs	3.1	360,147	48,187	507,177	1,058	78,872	
C. bairdi crabs	3.4	*204,545*	*204,545*	183,381	2,667	23,069	
Pelagic Zooplankton							
Copepods	2.5	11,122,056	n/a	6,380,644	n/a	3,805,384	n/a
Euphausiids	2.5	7,841,619	n/a	5,884,061	n/a	2,802,328	n/a
Fish Larvae	2.5	92,784	n/a	175,034	n/a	40,260	n/a
Gelatinous filter feeders	2.5	226,235	n/a	170,823	n/a	179,737	n/a
Mysids	2.5	5,779	n/a	1,103	n/a	128,487	n/a
Pelagic Amphipods	2.5	348,099	n/a	274,105	n/a	367,304	n/a
Pteropods	2.5	483,179	n/a	104,461	n/a	29,054	n/a
Chaetognaths	2.9	763,250	n/a	394,139	n/a	92,417	n/a
Forage Fish							
Bathylagidae	3.5	80,047	n/a	21,512	n/a	25,364	n/a
Capelin	3.5	613,714	1,840	2,050,112	137	203,697	0
Eulachon	3.5	273,583	6,719	335,636	30,229	197,608	2,425
Myctophidae	3.5	394,664	n/a	185,269	n/a	1,473,317	n/a
Oth. managed forage	3.5	521,895	1,288	415,443	753	217,139	4
Oth. pelagic smelt	3.5	247,139	n/a	187,399	30,409	197,156	n/a
Sandlance	3.5	1,229,948	34	712,880	33	213,509	127
Eelpouts	3.6	1,173,860	39,335	312,102	446	14,554	392

Groups between TL 2.6 and 3.4 are primarily benthic invertebrate groups in all three model ecosystems, with the exception of the pelagic zooplankton group chaetognaths. Nevertheless, the differences in consumption from benthic and pelagic pathways are evident in ecosystem comparisons at these trophic levels as well: chaetognath consumption accounts for one third of AI consumption at these TLs, compared with only 13-15% in the EBS and GOA (Fig. 21). Commercial crabs account for much more of the consumption in the EBS (11%) compared with the other systems (2-3%). Consumption of pandalid (commercial) shrimp is proportionally highest in the GOA, but non-pandalid (NP) shrimp consumption is high in all three systems, and is dominant (37%) in the EBS.

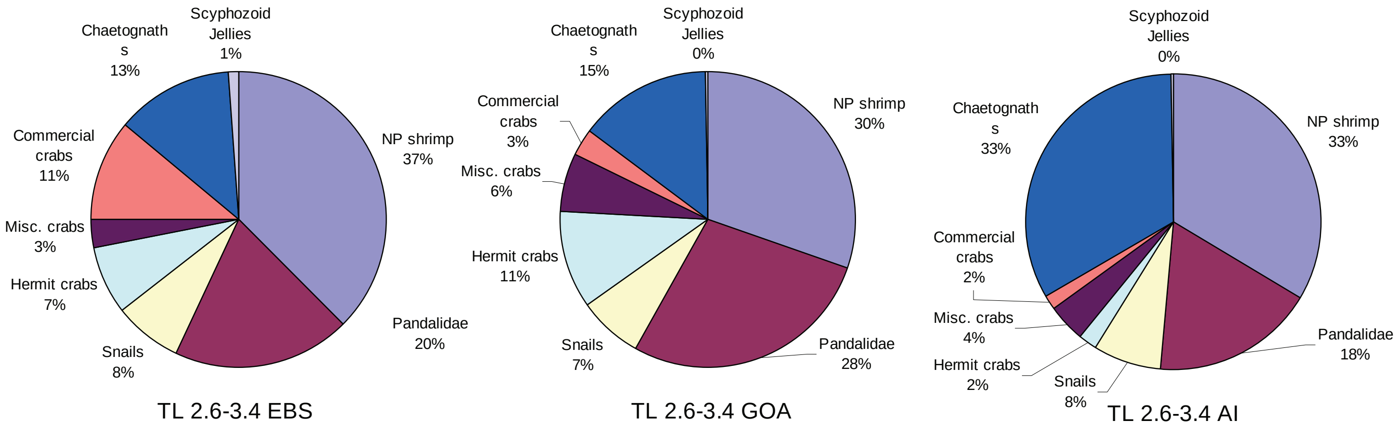


Figure 21. Consumption of groups between TL 2.6 and TL 3.4 by predators in the Eastern Bering Sea (left), Gulf of Alaska (center), and Aleutian Islands (right).

Because the biomass estimates reported in Table 27 depend on the consumption estimates, we determined which diet information is influential in estimating the consumption of each forage species by examining the mortality sources for each forage species. Species causing the most mortality are responsible for the most consumption within the context of the food web model. In each ecosystem, the primary consumers of the most important forage species above TL 2.5 are groundfish, so the consumption estimates are based on time- and area-specific food habits information in each ecosystem. For example, pollock and cod alone account for over 60% of pandalidae mortality in the EBS and over 50% in the GOA models (Fig. 19), and these predators' diets are estimated from detailed field-collected food habits data. Similarly, other sculpins, grenadiers and pollock account for over 50% of NP shrimp mortality in the EBS (Fig. 22). Pollock, grenadiers, other sculpins, miscellaneous deep groundfish and cod also explain the majority of NP shrimp mortality in the GOA and AI (Fig. 22).

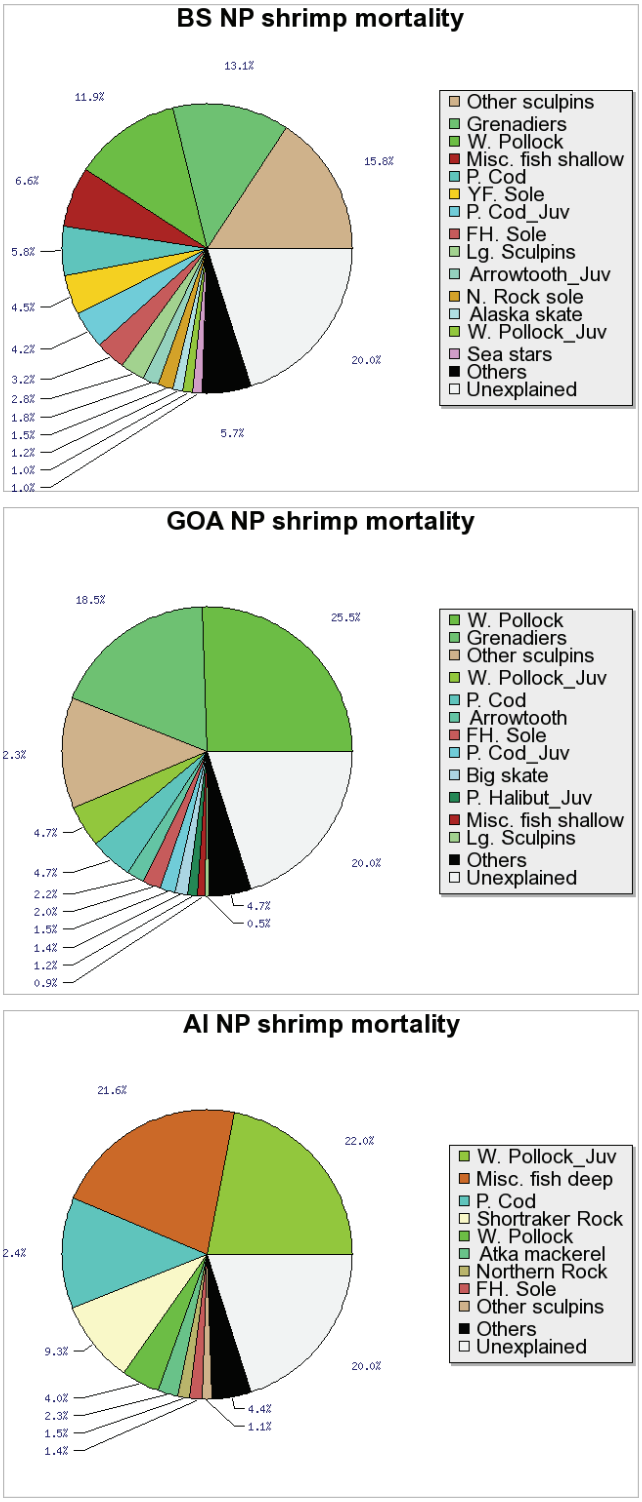
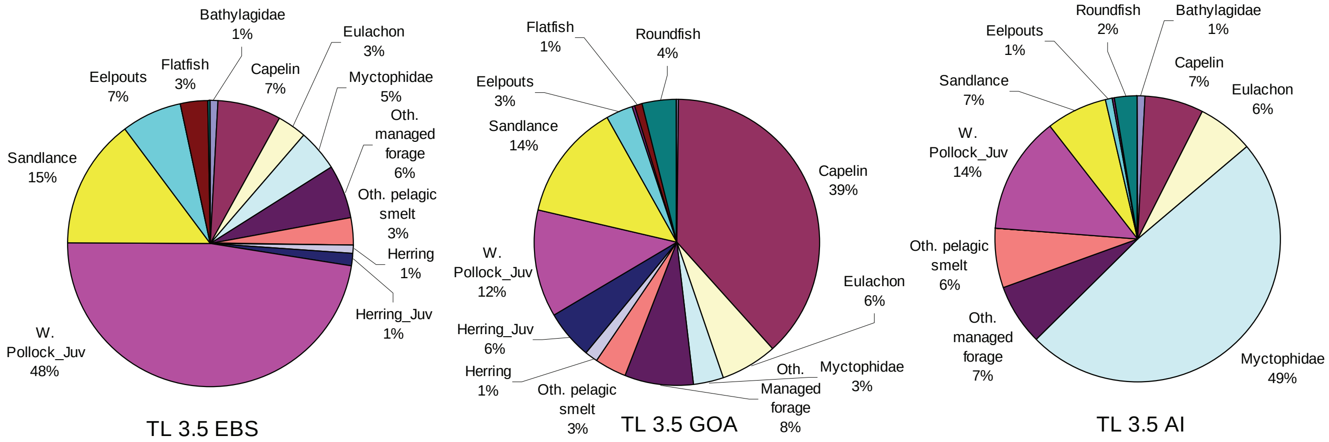


Figure 22. Mortality sources for NP shrimp in the Eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom).

Information quality increases further when estimating consumption and biomass of forage species at TL 3.5, including groups in the NPFMC's "Forage Fish" management category, because data-rich groundfish consume these forage species. Each ecosystem has a different dominant forage fish according to consumption estimates. In the EBS, the most consumed forage fish is juvenile pollock (48% of consumption, Figure 23), while capelin are most consumed (39%) in the GOA, and myctophids are most consumed (49%) in the AI. Sand lance are the second most consumed forage fish in both the EBS and the GOA, at 14-15% of total consumption of TL 3.5. In the AI, juvenile pollock are second most consumed (14%). In the EBS, approximately half of the consumption of juvenile pollock is attributable to adult pollock cannibalism (which accounts for nearly 40% of juvenile pollock mortality, Fig.10a). Adult and juvenile arrowtooth flounder predation combined accounts for nearly half of all capelin consumption in the GOA and more than one third of capelin total mortality; adult pollock also contribute substantially to capelin mortality (Fig. 18). Predation by pollock and grenadiers together account for nearly two thirds of myctophid consumption in the AI. Atka mackerel account for a majority of juvenile pollock mortality in the AI (Fig. 10c).



TL 3.5 EBS TL 3.5 GOA TL 3.5 AI

Figure 23. Consumption of groups at TL 3.5 by predators in the Eastern Bering Sea (left), Gulf of Alaska (center), and Aleutian Islands (right).

The NPFMC Forage fish management category includes euphausiids, capelin, eulachon and other smelts, bathylagids, myctophids, sand lance, and other managed forage including sandfish and sticheids. In all systems, euphausiid consumption accounts for 77-78% of all consumption in these selected groups. All forage fish are protected under the Forage Fish amendment prohibiting directed fishing, but this analysis of consumption estimates within the management category shows that different forage fish species are important in each ecosystem. In this subset of the full TL 3.5 forage base, the benthic-associated sand lance are the most consumed forage fish in the EBS, the coastal pelagic capelin dominate forage fish consumption in the GOA, and the oceanic pelagic myctophids are the dominant forage consumed in the AI (Fig. 24). Northern rock sole account for a third of sand lance consumption in EBS; the primary consumers of GOA capelin and AI myctophids are as described above.

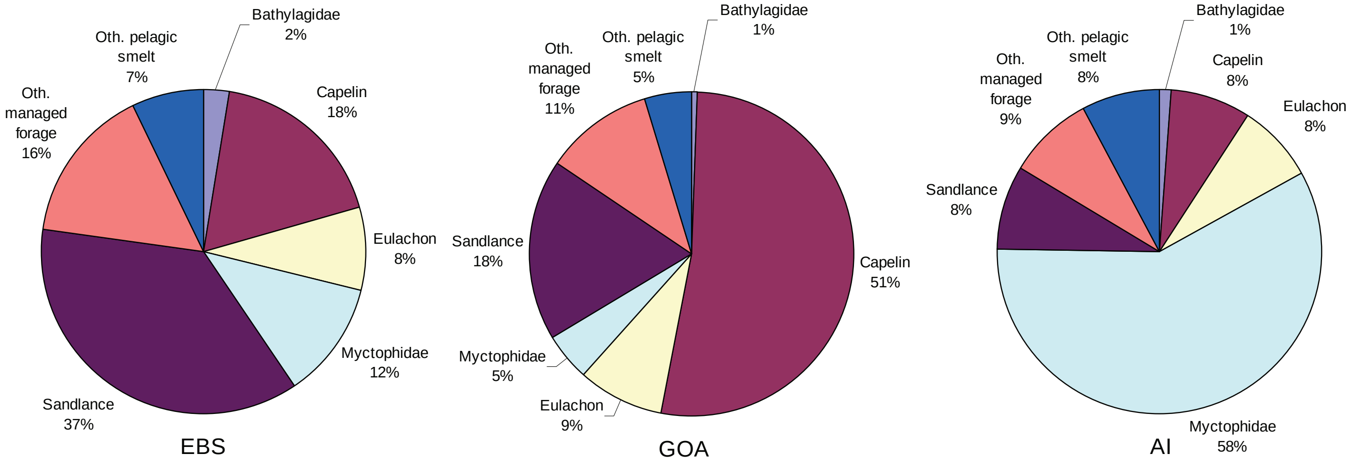


Figure 24. Consumption of "forage fish" management category in the Eastern Bering Sea (left), Gulf of Alaska (center), and Aleutian Islands (right).

The management implications of this analysis differ by ecosystem, both because of the current management of the species involved and due to the physical differences between systems implied by the results. First we discuss management of the species: in the EBS, pollock, the primary "forage fish" is also a primary commercially fished species as an adult. Therefore, in the EBS, the sustainability of the pollock fishery as well as a large proportion of predator (including adult pollock) consumption depends on continued juvenile pollock production. In the GOA and AI the primary forage fish, capelin and myctophids, are both given protected status by the NPFMC forage fish FMP amendment, which prohibits directed fishing for all species in the forage fish category. While this protected status was designed to minimize any potentially negative direct effects of fishing on the primary forage species in the AI and GOA, there is also little information available to study the fluctuations in forage resources in these systems precisely because they are non-commercial species.

These differences in data quality ultimately affect model-based prediction. It is straightforward to demonstrate the sensitivity of other species in the ecosystem to each of these influential forage groups using a simulation analysis where the survival of a given group is decreased and the equilibrium response of other groups is evaluated. Fluctuating myctophid survival most clearly impacts AI groups while it has little impact in the EBS or GOA (Fig. 25); similarly capelin fluctuations are most influential in the GOA, to a lesser extent the EBS, and are least influential in the AI (Fig. 26). Juvenile pollock fluctuations affect multiple groups in each ecosystem, but effects are strongest and most certain in the EBS (Fig. 27). In addition, the uncertainty in predictions for AI myctophids and GOA capelin are much higher than for EBS juvenile pollock. Because pollock are both an important commercial species and an important forage species in the EBS, we may have a unique opportunity to study the ecosystem dynamics surrounding fluctuating forage fish availability there because pollock recruitment is closely monitored for stock assessment purposes. However, the sensitivity of other species in the AI and GOA to myctophids and capelin, respectively, suggest that further study of these non-fishery resources would be a priority for ecosystem-based analyses there.

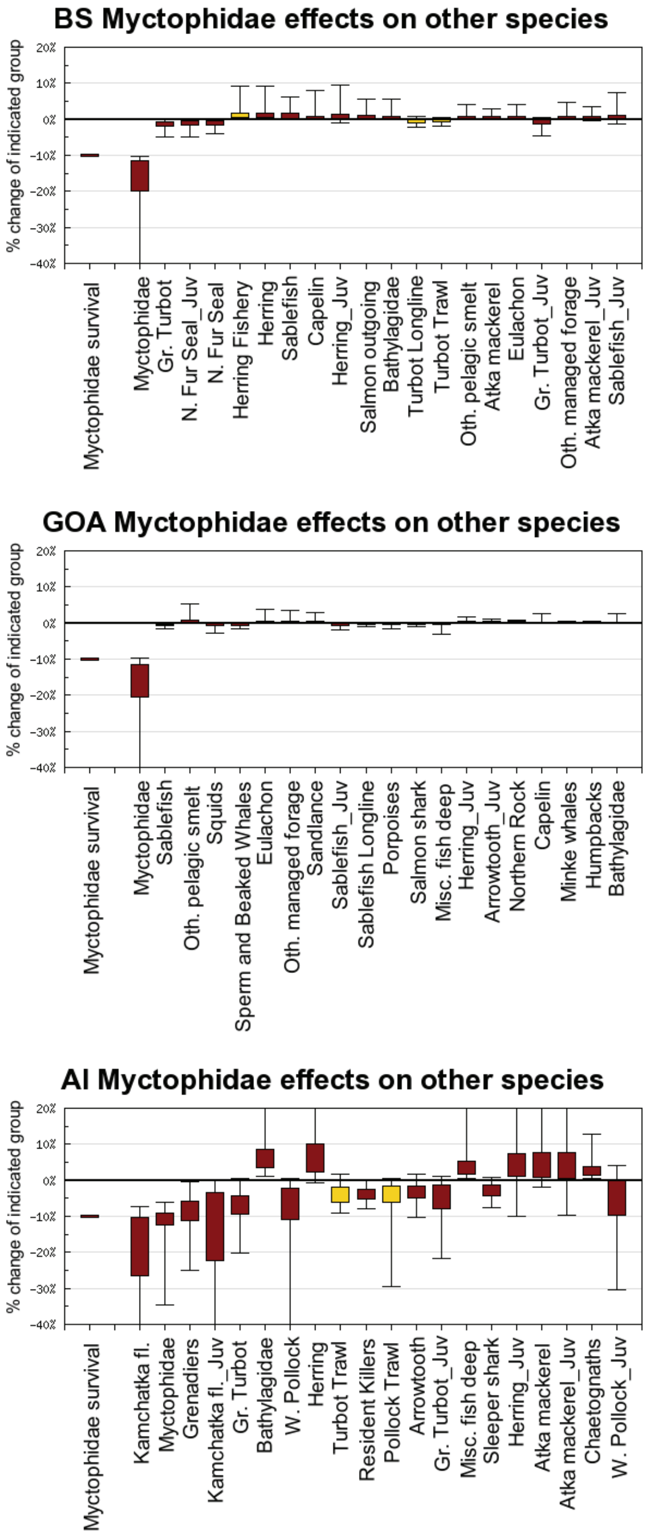


Figure 25. Influence of myctophids in the Eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom) food webs.

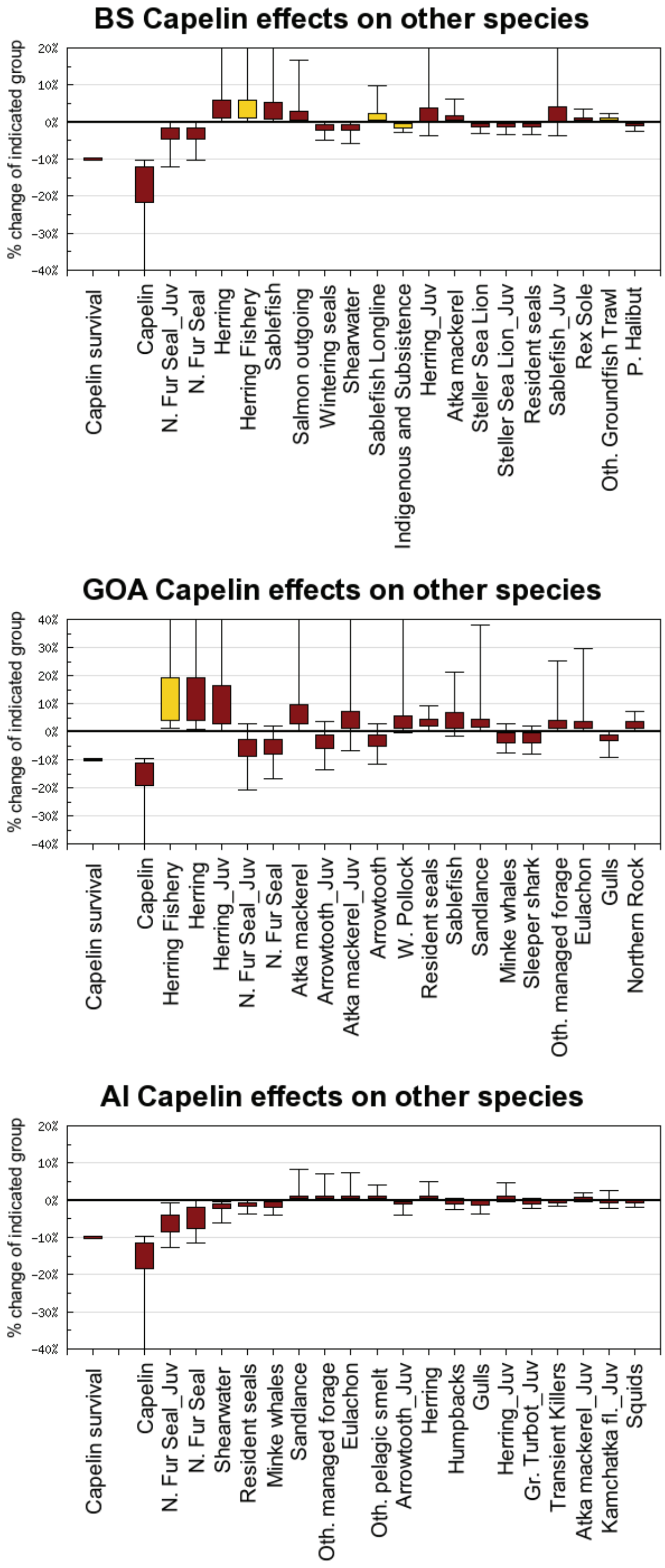


Figure 26. Influence of capelin in the Eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom) food webs.

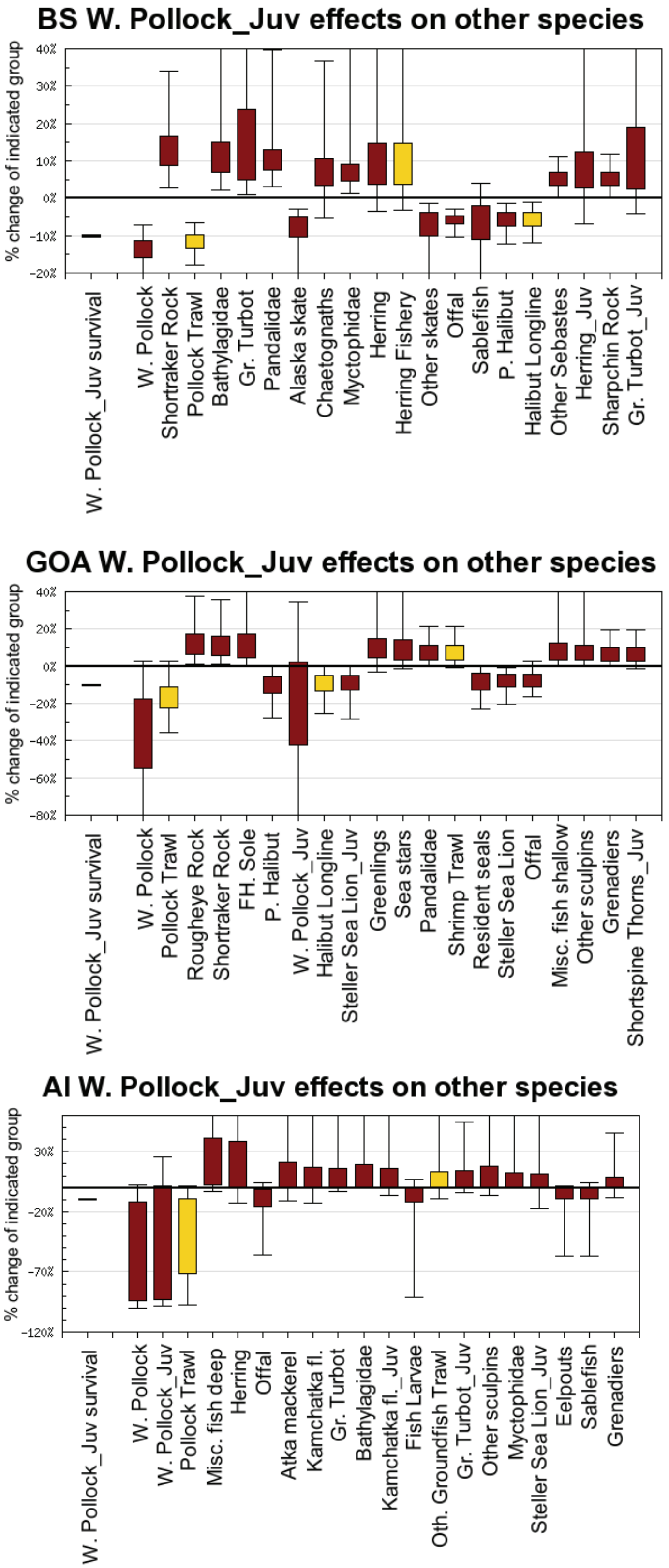


Figure 27. Influence of juvenile pollock in the Eastern Bering Sea (top), Gulf of Alaska (center), and Aleutian Islands (bottom) food webs.

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Although the primary forage fish consumed in the AI and the GOA are similar form a management standpoint, they represent very different forage from a biological/physical standpoint. Capelin are primarily a coastal, continental shelf species, while myctophids are an oceanic, deepwater family of forage fish. This suggests that different climatic and oceanographic factors would affect production for the forage base in each ecosystem. Therefore, different climate and physical indicators might be appropriate signals of changing forage production in the AI as opposed to the GOA. Overall, using food web model-based estimates of consumption to characterize the forage base in each ecosystem may help tailor physical indicators to each ecosystem. Consumption patterns confirm that the EBS is more self-contained shelf oriented ecosystem with equal benthic and pelagic energy inputs, with little oceanic influence. In contrast, the AI is mostly open ocean-influenced. Ecosystem boundaries may be more difficult to discern in an open, oceanic food web from an energetic perspective. The GOA food web seems intermediate, with an oceanic influence but also localized benthic and coastal pelagic forage base.

3.3.3 Trophodynamic Comparisons of the EBS, AI, and GOA

The previous sections used the ecosystem models to provide context for single species management by evaluating the roles of different commercially important and forage species within each ecosystem. In this section, we give more emphasis to whole-system indicators of ecosystem structure and function to compare and contrast the three ecosystems. Numerous ecosystem indicators have been suggested in the literature (e.g., Rice 2000, Rice 2003, Cury et al. 2005). We select two simple indicators, biomass and consumption, to characterize basic differences in structure and potential energy flow between the systems. A third indicator uses calculated energy flow between trophic levels to estimate the “footprint” of each group, including fisheries, in terms of the amount of energy removed from the ecosystem by that group. The objective of these comparisons is to provide a basis for system-level evaluation of ecosystem state and fishery impacts, and to develop potential management thresholds appropriate to the distinct structure of each Alaskan ecosystem.

3.3.3.1 Biomass at Trophic Level

Relative biomass of major species groups within the ecosystem is the most basic ecosystem indicator, and is most often used to evaluate ecosystem change over time (Cury et al. 2005). However, it is also instructive to compare biomass of similar groups between ecosystems to evaluate ecosystem differences which might suggest fishery management methods tailored to each ecosystem. Here, we compare biomass density (t/km^2) of groups between ecosystems because the three systems are so different in areal extent. In the first comparison, we simply plot biomass density at trophic level (TL) to examine whether groups at similar levels in each system have similar biomass densities. Then, we compare the relationship between biomass density and TL for each ecosystem using linear regressions of log biomass density on TL. Residuals from these regressions indicate which groups have the greatest anomalies from the overall relationship. Because the three models were built to have comparable groups, and identical assumptions were made to parameterize certain groups where data were lacking, we might expect considerable similarity in the biomass densities of many groups at each trophic level. Nevertheless, for key species groups biomass density at TL differs greatly between systems.

In a simple plot of biomass density at TL, differences between the AI and the other two systems are apparent for low TL groups such as copepods and euphausiids. There are no biomass estimates for any of these groups in any ecosystem, so these biomass densities are estimated by consumption requirements in each ecosystem. The much higher estimated densities of copepods and euphausiids in the AI (Fig. 28) likely reflects the dominance of pelagic energy flow relative to the other two systems that was discussed in Sections 3.1.2 and 3.3.2. Conversely, the density of EBS bivalves which is the same order of magnitude as AI copepods and euphausiids, reflects the dominant benthic energy flow in the EBS. Unlike the copepod and euphausiid density estimates, the density of bivalves in the EBS is based on field survey data (McDonald et al. 1981, and see Appendix A).

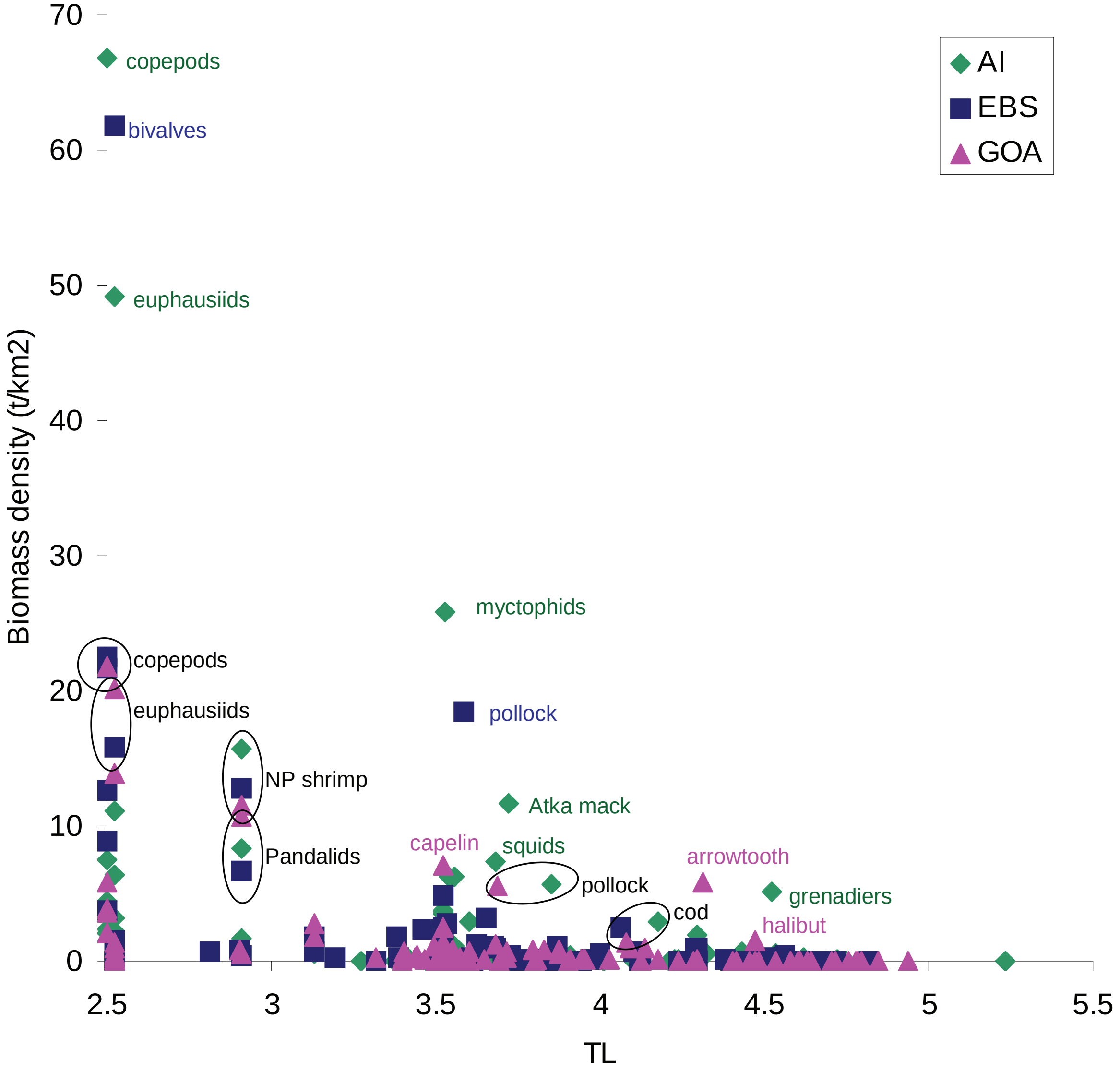

Figure 28. Biomass density (t/km^2) for species groups in the Aleutian Islands (diamonds), Eastern Bering Sea (squares), and Gulf of Alaska (triangles) ecosystem models, trophic levels (TL) 2.5 through 5.5.

The differences between systems again become pronounced above TL 3.5, although the systems are remarkably similar in biomass density for groups between TL 2.5 and 3.5. In contrast to the TL 2.5 copepods, euphausiids, and bivalves, there are few differences between the AI, EBS, and GOA in terms of shrimp group biomass at TL 2.9 (Fig. 28). Because shrimp groups lack biomass estimates in all three models, this similarity in biomass density reflects the similar consumption demand for shrimp in each ecosystem. Above TL 3.5, there is a mix of groups with field-based biomass estimates and consumption-based biomass estimates, but differences between ecosystems are clear from both types of groups. Myctophids, squids, and capelin are important forage groups with consumption-based biomass estimates; these groups have distinctly high biomass in the AI (myctophids and squids) and in the GOA (capelin; Fig. 28). Commercially important forage groups in each ecosystem (adult pollock and adult Atka mackerel) have biomass densities based on extensive surveys and stock assessments. These field-based estimates indicate that EBS pollock have remarkably high biomass, on the same order of magnitude as copepods and euphausiids in that ecosystem, and far higher than pollock in either the AI or GOA (although the TL of adult pollock is lower in the EBS than in the GOA and AI, indicating a different diet). The EBS pollock biomass density is the highest survey/assessment-based density for any fish in the three ecosystems. The second highest survey/assessment-based fish density is for AI Atka mackerel. We note, however, that the high mid-TL fish densities measured and estimated in the AI are still far lower in magnitude than the lower TL copepod and euphausiid densities estimated in that ecosystem, unlike the pollock situation in the EBS. This suggests not just a different species biomass distribution between the AI and the EBS, but also a fundamentally different ecosystem structure, with a biomass-dominant mid-TL group in the EBS versus the apparent biomass dominance of low-TL zooplankton groups supporting moderately high fish biomass in the AI.

Above TL 4, the species with relatively high biomass density are found in the GOA and AI model ecosystems. Cod, an important predator in all three ecosystems, does not display distinctly different biomass density between the GOA, EBS, and AI (Fig. 28). The primary difference is that AI cod have a higher TL, indicating a different diet (as described more fully above in Section 3.3.1). In the AI, the highest biomass density in any system above TL 4.5 is of a deepwater predator, grenadiers (Fig. 28). The biomass of grenadiers in the AI model is based on trawl survey estimated biomass from 1980s surveys which extended into the deepwater habitats inhabited by grenadiers (see Appendix A). Similarly to birds, marine mammals, sablefish, and pollock in the AI, a portion of the grenadier biomass and foraging activity occurs outside the area of the model as defined by the bottom trawl survey. The AI grenadier diet reflects the oceanic nature of this ecosystem in that it is dominated by myctophids (47%) and squid (45%). Therefore, this high density of grenadiers (along with pollock, birds, and marine mammals) is partially responsible for the high consumption-based estimates of densities for myctophids and squids in the AI, but all of these estimates can be viewed as reflecting imports from a wider area than is represented by the AI model area itself. While import of oceanic biomass by foraging animals may inflate consumption-based density estimates relative to the trawl-survey based model area, it is difficult to quantify how to alter the bounds of the AI model to best accommodate these oceanic imports; simply extending the model area to a deeper bathymetric contour does not address that imports are from pelagic habitats where animals do not necessarily distribute according to bottom depth. The implication for management is that unlike the EBS, the continental shelf surrounding the AI cannot be considered as a self-contained, closed ecosystem.

In contrast with the oceanic-influenced AI, biomass distributions above TL 4 in the GOA reflect a dominance of predatory continental shelf species. Arrowtooth flounder biomass density in the GOA is the highest density above TL 4 in any of the three ecosystems (Fig. 28). This is especially notable considering that the biomass density of forage species in the GOA appears generally lower than in the AI (where the high grenadier biomass is “supported” by even higher squid and myctophid biomass) and roughly equal to or lower than the EBS (where the high pollock biomass does not appear to support similarly high biomass of predatory species). GOA arrowtooth flounder distribute their consumption over multiple moderate density prey, including capelin (22% of diet), euphausiids (17%), pollock (14% adult and 10% juvenile), and pandalid shrimp (10%). In addition to arrowtooth flounder, Pacific halibut are another high density GOA species above TL 4. This high predator biomass relative to forage biomass in the GOA distinguishes it structurally from the EBS and AI.

While examining biomass distributions by TL demonstrates differences between systems for certain groups, regression analysis addresses more general structural differences, such as whether there is a fundamentally different biomass at a given TL between ecosystems. The relationship between (log) biomass density and TL appears similar for the GOA and AI models, while the EBS model relationship has a steeper negative slope (Fig. 29). Once again, the AI and EBS models are most different in terms of regression slope and intercept, with the GOA intermediate. All of these regressions are statistically significant ($p<0.001$) with R^2 fits ranging from 0.25 to 0.36. However, there are not statistically significant differences between the parameters of these log biomass regressions, despite the visual differences in slope. Although we detect no fundamentally different relationship between biomass and TL between the ecosystems as modeled, improved information on low TL groups (where we elected to make common assumptions) might change this result.

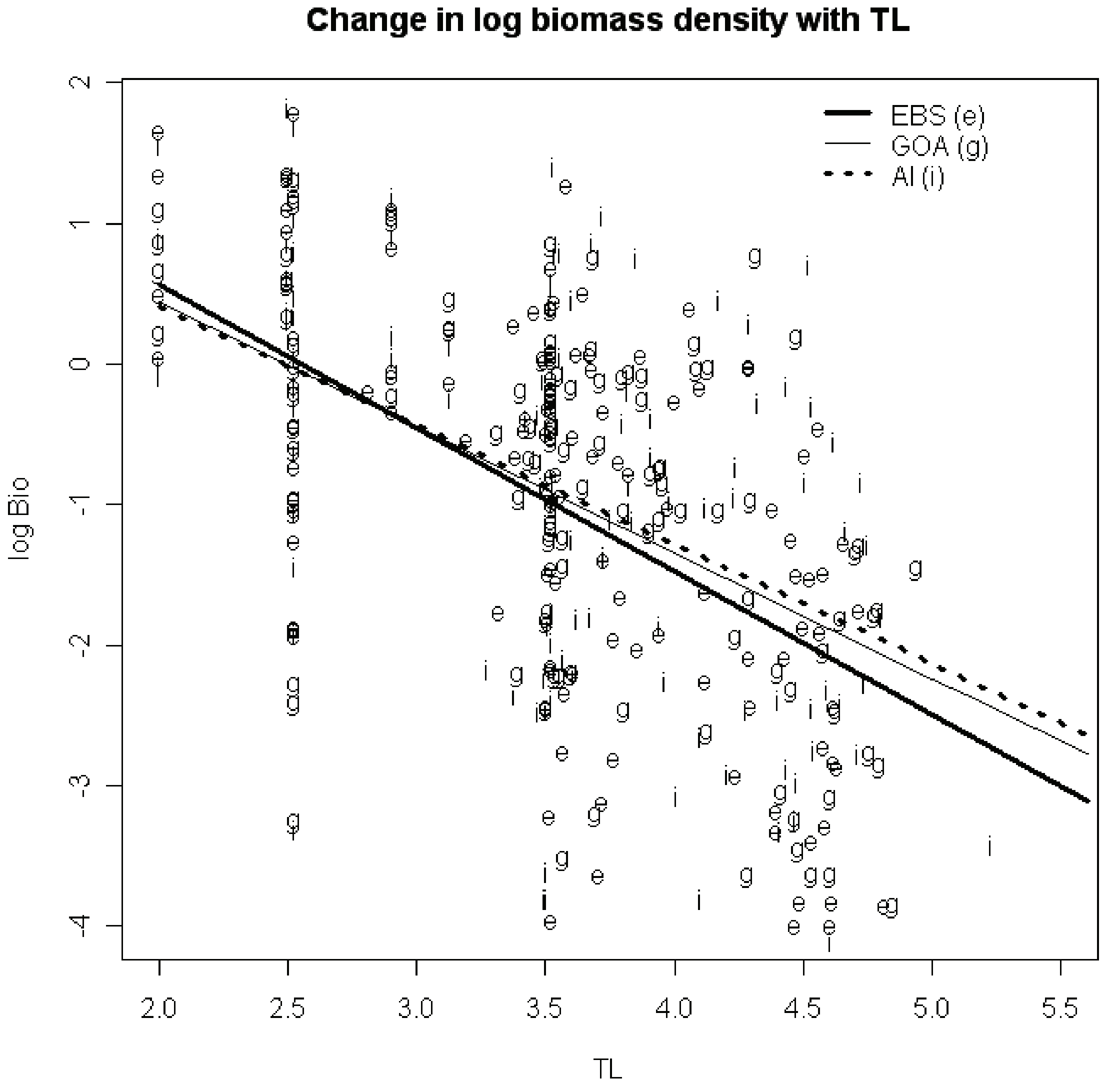

Figure 29. **Relationship of log biomass density (t/km^2) with trophic level (TL) in the Eastern Bering Sea, Gulf of Alaska and Aleutian Islands.**

Given the similar nature of the overall relationships between biomass density and TL between the models, the individual groups deviating most from these relationships provide further insight into commonalities and differences between the ecosystems. The residuals from each of these regressions delineate which species groups are at the extreme ends of the biomass scale at a given TL. Examining the ten most extreme residuals from each system's regression supports the conclusions drawn above for high biomass species, but also shows which species have especially low biomass density in each system, a result not obvious from the simple plot shown in Figure 28. In the EBS, pollock and cod are the two largest positive residuals from the regression, with adult pollock having the largest positive residual overall (Fig. 30a). In the AI, grenadiers, myctophids, Atka mackerel and pollock have the largest positive residuals, and in the GOA, arrowtooth flounder and Pacific halibut have the largest positive residuals (Fig. 30b and 30c). Negative residuals in each ecosystem represent the lowest biomass at a given TL. Several bird groups were consistently low across systems, and corals were low in the EBS and GOA, while sea pens were low in the AI and GOA (Fig. 30a-c). Fish larvae, a top-down balanced group consumed by jellyfish, made the top ten residuals with low values in the EBS and GOA. In the EBS, dusky rockfish, Dover sole and sea otters had low biomass density, as well as juvenile Atka mackerel (Fig. 30a). In the AI model, juvenile flatfish groups had extremely low biomass densities for their trophic level (Fig. 30b). In the GOA model, juvenile thornyheads and juvenile fur seals also had highly negative residuals (Fig. 30c).

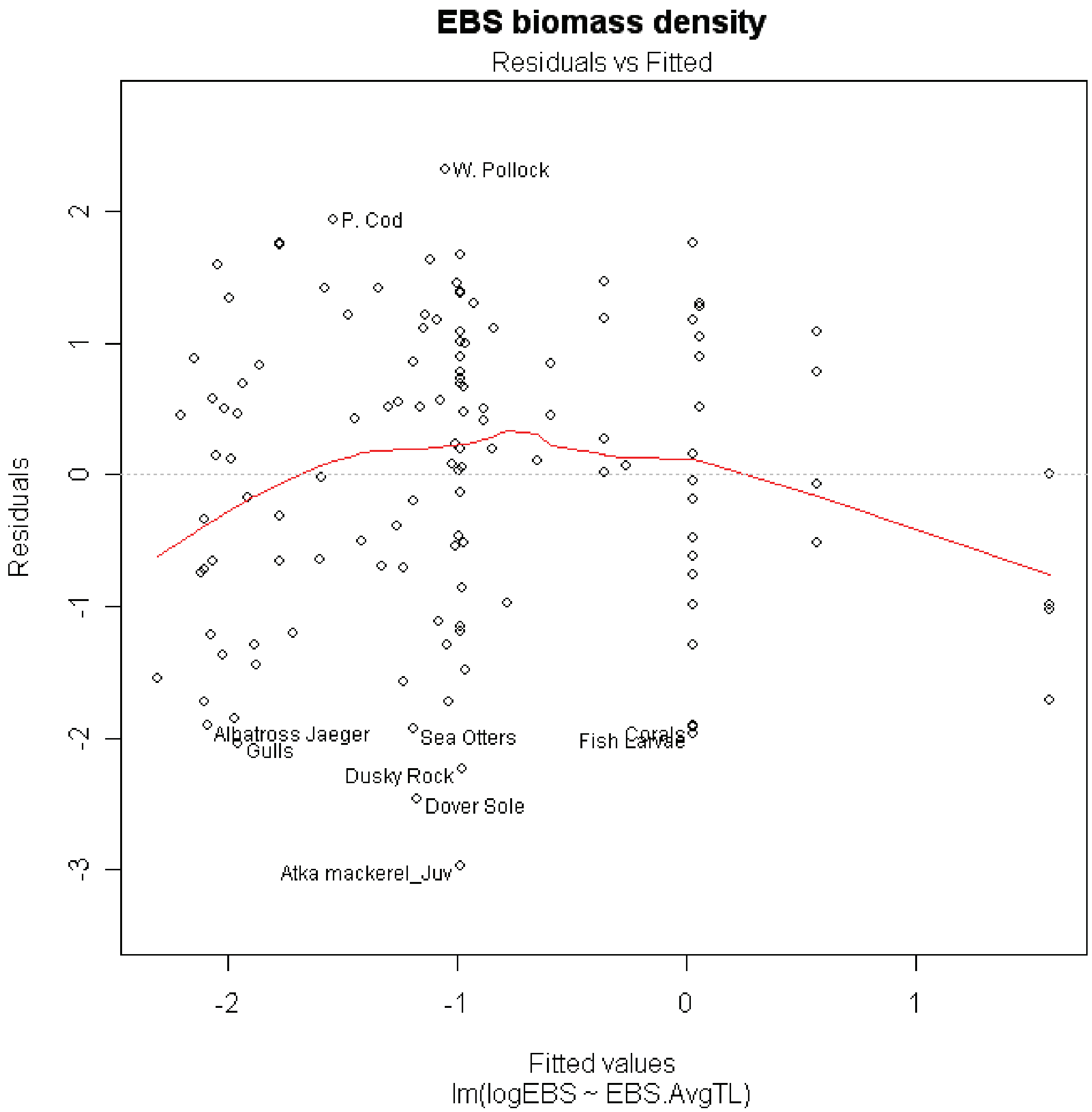

Figure 30a. Regression residuals from the relationship of log biomass density with trophic level (TL) in the Eastern Bering Sea. Species groups with the largest residuals (most extreme biomass at a given TL) are labeled. In the axis label, lm(logEBS~EBS.AvgTL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.

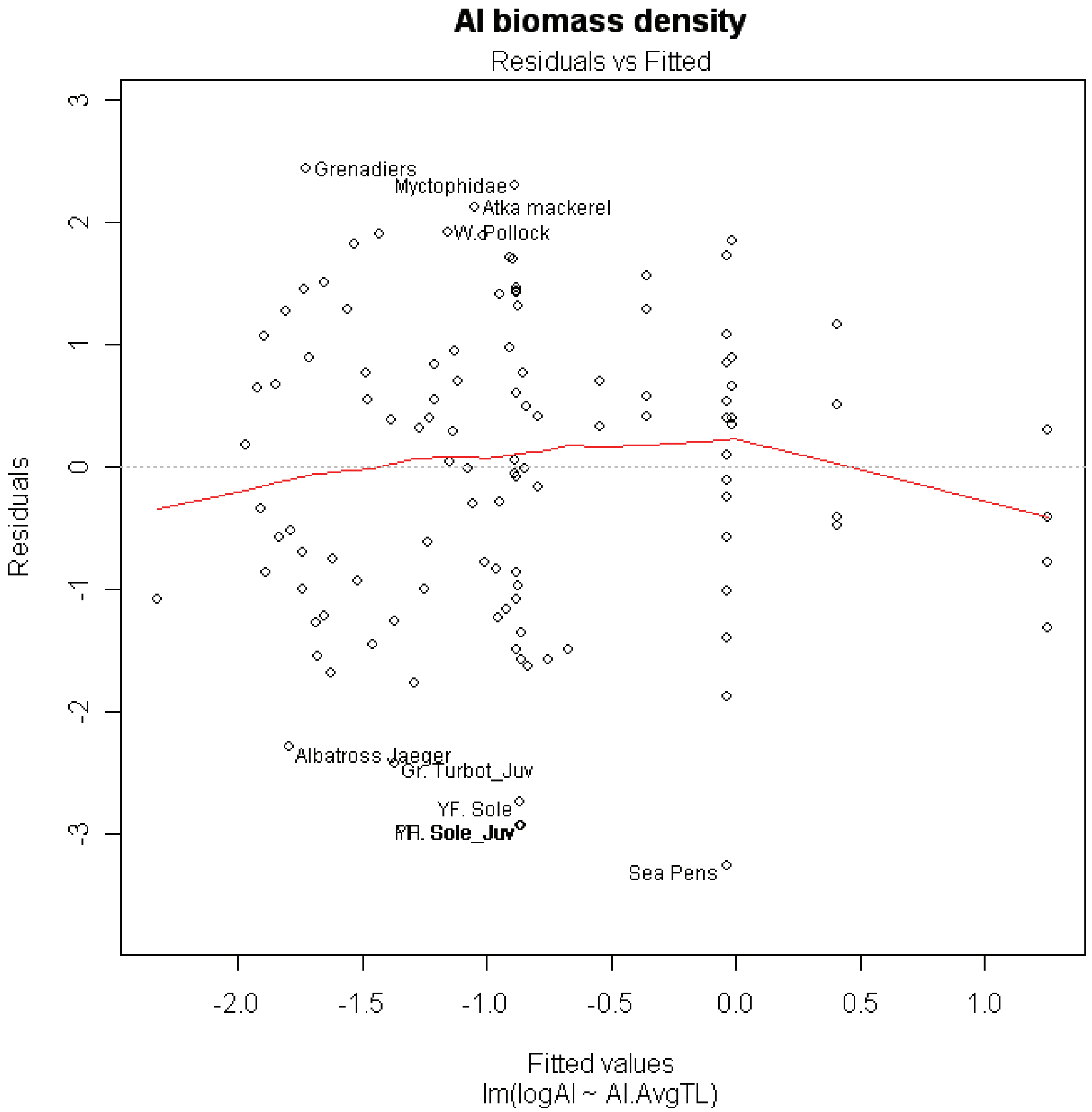

Figure 30b. **Regression residuals from the relationship of log biomass density with trophic level (TL) in the Aleutian Islands. Species groups with the largest residuals (most extreme biomass at a given TL) are labeled. In the axis label, lm(logAI~AI.AvgTL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.**

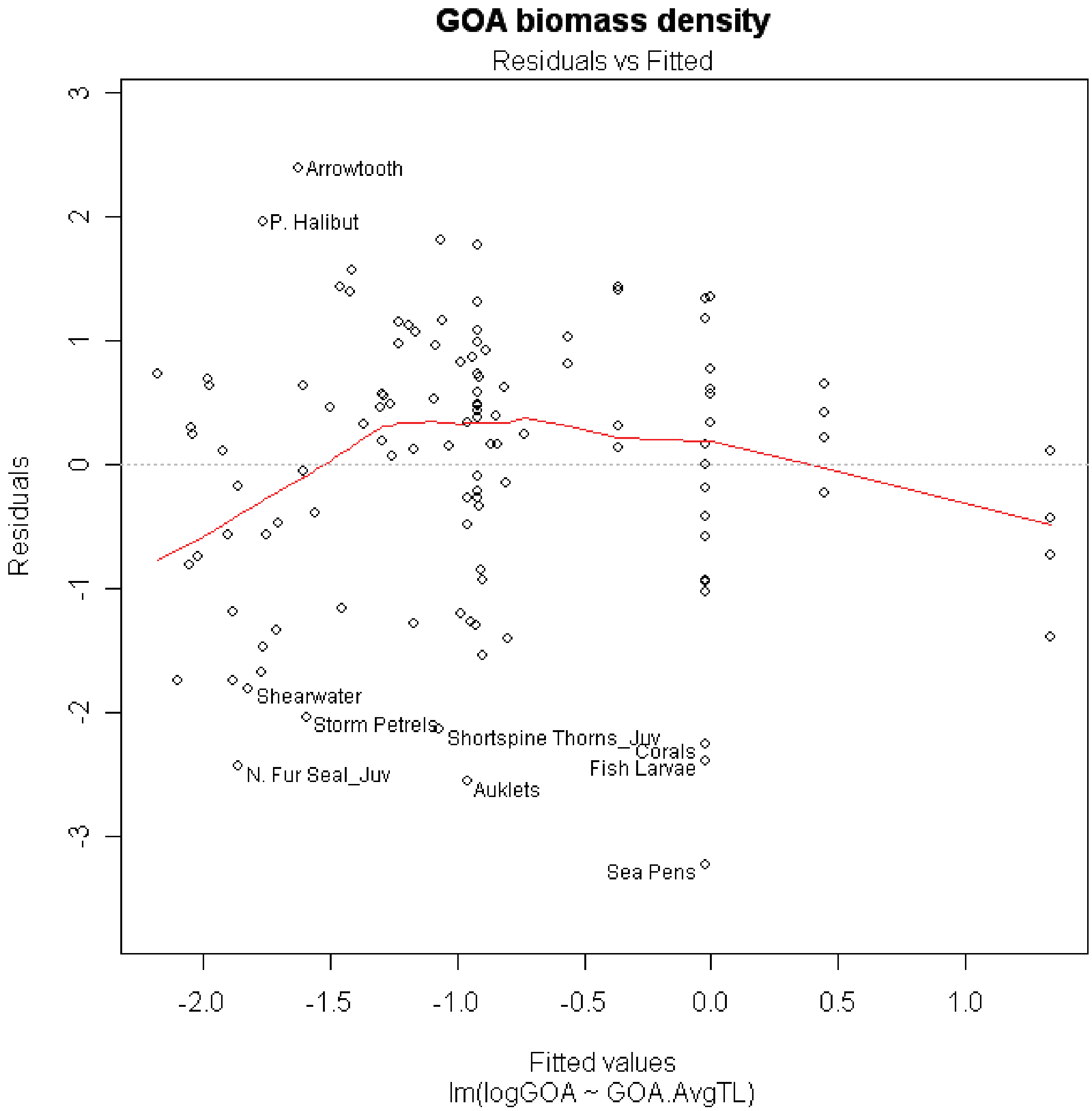

Figure 30c. Regression residuals from the relationship of log biomass density with trophic level (TL) in the Gulf of Alaska. Species groups with the largest residuals (most extreme biomass at a given TL) are labeled. In the axis label, lm(logGOA~GOA.AvgTL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.

Given the extremely wide spread in values of biomass density at trophic level, the “outliers” in each ecosystem may be disproportionately influential or vulnerable, and therefore of management interest in the ecosystem context. The high-biomass groups identified by this analysis are different between systems, and suggest different structural properties (e.g., the pollock dominated EBS versus the predator dominated GOA). However, biomass distributions should be viewed as one component of a suite of ecosystem indictors to provide a more accurate assessment of ecosystem state (Rice 2000, 2003, Cury et al. 2005). For example, all three ecosystems have birds among the low biomass outliers, as well as structure forming benthic invertebrates such as corals and sea pens. This suggest that aggregate biomass-based indicators of ecosystem condition might undervalue these ecosystem components, which may have high consumption despite low biomass (birds) or contribute to ecosystem productivity in a non-trophic way which is difficult to measure with a food web model (corals and sea pens). Therefore, we next examine consumption and finally fishery impact at each trophic level to provide a fuller suite of indicators for management.

3.3.3.2 Consumption at Trophic Level

In addition to biomass per unit area, we compared total consumption/km^2 of each group by trophic level. While comparing consumption is similar to comparing the biomass density for many species (because consumption = Q/B * B), the additional benefit in examining consumption is that the "consumption" of fisheries (catches) can be compared alongside the consumption of predators. We also note that this analysis is different from the analysis discussed above in Section 3.3.2 in that we now examine total consumption by a given predator group or fishery, rather than consumption of a given forage group by predators. The patterns of consumption at low TL largely reflect the biomass density patterns discussed above, so here we focus on consumption patterns for TL 3 and above.

Aleutian Island model species groups have the highest consumption per unit area above TL 3. Myctophids, Atka mackerel and squids are all estimated to have consumption per unit area exceeding that of EBS pollock, the next highest consumer group in any model (Fig. 31). In the GOA, capelin are estimated to have the highest consumption above TL 3, followed by AI and GOA pollock, but both are well below the EBS pollock consumption estimate. Above TL 4, cod are estimated to have similar consumption in all three ecosystems, although as reflected above in the biomass at TL discussion, AI cod have a slightly higher TL relative to GOA and EBS cod, and a slightly higher consumption estimate as well. The highest consumption after cod for each ecosystem comes from very different sources: from arrowtooth flounder in the GOA, from grenadiers in the AI, and from the pollock trawl fishery in the EBS (where "consumption" = catch per unit area).

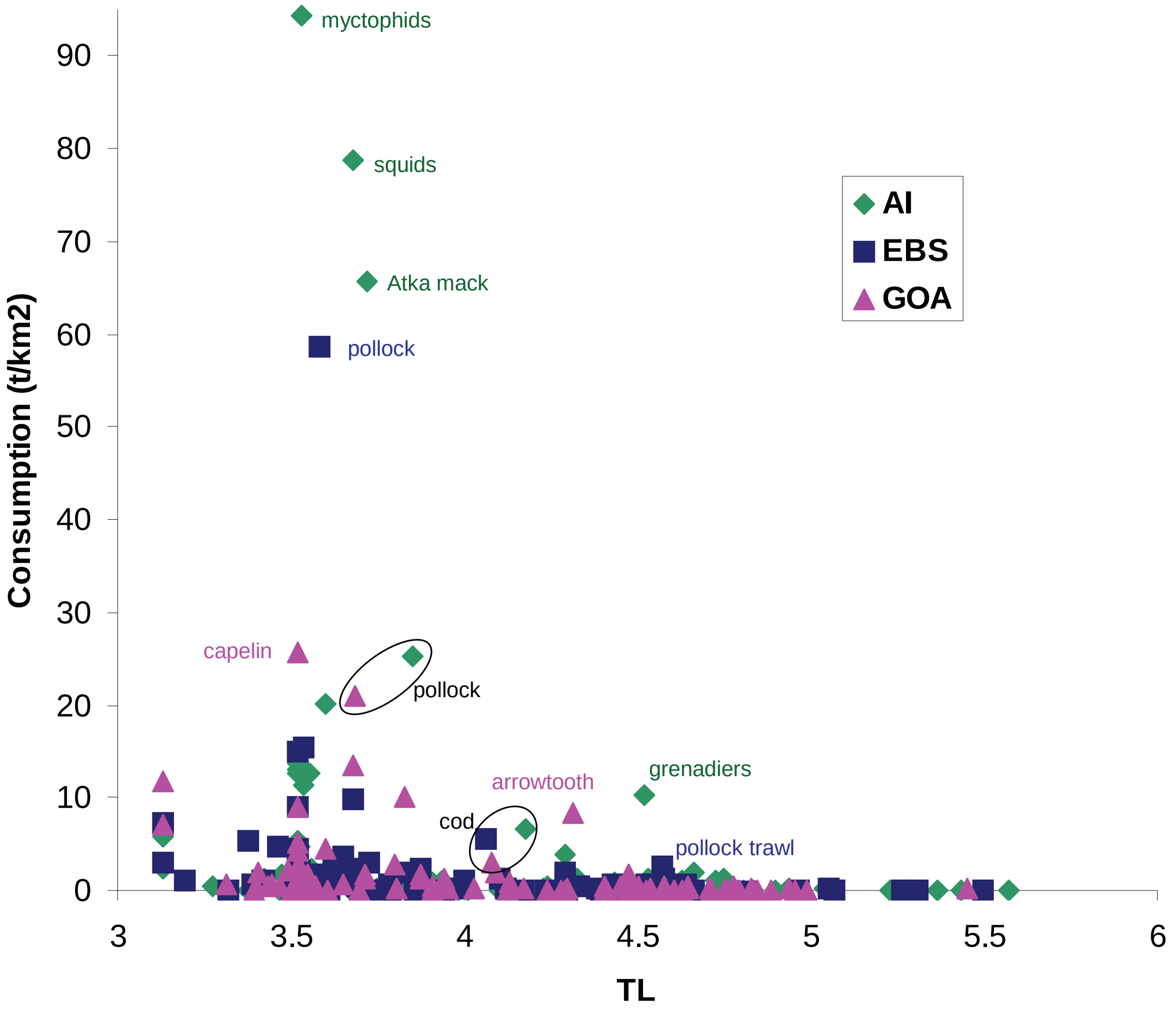

Figure 31. **Total consumption and total catch (t/km^2) for species groups and fisheries in the Aleutian Islands (diamonds), Eastern Bering Sea (squares), and Gulf of Alaska (triangles) ecosystem models, trophic levels (TL) 3 through 5.5.**

As with the biomass at TL analysis discussed above, we applied regression analysis to addresses more general structural differences between ecosystems, such as whether there is a fundamentally different consumption at a given TL. Similar to the biomass relationships, the relationship between (log) consumption per area and TL appears similar for the GOA and AI models, while the EBS model relationship has a steeper negative slope (Fig. 32). All of these regressions are statistically significant ($p<0.001$) with R^2 fits ranging from 0.26 to 0.39. However, there are not statistically significant differences between the parameters of these log consumption regressions, despite the visual differences in slope. Although we detect no fundamentally different relationship between consumption and TL between the ecosystems as modeled, as with the biomass relationships, improved information on low TL groups (where we elected to make common assumptions in the absence of data) might change this result.

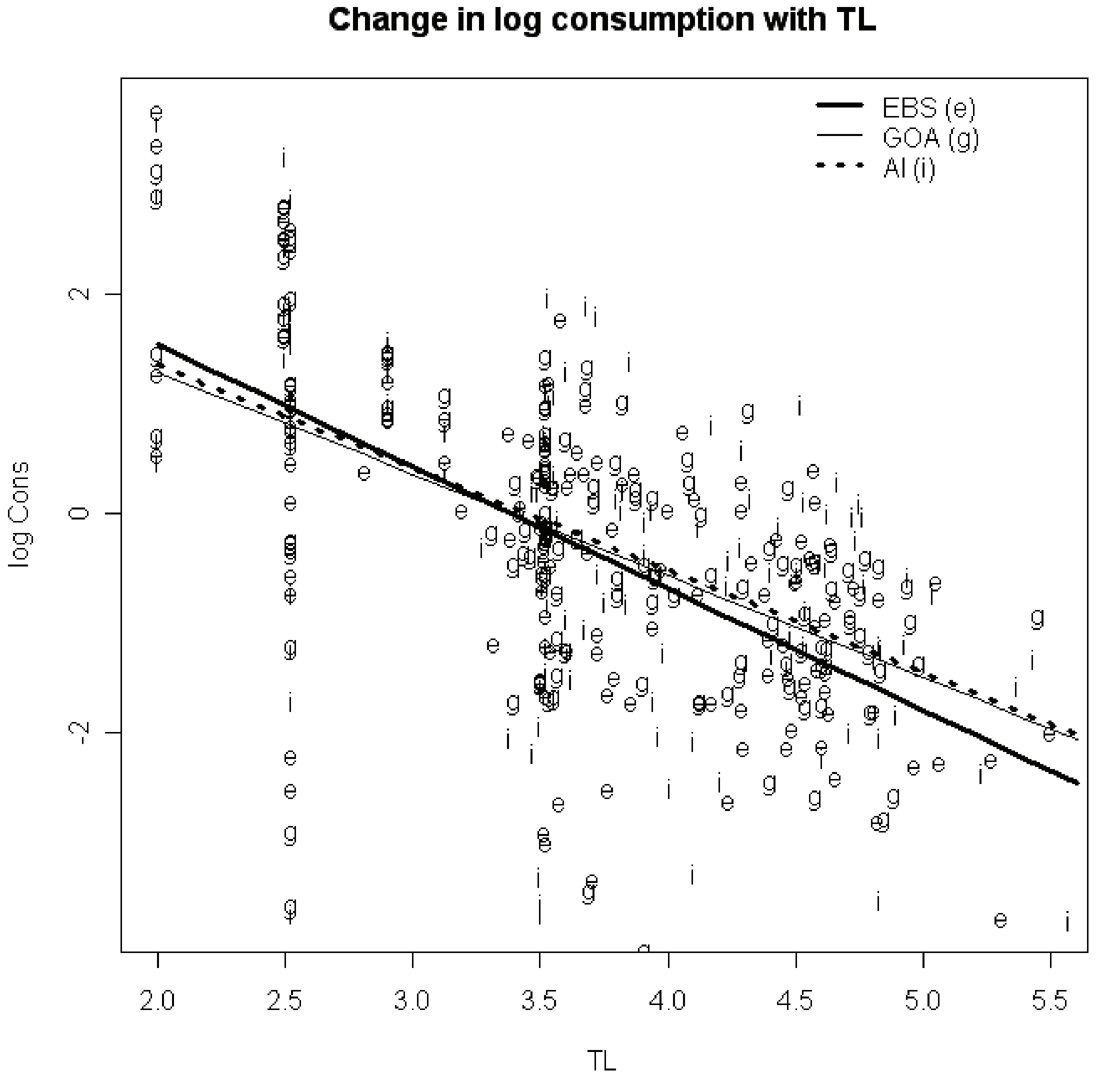

Figure 32. Relationship of log consumption (t/km^2) with trophic level (TL) in the Eastern Bering Sea, Gulf of Alaska and Aleutian Islands.

Similar to the analysis above presented for biomass relationships, we examine the individual groups deviating most from the consumption relationships shown in Figure 32 to provide further insight into commonalities and differences between the ecosystems. The residuals from each of these regressions delineate which species groups are at the extreme ends of the consumption scale at a given TL. Examining the ten most extreme residuals from each system's regression supports the conclusions drawn above for high consumption species, but also shows which species have especially low consumption in each system.

In the EBS, pelagic microbes, pollock, and benthic microbes are the three largest positive residuals from the regression, with pelagic microbes having the largest positive residual overall (Fig. 33a). It seems remarkable given the consumption estimates for microbes that the consumption of a fish group could be similarly high relative to its TL. In the AI, copepods and pelagic microbes have the largest positive residuals, and in the GOA, copepods, pelagic microbes, arrowtooth flounder and euphausiids have the largest positive residuals (Fig. 33 b and 33 c, respectively). These groups with very large consumption for their TL appear consistent with our previous results; for example, the strong benthic energy pathway in the EBS relative to the other ecosystems is reflected in the appearance of high benthic microbial consumption only in the EBS. Only pelagic zooplankton groups rank highest in the positive consumption residuals in the AI, while a similar set of pelagic zooplankton plus arrowtooth flounder rank highest in the GOA. As with pollock in the EBS, it seems remarkable in the GOA that arrowtooth flounder's consumption would be as high for its TL as high biomass, rapid turnover groups such as microbes and zooplankton. These results demonstrate the extent to which a single groundfish species is influential in a food web, and suggest that the trophic interactions of these influential species be monitored as one component of a suite of ecosystem indicators tailored to the EBS and GOA, especially since they are commercially exploited.

Negative residuals in each ecosystem represent the lowest consumption at a given TL. While the biomass regressions presented above showed that bird groups were consistently low across systems, consumption regressions never have birds among the lowest groups at a given TL, because high seabird consumption rates combined with relatively low biomass still places consumption well within the range of that for other groups at a given TL. However, similar to the biomass at TL results, sea pens and corals had consistently low consumption in all three ecosystems (Fig. 33 a-c); this is consistent with relatively low biomass of both groups combined with relatively low consumption rates. The higher biomass of corals in the AI relative to the other two ecosystems is reflected in coral consumption that is closer to average consumption for that TL (Fig. 33b), whereas corals are extremely low outliers in the EBS and GOA (Figs. 33 a and c). In the EBS, dusky rockfish, Dover sole, juvenile Atka mackerel and sea otters had low biomass density, and all of these groups except for sea otters had low consumption for their TL as well (Fig. 33 a). Like birds, sea otters and other marine mammals have low biomass but a high consumption rate, so comparing consumption gives a more accurate picture of group influence (or lack thereof) than biomass alone. Similarly, in the GOA model, juvenile thornyheads and juvenile fur seals had highly negative biomass residuals, but only thornyheads remain low in consumption residuals (Fig. 33c). The remaining groups with highly negative consumption regression residuals in each ecosystem model are either low biomass fish or invertebrates, or fisheries with extremely low catch. These include rockfish groups in the EBS, flatfish groups and salmon fisheries in the AI, and fish larvae, king crabs and the shrimp trawl fishery in the GOA (Fig. 33a-c).

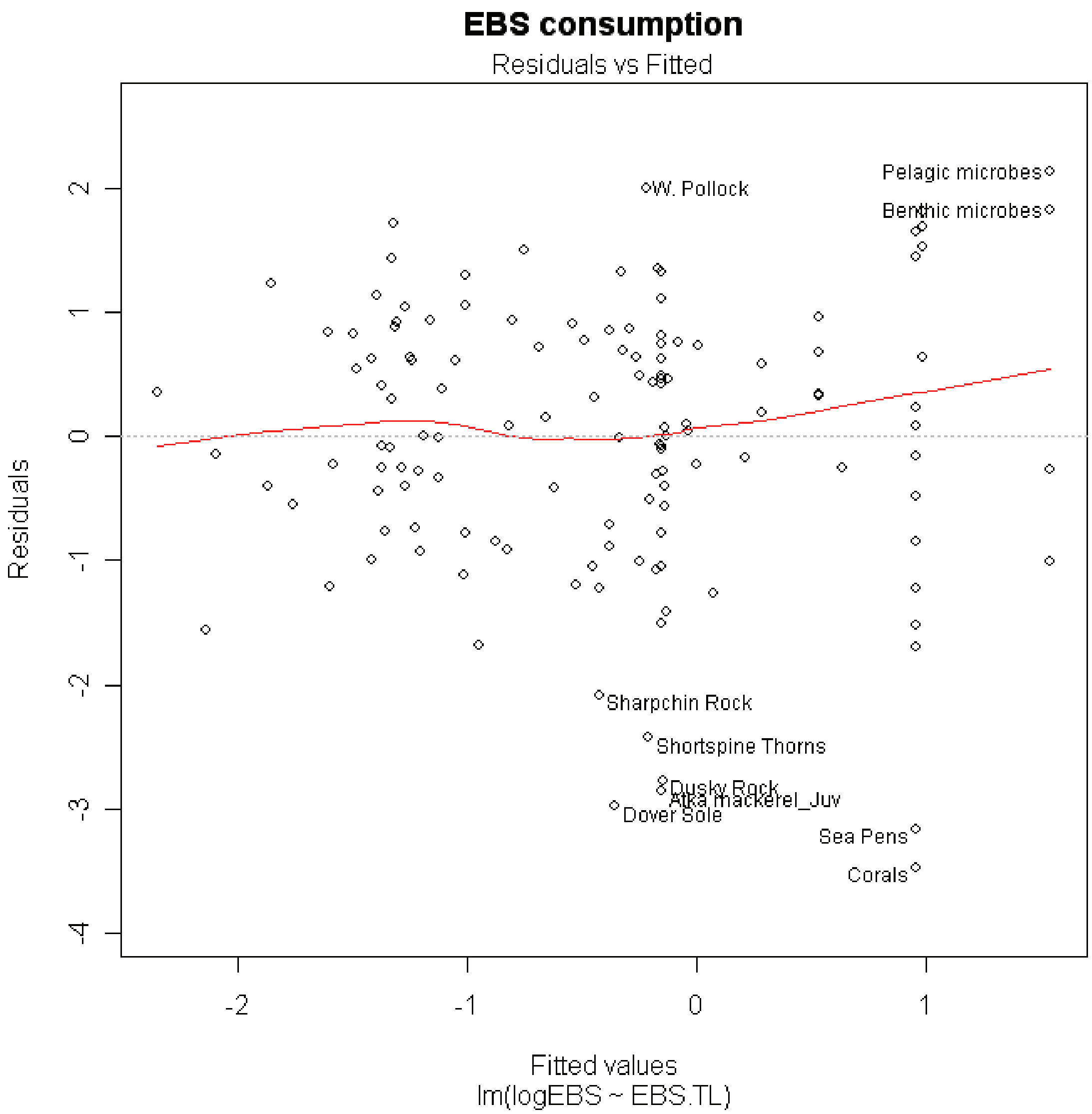

Figure 33a. Regression residuals from the relationship of log consumption and catch per unit area with trophic level (TL) in the Eastern Bering Sea. Species groups or fisheries with the largest residuals (most extreme consumption or catch at a given TL) are labeled. In the axis label, lm(logEBS~EBS.TL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.

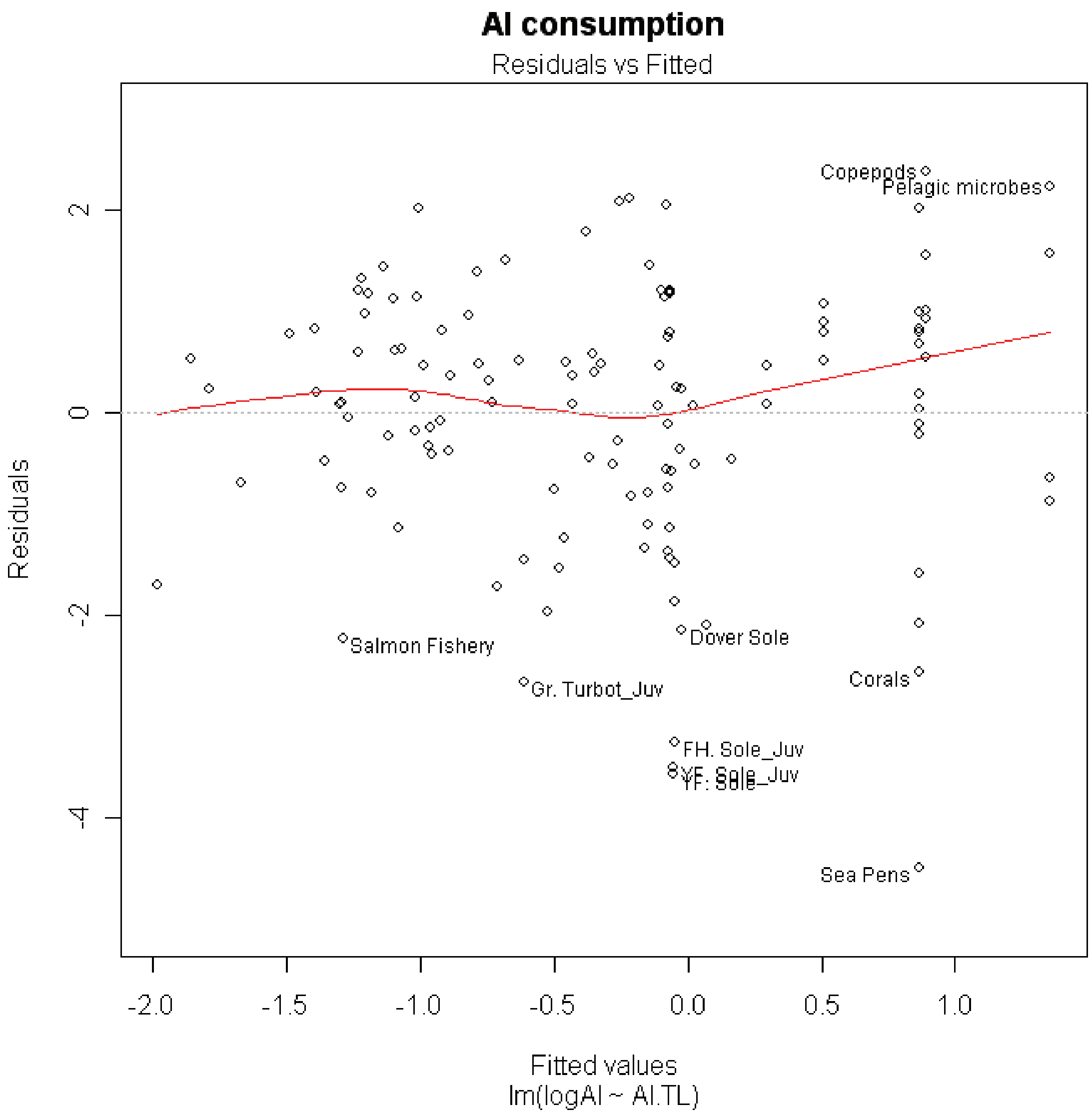

Figure 33b. **Regression residuals from the relationship of log consumption and catch per unit area with trophic level (TL) in the Aleutian Islands. Species groups or fisheries with the largest residuals (most extreme consumption or catch at a given TL) are labeled. In the axis label, lm(logAI~AI.TL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.**

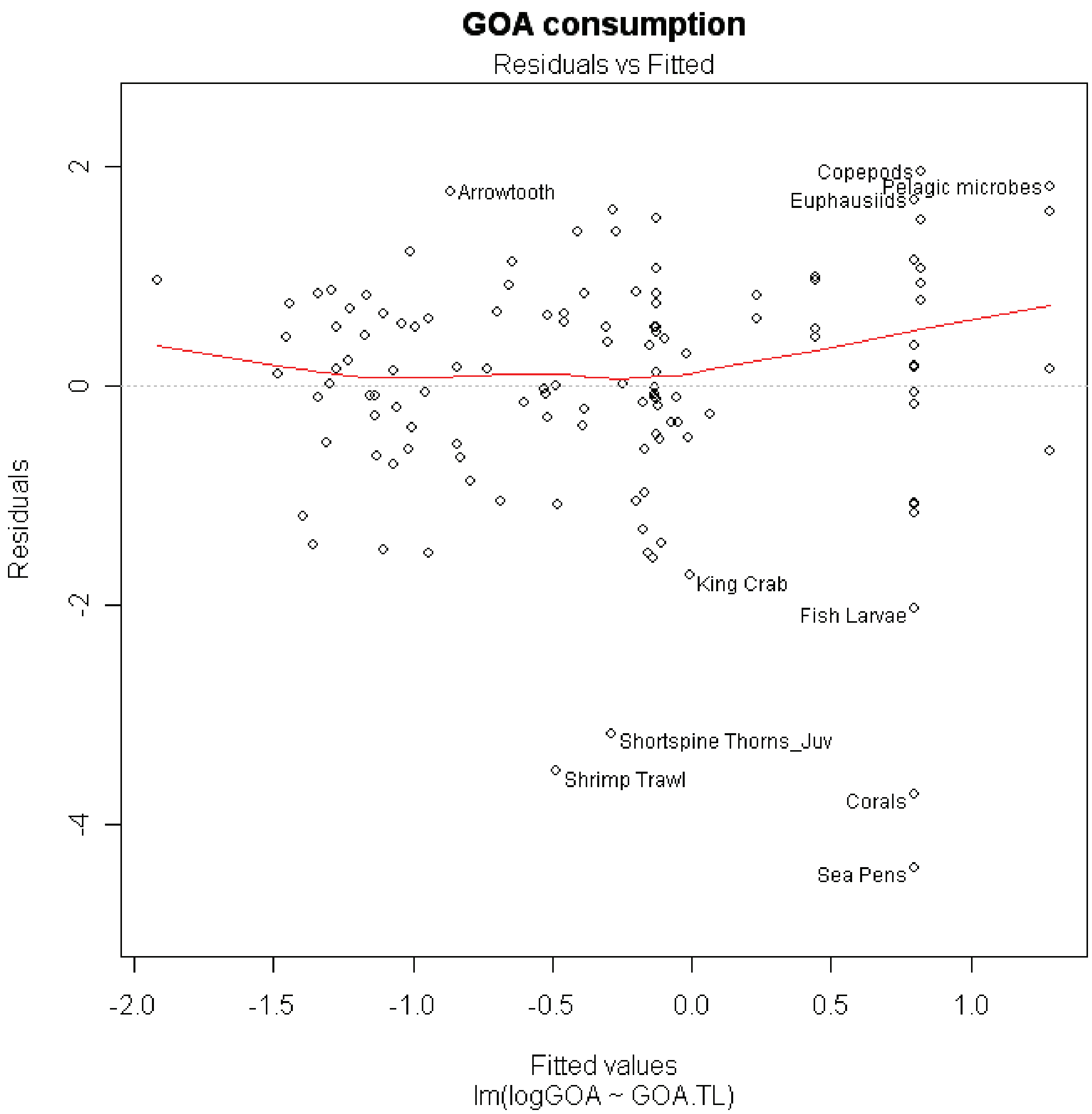

Figure 33c. Regression residuals from the relationship of log consumption and catch per unit area with trophic level (TL) in the Gulf of Alaska. Species groups or fisheries with the largest residuals (most extreme consumption or catch at a given TL) are labeled. In the axis label, lm(logGOA~GOA.TL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.

To further clarify the relationships between fishery catch and predator consumption in each modeled ecosystem, we examine consumption at TL for TL 4 and greater. The AI ecosystem has two of the three groups with the highest consumption over TL 4, grenadiers (first), and cod (third; Figure 34). GOA arrowtooth have the second highest consumption of any group over TL 4, and EBS cod rank fourth. The remaining groups in the top ten consumers have considerably lower consumption than the top 4. Ranked fifth through tenth are, respectively, AI miscellaneous deepwater fish, GOA cod, the EBS pollock trawl fishery, AI porpoises, and EBS and GOA grenadiers (Fig. 34). While cod and grenadiers from all three ecosystems appear in the top ten consumers above TL 4, some groups have vastly different consumption estimates between ecosystems. For example, arrowtooth flounder, halibut, and sablefish have much higher consumption in the GOA relative to the other ecosystems, while Alaska skates, fur seals and large sculpins have much higher consumption in the EBS. In the AI, Steller sea lions and Kamchatka flounder have relatively high consumption as well as the porpoises and misc. deep fish mentioned above. In terms of fisheries, the EBS pollock trawl fishery has a much higher catch rate than its counterpart in the AI or GOA, and is the fishery with the overall highest consumption rate in any ecosystem. In the AI, the pollock and Atka mackerel trawl fisheries have consumption of a magnitude slightly lower that estimated for AI sea lions, but higher than for other fisheries in that ecosystem. Above TL 5, the EBS cod longline fishery and the GOA halibut longline fisheries have the highest consumption rates of the few groups (mostly fisheries) at that TL (Fig. 34).

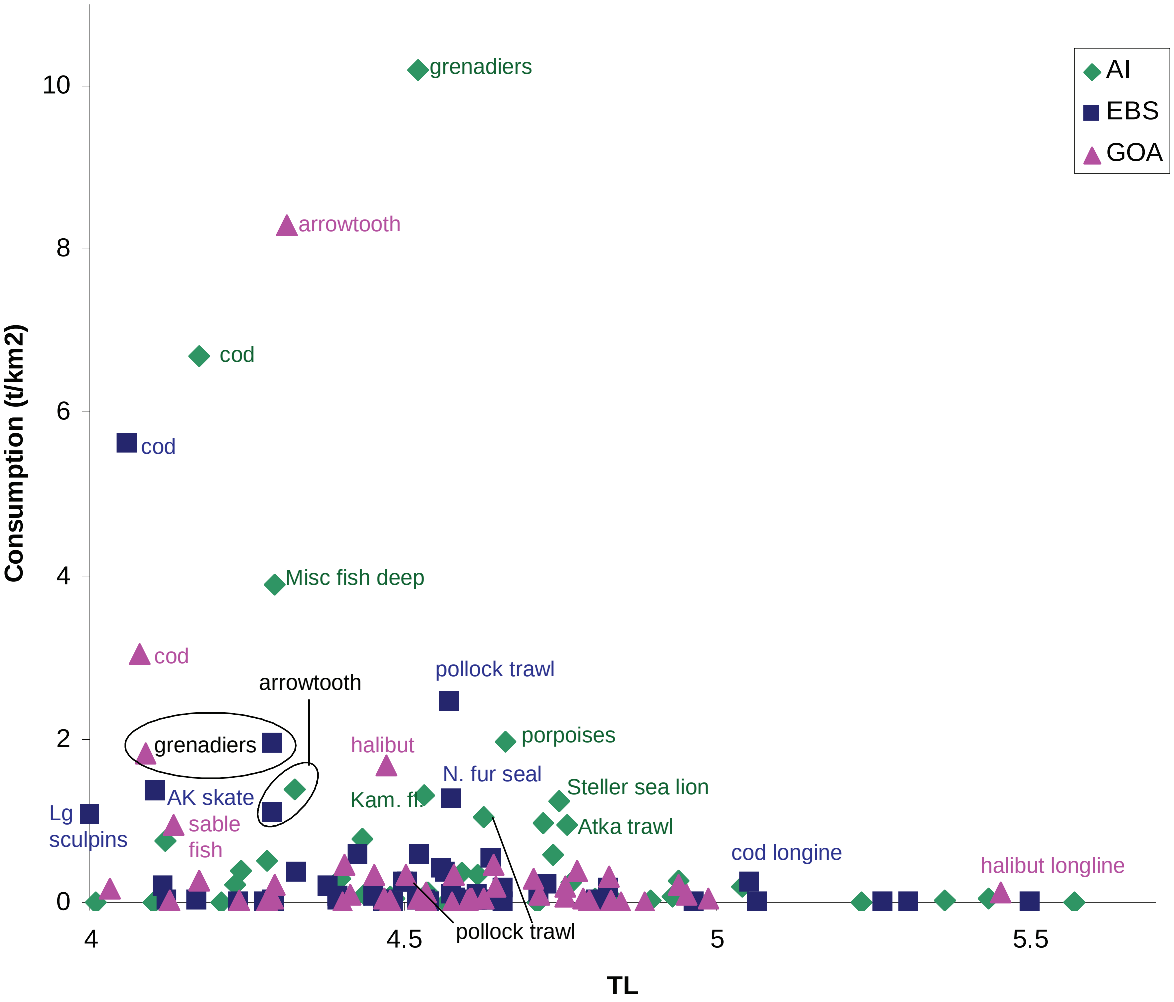

Figure 34. Total consumption and total catch (t/km^2) for species groups and fisheries in the Aleutian Islands (diamonds), Eastern Bering Sea (squares), and Gulf of Alaska (triangles) ecosystem models, trophic levels (TL) 4 through 5.5.

Once again, we applied regression analysis to addresses more general structural differences between ecosystems to determine whether there is a fundamentally different consumption at a given TL for these predators and fisheries above TL 4. Similar to the biomass relationships, the relationship between (log) consumption per area and TL appears similar for the GOA and AI models, while the EBS model relationship has a steeper negative slope (Fig. 35). The EBS consumption for TL>4 regression is statistically significant ($p<0.001$) with an R^2 fit of 0.19. The AI and GOA regressions were statistically significant only at the $p<0.10$ level, with very low R^2 fits of 0.04 to 0.06. Visually, the difference in regression suggests a potential difference in structure between the EBS and the other two ecosystems in terms of predator and fishery consumption; however, the poor fits for the AI and GOA relationships make it difficult to assert that there is a statistical difference between these regressions. Nevertheless, it is instructive to compare outliers for these regressions as above to determine which might be influential consumers above TL 4 in the three ecosystems.

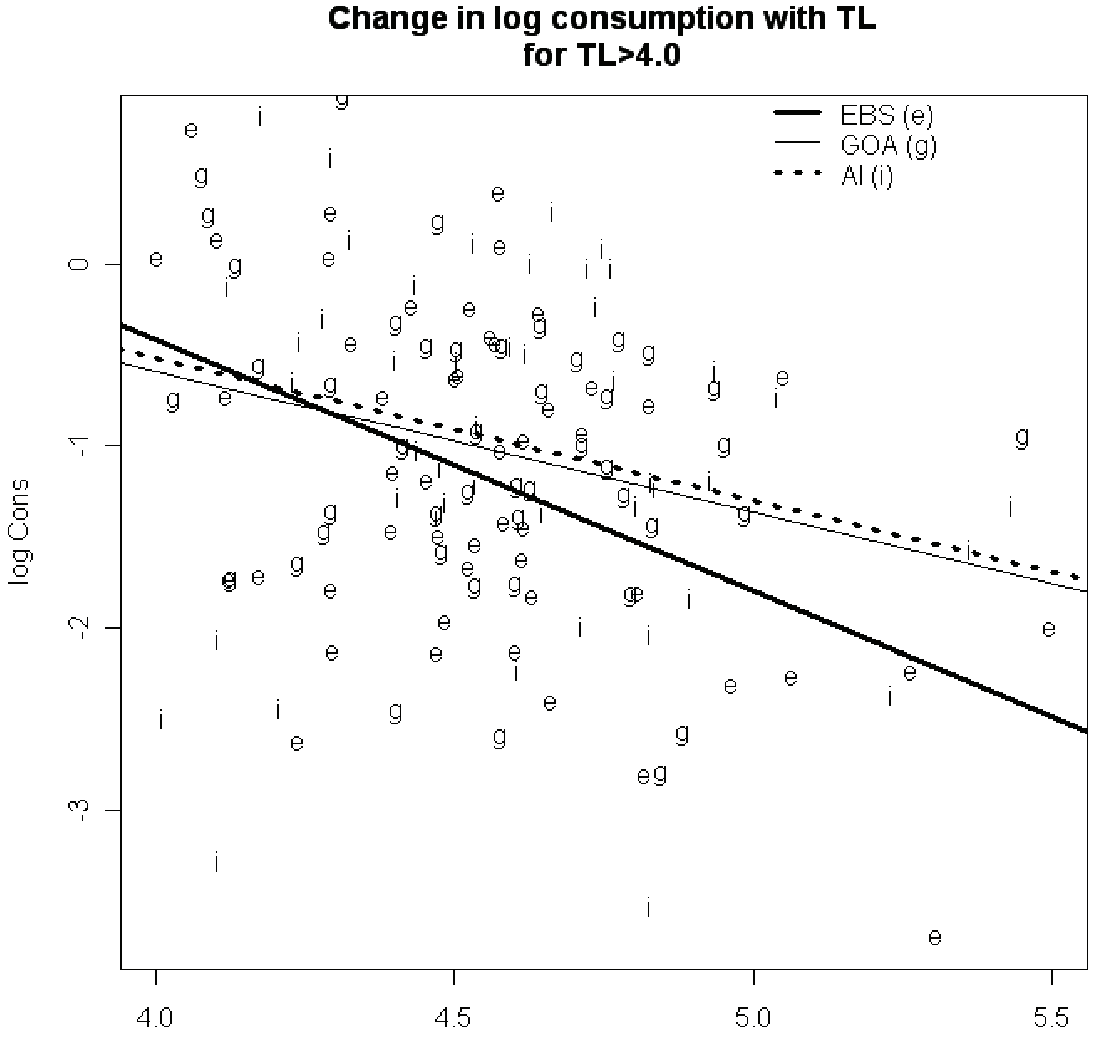

Figure 35. Relationship of log consumption (t/km^2) with trophic level (TL) for apex predators and fisheries (TL 4 and greater) in the Eastern Bering Sea, Gulf of Alaska and Aleutian Islands.

Residuals from the highly significant EBS regression of consumption at TL>4 include both fisheries and important predators. The pollock trawl fishery has the highest residual, indicating the greatest consumption for its trophic level (Fig. 36a). Next highest (and at the same TL) is the Northern fur seal. Pacific cod, the cod longline fishery, and grenadiers have the remaining highest residuals, although there are few groups for comparison at the TL of the cod longline fishery (Fig. 36a). The highest positive residuals in the less significant AI and GOA regressions follow the pattern established in Figure 34, with grenadiers, cod, porpoises and misc. deep fish highest in the AI (Fig. 36b), and arrowtooth, halibut, cod and grenadiers in the GOA (Fig. 36c). The notable difference between the EBS and the other ecosystems is the presence of fisheries in its high consuming groups above TL 4, where the GOA and AI have only groundfish predators.

All three ecosystems have a fishery among the lowest consuming groups at a given TL: the indigenous and subsistence fishery, which takes marine mammals but in small amounts (Figs. 36 a-c). In addition, the GOA and AI have crab pot and salmon fisheries, respectively, among low consuming groups. Additional low consuming groups in each system reflect some of the patterns from lower TL, such as juvenile flatfish in the AI and rockfish in the EBS. Perhaps the most surprising pattern in the low consuming groups is the presence of transient killer whales among the lowest residuals for their TL in both the EBS and the GOA, where they are commonly considered important apex predators. Transient killer whales have consumption more in line with other groups at their trophic level in the AI. However, it is difficult to draw many conclusions from these comparisons of the highest trophic levels where there are relatively few groups in any ecosystem.

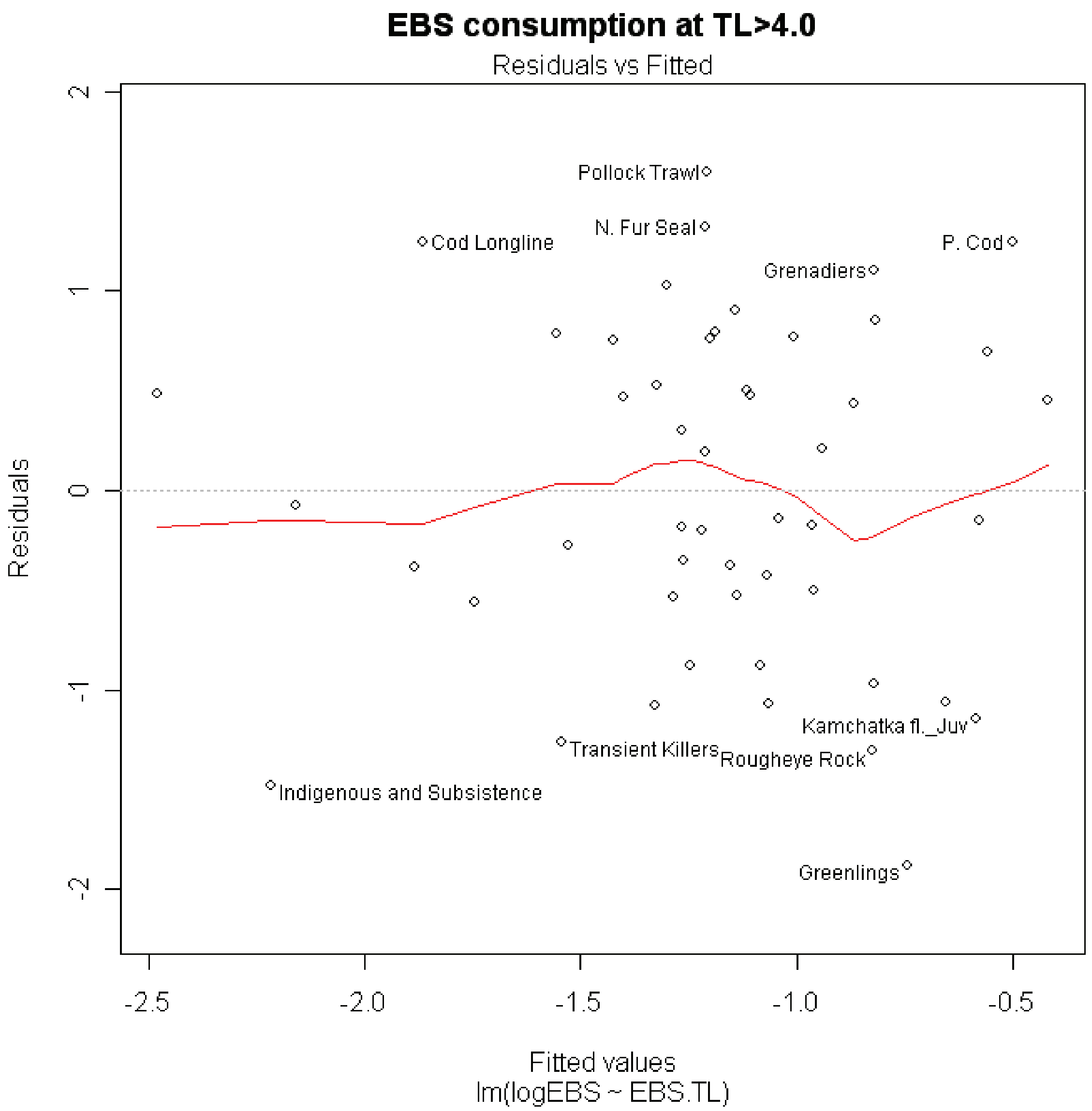

Figure 36a. **Regression residuals from the relationship of log consumption and catch per unit area with trophic level (TL) for apex predators and fisheries (TL 4 and up) in the Eastern Bering Sea. Species groups or fisheries with the largest residuals (most extreme consumption or catch at a given TL) are labeled. In the axis label, lm(logEBS~EBS.TL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.**

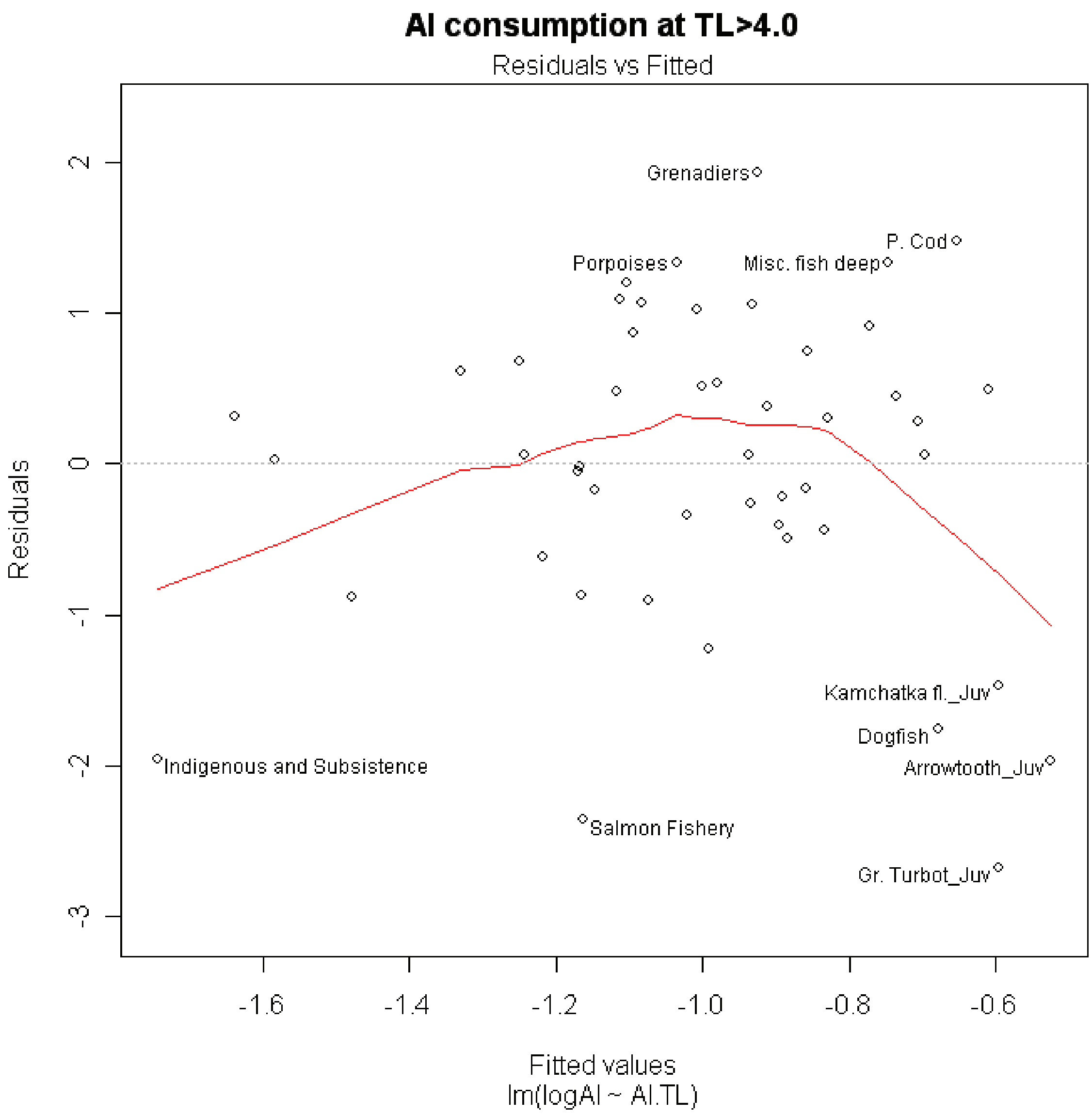

Figure 36b. **Regression residuals from the relationship of log consumption and catch per unit area with trophic level (TL) for apex predators and fisheries (TL 4 and up) in the Aleutian Islands. Species groups or fisheries with the largest residuals (most extreme consumption or catch at a given TL) are labeled. In the axis label, lm(logAI~AI.TL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.**

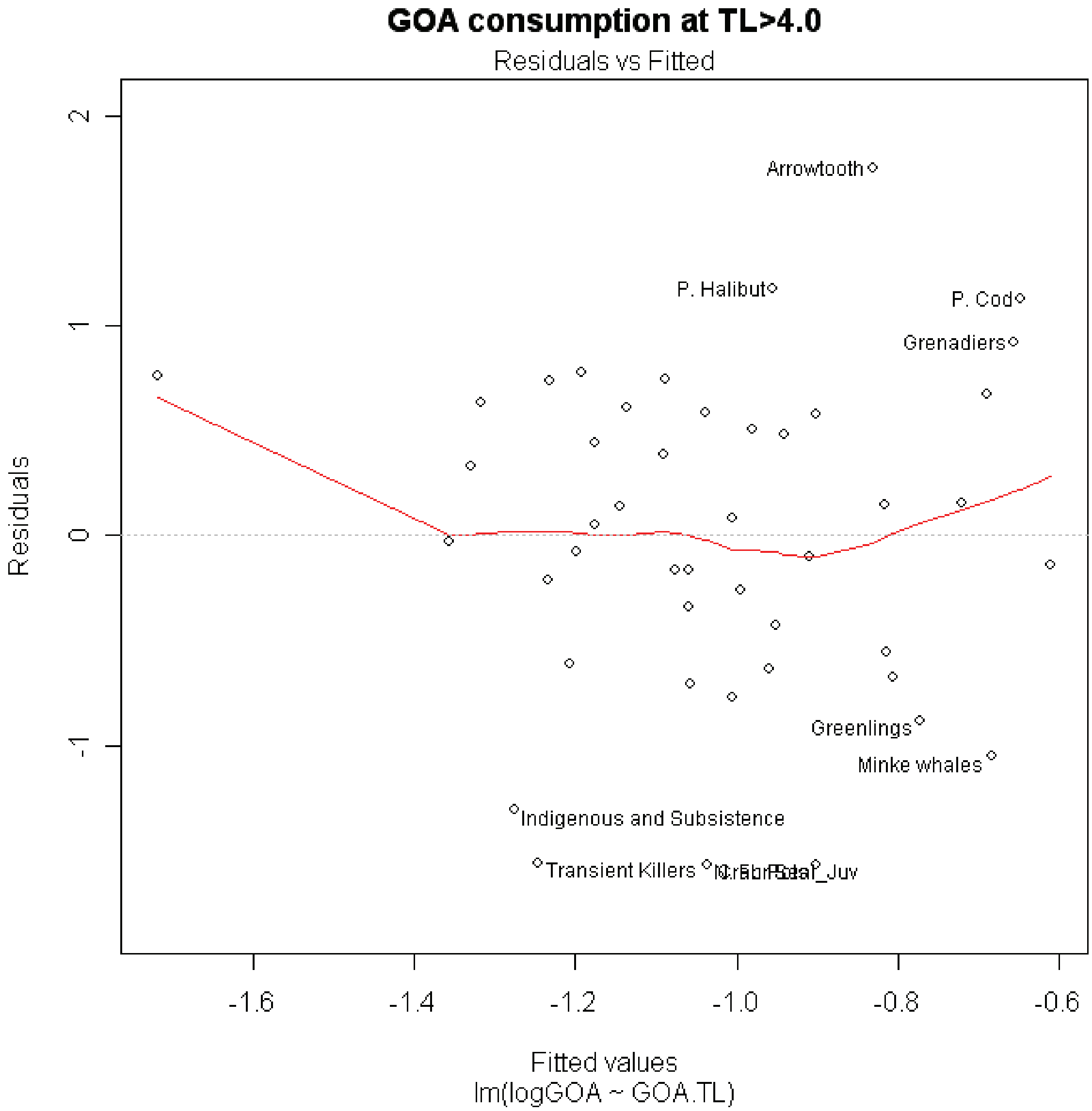

Figure 36c. Regression residuals from the relationship of log consumption and catch per unit area with trophic level (TL) for apex predators and fisheries (TL 4 and up) in the Aleutian Islands. Species groups or fisheries with the largest residuals (most extreme consumption or catch at a given TL) are labeled. In the axis label, lm(logGOA~GOA.TL) means the fitted values from the linear regression model where log biomass is predicted by trophic level.

3.3.3.3 Fishery "footprint" comparisons

The comparison of consumption at a given TL presented above in Section 3.3.3.2 provides some insight into the interaction of fisheries and predators within each ecosystem on a group-by-group basis. In this section, we present a more integrated analysis of the effects of fishing and predation within each ecosystem by examining the sources and fates of the production of each group. By accounting for where the production of each species group ultimately exits the system, we can examine the "footprint" of a given predator or fishery—how much production of each group throughout the food web is used by the given consumer? In general, there are three ultimate fates, or sinks, for the production of a group: it can be consumed by a predator, be removed by a fishery, or it can go to detritus (we simplify the analysis by disregarding respiration and growth for each population). In this analysis, we trace production throughout the food web to its apex predator. Therefore, when a prey species is consumed by a predator, and that predator is then caught by a fishery, the fishery has ultimately removed both the biomass of predator caught and that proportion of prey production required to support it. In the first analysis discussed below, we aggregate predator and fishery types to compare the ultimate fate of the production of each group between ecosystems, and provide an overview of the extent to which mammal, fish, and fishery predators are dominant systemwide energy sinks. The analysis discussed second explores the influence of selected individual dominant predators and fisheries in each ecosystem by including both the direct removals by a predator or fishery (the prey consumed or catch removed) and the indirect removals in terms of the production of other species groups required to support that prey or catch.

In Figure 37, we show an estimate of the proportion of total production of each species group removed by predators (grouped into marine mammals, birds, fish, forage species, benthos, and planktonic predators) and fisheries (grouped by management agency into the Federal groundfish fisheries, the halibut fishery, the Alaska salmon, crab, and herring fisheries, and the subsistence fishery). The leftmost white portions of each species bar represent the amount of energy exiting the system as detritus, meaning the production was neither consumed by predators nor caught in fisheries. The common assumption of 80% utilization of data-poor species in each ecosystem is reflected in the groups where this white bar reaches exactly 0.2. Conversely, the rightmost darker portions of bars represent the production exiting as a result of fishing, either through direct catch or consumption by a predator which was ultimately caught. In between, lighter colors represent the proportion of energy for each group exiting the system via apex predator consumption.

Comparing energy sinks by species in Figures 37 a-c, each ecosystem is characterized by some similar consumption patterns observed in previous analyses combined with newly apparent fishery patterns. For example, benthic energy sinks (pink) are more prevalent in the EBS (Fig. 37a) than in either of the other ecosystems, while pelagic forage energy sinks (pale blue) are most apparent in the AI (Fig. 37b), and fish predators (pale orange) are the predominant non-fishery energy sink in the GOA (Fig. 37c). Fishery influences also vary by system: the combined dark bars representing fishing sinks appear to occupy the most area in the AI plot relative to the other two ecosystems, mostly as a result of Federal groundfish fisheries (dark red bars, Figure 37b). The halibut longline fishery is a large energy sink for many species only in the GOA (dark blue bars, Figure 37c). Finally, a small amount of the energy of many low TL species in the EBS exits the system as a result of the AK state managed salmon and crab fisheries (bright red bars, Figure 37a). These results suggest that fisheries act as significant energy sinks throughout the food web in all three systems, but that the largest withdrawl of energy proportionally was in the AI during the early 1990s. In each ecosystem, fisheries “reach” all the way to primary producers, with an estimated range of 3.5% (GOA) to 16% (AI) of phytoplankton group production exiting the system via fisheries.

Following pages:

Figure 37 a-c. Ecosystem wide footprint for each species group in the Eastern Bering Sea (a), Aleutian Islands (b), and Gulf of Alaska (c).

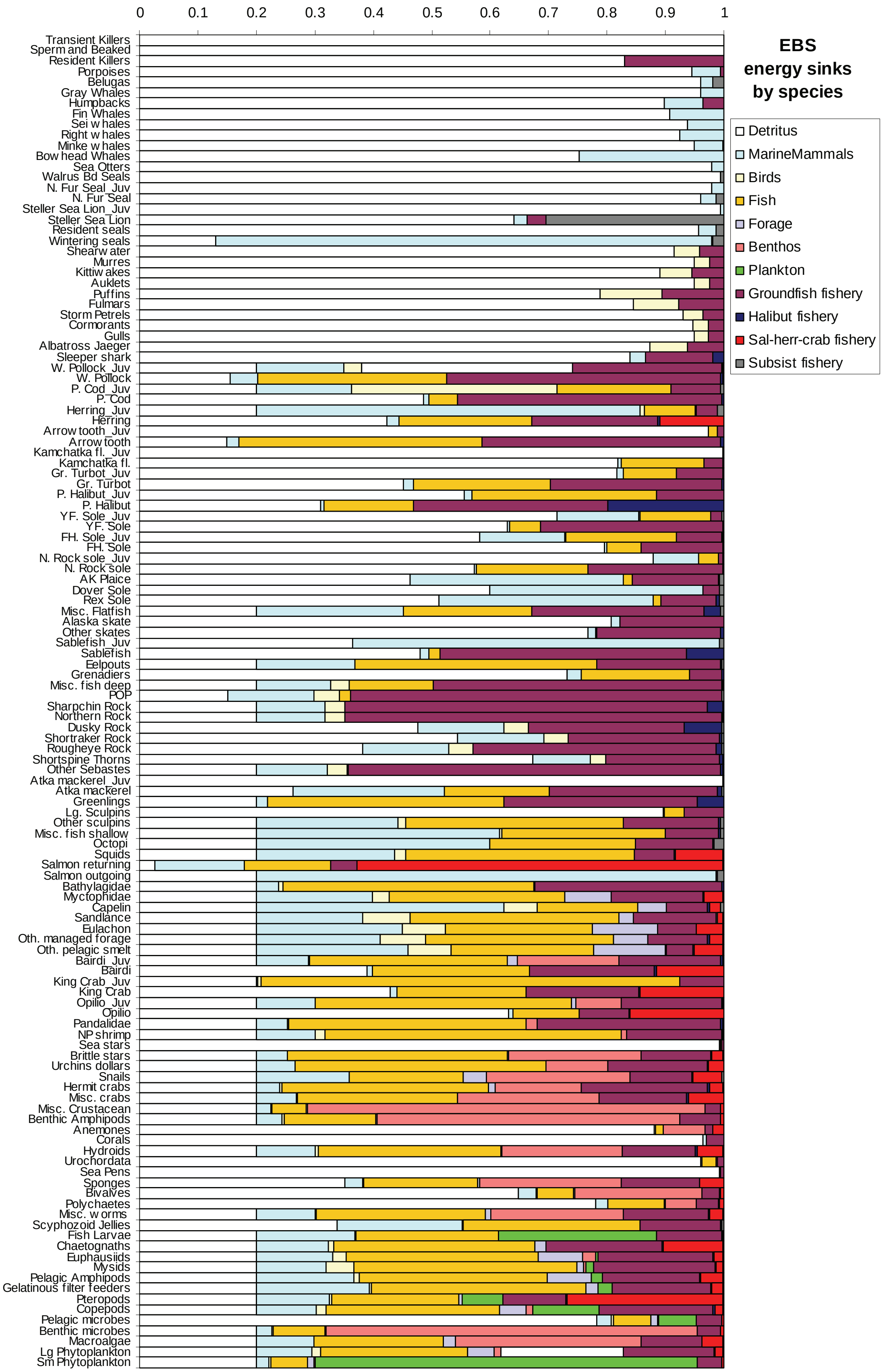
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
EBS energy sinks by species
Detritus
MarineMammals
Birds
Fish
Forage
Benthos
Plankton
Groundfish fishery
Halibut fishery
Sal-herr-crab fishery
Subsist fishery
Transient Killers
Sperm and Beaked
Resident Killers
Porpoises
Belugas
Gray Whales
Humpbacks
Fin Whales
Sei whales
Right whales
Minke whales
Bowhead Whales
Sea Otters
Walrus Bd Seals
N. Fur Seal_Juv
N. Fur Seal
Steller Sea Lion_Juv
Steller Sea Lion
Resident seals
Wintering seals
Shearwater
Murres
Kittiwakes
Auklets
Puffins
Fulmars
Storm Petrels
Cormorants
Gulls
Albatross Jaeger
Sleeper shark
W. Pollock_Juv
W. Pollock
P. Cod_Juv
P. Cod
Herring_Juv
Herring
Arrowtooth_Juv
Arrowtooth
Kamchatka fl._Juv
Kamchatka fl.
Gr. Turbot_Juv
Gr. Turbot
P. Halibut_Juv
P. Halibut
YF. Sole_Juv
YF. Sole
FH. Sole_Juv
FH. Sole
N. Rock sole_Juv
N. Rock sole
AK Plaice
Dover Sole
Rex Sole
Misc. Flatfish
Alaska skate
Other skates
Sablefish_Juv
Sablefish
Eelpouts
Grenadiers
Misc. fish deep
POP
Sharpchin Rock
Northern Rock
Dusky Rock
Shortraker Rock
Rougheye Rock
Shortspine Thorns
Other Sebastes
Atka mackerel_Juv
Atka mackerel
Greenlings
Lg. Sculpins
Other sculpins
Misc. fish shallow
Octopi
Squids
Salmon returning
Salmon outgoing
Bathylagidae
Myctophidae
Capelin
Sandlance
Eulachon
Oth. managed forage
Oth. pelagic smelt
Bairdi_Juv
Bairdi
King Crab_Juv
King Crab
Opilio_Juv
Opilio
Pandalidae
NP shrimp
Sea stars
Brittle stars
Urchins dollars
Snails
Hermit crabs
Misc. crabs
Misc. Crustacean
Benthic Amphipods
Anemones
Corals
Hydroids
Urochordata
Sea Pens
Sponges
Bivalves
Polychaetes
Misc. worms
Scyphozoid Jellies
Fish Larvae
Chaetognaths
Euphausiids
Mysids
Pelagic Amphipods
Gelatinous filter feeders
Pteropods
Copepods
Pelagic microbes
Benthic microbes
Macroalgae
Lg Phytoplankton
Sm Phytoplankton

Figure 37a

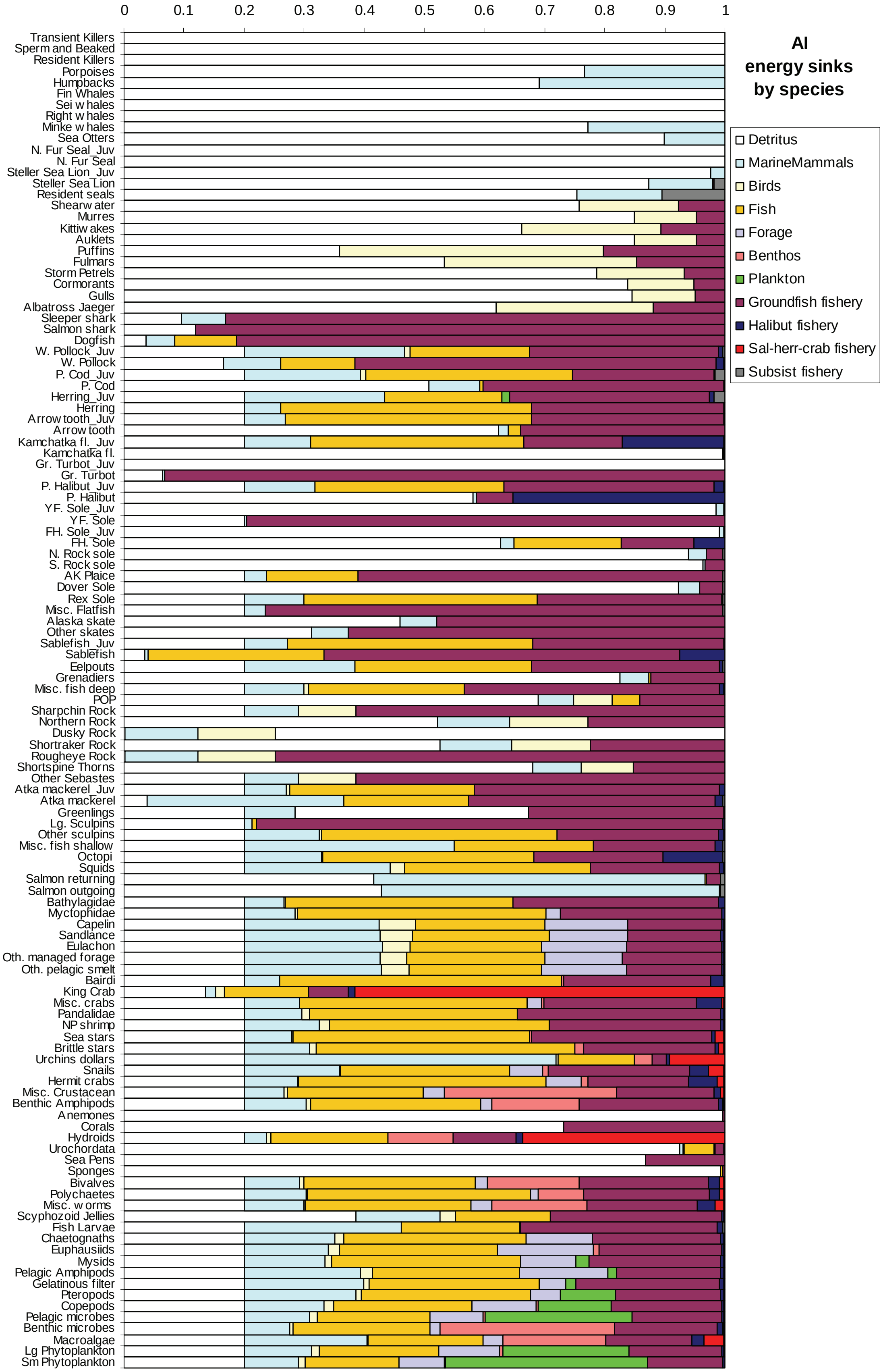
AI
energy sinks
by species
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Transient Killers
Sperm and Beaked
Resident Killers
Porpoises
Humpbacks
Fin Whales
Sei w hales
Right w hales
Minke w hales
Sea Otters
N. Fur Seal_Juv
N. Fur Seal
Steller Sea Lion_Juv
Steller Sea Lion
Resident seals
Shearw ater
Murres
Kittiw akes
Auklets
Puffins
Fulmars
Storm Petrels
Cormorants
Gulls
Albatross Jaeger
Sleeper shark
Salmon shark
Dogfish
W. Pollock_Juv
W. Pollock
P. Cod_Juv
P. Cod
Herring_Juv
Herring
Arrow tooth_Juv
Arrow tooth
Kamchatka fl._Juv
Kamchatka fl.
Gr. Turbot_Juv
Gr. Turbot
P. Halibut_Juv
P. Halibut
YF. Sole_Juv
YF. Sole
FH. Sole_Juv
FH. Sole
N. Rock sole
S. Rock sole
AK Plaice
Dover Sole
Rex Sole
Misc. Flatfish
Alaska skate
Other skates
Sablefish_Juv
Sablefish
Eelpouts
Grenadiers
Misc. fish deep
POP
Sharpchin Rock
Northern Rock
Dusky Rock
Shortraker Rock
Rougheye Rock
Shortspine Thorns
Other Sebastes
Atka mackerel_Juv
Atka mackerel
Greenlings
Lg. Sculpins
Other sculpins
Misc. fish shallow
Octopi
Squids
Salmon returning
Salmon outgoing
Bathylagidae
Myctophidae
Capelin
Sandlance
Eulachon
Oth. managed forage
Oth. pelagic smelt
Bairdi
King Crab
Misc. crabs
Pandalidae
NP shrimp
Sea stars
Brittle stars
Urchins dollars
Snails
Hermit crabs
Misc. Crustacean
Benthic Amphipods
Anemones
Corals
Hydroids
Urochordata
Sea Pens
Sponges
Bivalves
Polychaetes
Misc. w orms
Scyphozoid Jellies
Fish Larvae
Chaetognaths
Euphausiids
Mysids
Pelagic Amphipods
Gelatinous filter
Pteropods
Copepods
Pelagic microbes
Benthic microbes
Macroalgae
Lg Phytoplankton
Sm Phytoplankton
Detritus
MarineMammals
Birds
Fish
Forage
Benthos
Plankton
Groundfish fishery
Halibut fishery
Sal-herr-crab fishery
Subsist fishery

Figure 37b

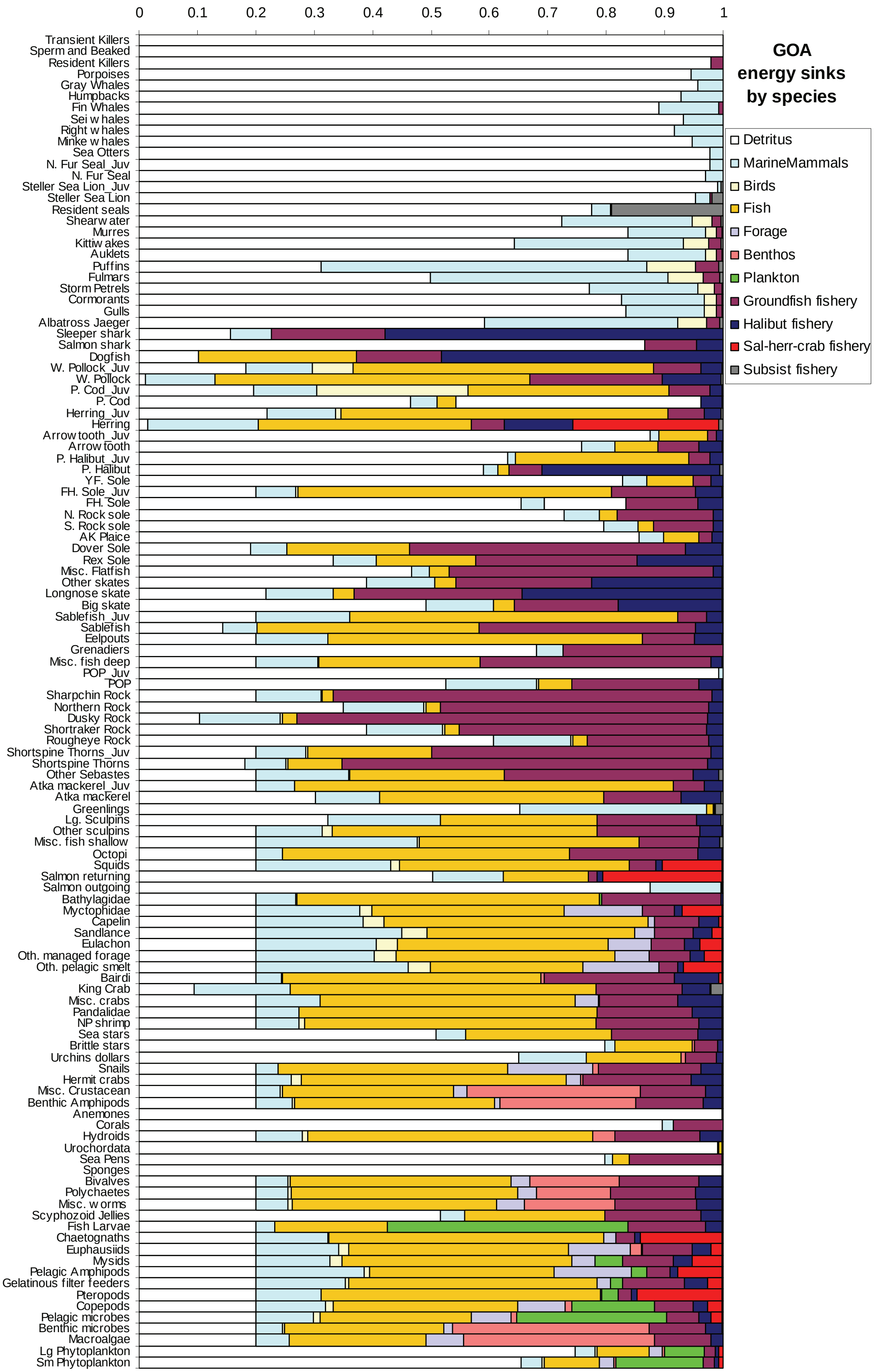
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
GOA energy sinks by species
Detritus
MarineMammals
Birds
Fish
Forage
Benthos
Plankton
Groundfish fishery
Halibut fishery
Sal-herr-crab fishery
Subsist fishery
Transient Killers
Sperm and Beaked
Resident Killers
Porpoises
Gray Whales
Humpbacks
Fin Whales
Sei whales
Right whales
Minke whales
Sea Otters
N. Fur Seal_Juv
N. Fur Seal
Steller Sea Lion_Juv
Steller Sea Lion
Resident seals
Shearwater
Murres
Kittiwakes
Auklets
Puffins
Fulmars
Storm Petrels
Cormorants
Gulls
Albatross Jaeger
Sleeper shark
Salmon shark
Dogfish
W. Pollock_Juv
W. Pollock
P. Cod_Juv
P. Cod
Herring_Juv
Herring
Arrowtooth_Juv
Arrowtooth
P. Halibut_Juv
P. Halibut
YF. Sole
FH. Sole_Juv
FH. Sole
N. Rock sole
S. Rock sole
AK Plaice
Dover Sole
Rex Sole
Misc. Flatfish
Other skates
Longnose skate
Big skate
Sablefish_Juv
Sablefish
Eelpouts
Grenadiers
Misc. fish deep
POP_Juv
POP
Sharpchin Rock
Northern Rock
Dusky Rock
Shortraker Rock
Rougheye Rock
Shortspine Thorns_Juv
Shortspine Thorns
Other Sebastes
Atka mackerel_Juv
Atka mackerel
Greenlings
Lg. Sculpins
Other sculpins
Misc. fish shallow
Octopi
Squids
Salmon returning
Salmon outgoing
Bathylagidae
Myctophidae
Capelin
Sandlance
Eulachon
Oth. managed forage
Oth. pelagic smelt
Bairdi
King Crab
Misc. crabs
Pandalidae
NP shrimp
Sea stars
Brittle stars
Urchins dollars
Snails
Hermit crabs
Misc. Crustacean
Benthic Amphipods
Anemones
Corals
Hydroids
Urochordata
Sea Pens
Sponges
Bivalves
Polychaetes
Misc. worms
Scyphozoid Jellies
Fish Larvae
Chaetognaths
Euphausiids
Mysids
Pelagic Amphipods
Gelatinous filter feeders
Pteropods
Copepods
Pelagic microbes
Benthic microbes
Macroalgae
Lg Phytoplankton
Sm Phytoplankton

Figure 37c

Next, we examine the footprint of a specific fishery or predator, which is measured as the amount of production of each group in the food web required to support that fishery or predator. In the context of the plots presented above, the footprint is the amount of each group's production exiting the system through the fishery or predator. Here, we compare the footprints of a major predator and a major fishery in each ecosystem: northern fur seals and the pollock fishery in the EBS, cod and the Atka mackerel fishery in the AI, and arrowtooth flounder and the halibut fishery in the GOA.

In the EBS, both northern fur seals and the pollock trawl fishery were identified as high consumers for their TL in Figure 36a above. Therefore, we might expect that these consumers are taking considerable portions of the production of other groups in the ecosystem, but they affect different groups. Fur seals are estimated to remove over 15% of Atka mackerel production from the EBS, over 20% of the production of several flatfish groups and capelin, and in excess of 40% of the production of several juvenile fish groups including herring, sablefish, and salmon (Fig. 38). Note that all of these juvenile fish groups have unknown biomass, so the assumption that 80% of their production is consumed within the system contributes to uncertainty in this result; if less than 80% of their production is actually consumed within the system, then proportionally less of that production would be removed by fur seals. Nevertheless, even this uncertain result indicates that fur seals are major sinks for juvenile herring, sablefish, and salmon production.

Unlike the fur seal, the EBS pollock fishery removes a high percentage of production for a single target species, which amounts to 35% of adult pollock production from the EBS ecosystem. Despite the extremely "clean" nature of the pollock fishery which has a catch of over 95% pure pollock, it is clear that the fishery relies on the production of many more species than just pollock in removing this catch from the ecosystem. Nearly 20% of the production of forage species such as bathylagids and pandalid shrimp are required to support the pollock fishery catch, and more than 10% of the production of herring, arrowtooth flounder, Greenland turbot, myctophids, and most pelagic zooplankton (including euphausiids, mysids, and copepods) are required to support the EBS pollock fishery (Fig. 38). For most zooplankton and phytoplankton groups, the pollock fishery requires more than double the production removed by fur seals to support its catch.

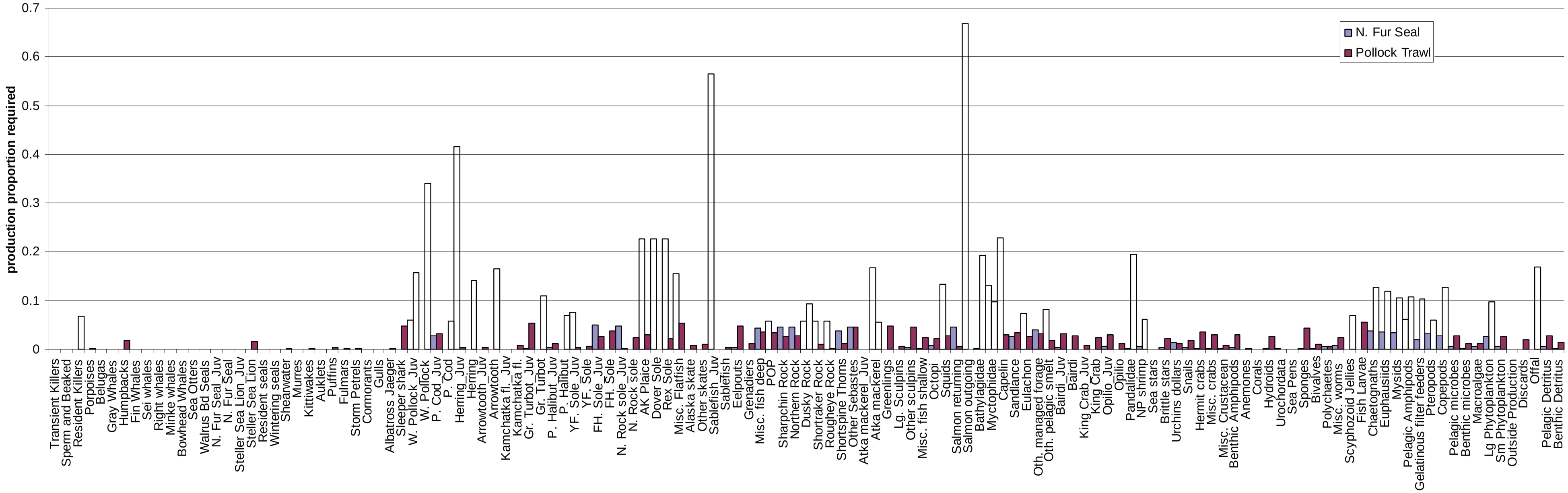

Figure 38. Eastern Bering Sea predator and fishery footprints for northern fur seal (blue) and the pollock fishery (dark red). The footprint is the production of each species on the x-axis required to support a given predator or fishery in the ecosystem.

In the AI, both Pacific cod and the Atka mackerel trawl fishery were identified as important consumers above TL 4, although only cod had especially high consumption relative to other species at its trophic level (Fig. 36b). As predators with high consumption and a diverse diet, cod remove substantial proportions of the production of several species in the AI ecosystem: 20% of Tanner crab, eelpout, and other sculpin production, 30% of greenling production, and up to 40% of rex sole, juvenile sablefish, and juvenile arrowtooth production (Fig. 39). As described above for EBS fur seals, AI cod's removal of juvenile fish production is estimated based on the assumption that 80% of that production is used within the ecosystem; if the actual amount of juvenile fish production used is higher or lower, than the removal by cod will be proportionally higher or lower. The footprint of AI cod affects many species in the ecosystem from fish through benthic invertebrates; in particular crabs, shrimp, sea stars, and benthic worms are large taxonomic aggregates which have 10-15% of annual production removed by cod alone.

The AI Atka mackerel fishery removes more than 20% of the production of its target species. This fishery also retains incidentally caught rockfish, resulting in high levels of production removal for several species: 18% for northern, 25% for rougheye, and 38% for dusky (Fig. 39). The highest removals attributed to the AI Atka mackerel fishery are for flatfish (55% for Alaska plaice and 73% for yellowfin sole), which are low biomass groups in this ecosystem. In contrast with the comparison above of the EBS pollock fishery and EBS fur seals, the AI Atka mackerel fishery removes a similar proportion of production from the lowest TL zooplankton as AI Pacific cod removes; approximately 5%. The amount of primary production required to support the Atka mackerel fishery and Pacific cod are also nearly identical, 3-4% for each phytoplankton group.

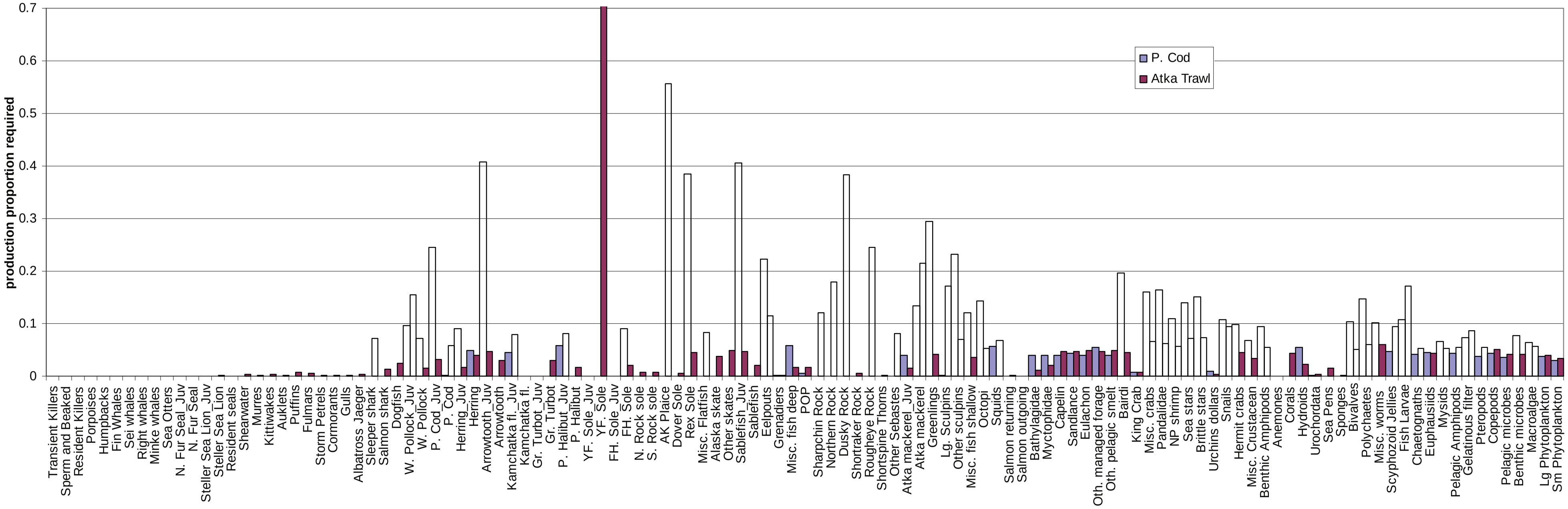

Figure 39. Aleutian Islands predator and fishery footprints for Pacific cod (blue) and the Atka mackerel fishery (dark red). The footprint is the production of each species on the x-axis required to support a given predator or fishery in the ecosystem.

Arrowtooth flounder and the Pacific halibut fishery are important high TL consumers in the GOA (see Figs. 34 and 36c). Arrowtooth flounder remove a high proportion of the production of many groups in the ecosystem, including about 25% of adult pollock, herring, and Atka mackerel production; 30-35% of capelin and eelpout production, and 40-55% of juvenile pollock, herring, sablefish, and Atka mackerel production (Fig. 40). In addition, between 10 and 20% of the production of other forage fish, shrimp, benthic invertebrates and half the zooplankton groups are removed by arrowtooth flounder in this ecosystem. The same caveats mentioned above for groups with uncertain biomass (juvenile fish, forage fish, some invertebrates) where we assumed 80% of production is used within the ecosystem apply here. However, if arrowtooth remove the majority of a species production under the current assumptions, that will not change even if the absolute amount of production removed changes. Therefore, it is clear that arrowtooth flounder require a considerable amount of production in this ecosystem to maintain their high biomass.

As the highest TL consumer in the GOA, the halibut fishery is estimated to remove 30% of its target species' production, as well as a substantial proportion of the production of other high TL consumers, such as sleeper sharks (58%) and dogfish (48%; Fig. 40). In addition, the halibut fishery removes 17-34% of skate production from the GOA, depending on the species. Rex sole is the next largest production removal at 15%; this is an indirect effect of fishery bycatch because rex sole are a primary prey of longnose skates in the GOA. The 10% of pollock and herring production removed by the halibut fishery support halibut directly as prey. Most other species in the halibut fishery footprint have less than 10% of production removed. Despite removing a majority of the production of several high TL predators, the GOA halibut fishery has a smaller footprint for all zooplankton and phytoplankton groups than GOA arrowtooth flounder.

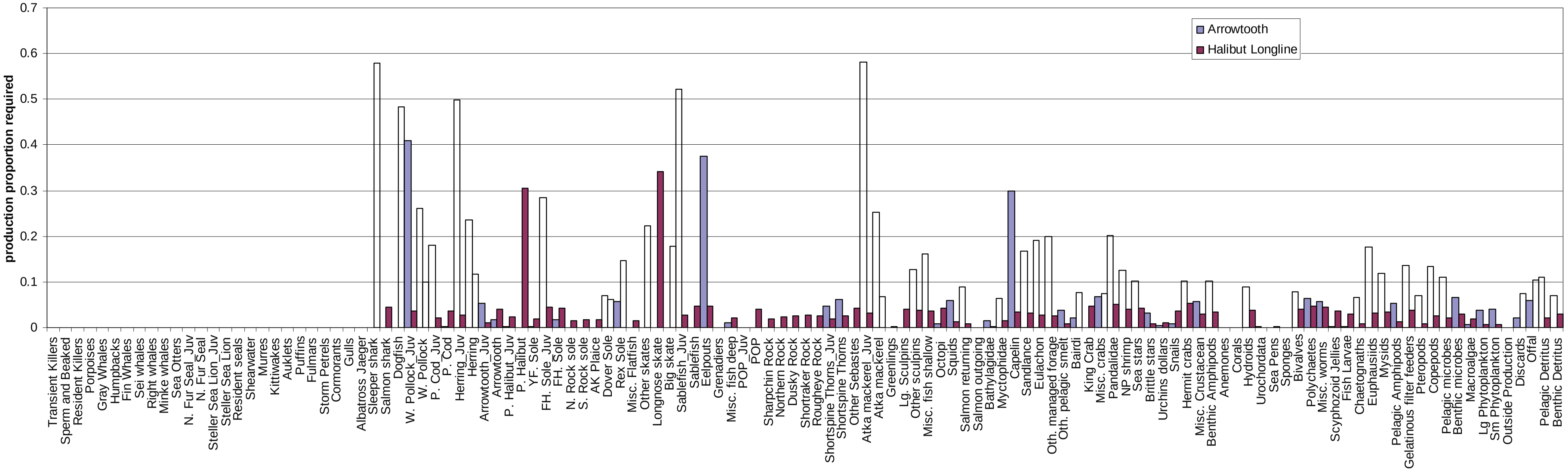

Figure 40. Gulf of Alaska predator and fishery footprints for arrowtooth flounder (blue) and the halibut longline fishery (dark red). The footprint is the production of each species on the x-axis required to support a given predator or fishery in the ecosystem.

Footprints of production required to support fisheries and predators are indicators of both potential single species impacts and ecosystem level impacts of individual consumers. Furthermore, comparing predator footprints with fishery footprints demonstrates some differences in the way these different consumers affect the ecosystem. For the fisheries and predators compared, fishery footprints extend across more species and trophic levels than those of the predators. In part, this is attributable to incidental catch of species not eaten by the predators, such as birds, whales, sponges, and corals. Viewing the production removed by fisheries of all ecosystem groups suggests that some fishery bycatch may have substantial impacts on nontarget species (e.g., the GOA halibut fishery's incidental catch of skates and sharks). Further comparisons suggest whether the removal of high proportions of certain group's production is more important as a single species consideration or as an ecosystem consideration.

Comparisons of low TL production required to support fisheries relative to top predators suggest different ecosystem impacts of fishing. In the EBS, the pollock fishery is very species specific relative fur seals, a predator at the same TL, but the production at the base of the food web (zooplankton and phytoplankton) required to support the pollock fishery is much higher than that required to support the predator. The AI Atka mackerel fishery requires a similar level of base ecosystem production as the dominant predator in that system, Pacific cod. At the other end of the spectrum, the GOA halibut fishery removes substantial predator production, but far less base ecosystem production than the dominant predator in that system, arrowtooth flounder. Of the three fisheries compared, the EBS pollock fishery has the largest impact on low trophic level production, while the GOA halibut fishery has the largest impact on high trophic level production. The AI Atka mackerel fishery appears to have a similar impact on low TL production as cod do in that ecosystem, and a similar range of effects (though on more and different species) on mid to high TL production. It seems likely that a fishery removing high proportions of primary production compared with natural predators might have different ecosystem level impacts through redirection of this basic energy flow than one removing high proportions of individual species, but lower proportions of primary production. We suggest that analyses of fishery footprints be supplemented with further simulation analyses to determine whether a threshold "safe" level of primary and low TL production removed exists which can then be used as an indicator for management at the ecosystem level.

4. Summary and Conclusions

The detailed food web models we constructed for the EBS, GOA, and AI marine ecosystems provide important insights for fishery management on multiple levels. First, the simple "accounting exercise" of assembling information for all species in the same units for the same time period forces the modeler to reconcile multiple, sometimes conflicting sources of information: survey data, food habits data, and production, consumption, and biomass estimates which may be based on stock assessment results from multiple agencies. The full accounting of biomass, production, consumption, diet composition, and catch information for each species in the three food webs was a formidable task, requiring access to data from multiple management agencies responsible for different resources (see Appendix A). Because stock assessments are conducted independently for different species, and different agencies maintain survey and fishery databases collected by diverse methods over different timeframes and for different goals, assembling this information into a consistent format implicitly checks information and assumptions for consistency. In the overwhelming majority of cases, information did prove to be consistent enough for each species group's estimated annual production to adequately supply the estimated annual catch and consumption by predators. In Ecopath terms, a majority of groups "balanced" using unadjusted information from field surveys and other available sources.

However, the instances where survey or assessment information was not immediately compatible within the food web are also instructive. Most inconsistencies could easily be attributed to inadequate field sampling; for example sharpchin rockfish (*Sebastes zacentrus*) survey biomass was too low in all three ecosystems to support the relatively small fishery catches and predation estimated on this species. Sharpchin rockfish inhabit rocky, steep areas which are very difficult to survey by trawl, so the NMFS trawl surveys likely underestimate biomass for this group. Inconsistencies of this type indicate where current field sampling efforts might be adjusted to improve biomass estimates if this is a priority for management. These models also provide a potential method for scaling biomass estimates for groups which are caught by surveys, but are not targets of the surveys, such as benthic invertebrates. Consumption-based estimates of biomass for these groups produced by the models are generally higher than survey-based estimates, suggesting that survey "catchability" for these invertebrates is low. The ratio of consumption based biomass to survey biomass can be used as a scaling factor to convert survey time series of invertebrate group biomass into time series of biomass consistent with the more data-rich upper trophic level components of the models. Finally, as a simple accounting procedure, construction of food web models may help reconcile different assumptions between single species stock assessments which may have conflicting results at the ecosystem level (see Recommendations, below).

We used these three models and comparisons between them to describe and explore key food web relationships and potential fisheries interactions in each ecosystem. The common modeling framework, including biomass pool and fishery definitions, resulted in comparable food webs for the three ecosystems which showed that they all have the same apex predator—the Pacific halibut longline fishery. However, despite the similar methods used to construct the models, the data from each system included in the analysis clearly defines differences in food web structure which may be important considerations for fishery management in Alaskan ecosystems. The initial descriptive results showed that the EBS has a much larger benthic influence in its food web than either the GOA or the AI. The groundfish groups "small flats" and yellowfin sole, along with crabs and pollock, are dominant in the EBS. Conversely, the AI has the strongest pelagic influence in its food web relative to the two other systems. Dominant groundfish in the AI occupy the pelagic pathway: Atka mackerel, and Pacific ocean perch (POP). The GOA appears balanced between benthic and pelagic pathways, but is notable in having a relatively smaller "biomass" of fisheries (catch) relative to the two other systems, and a high biomass of fish predators above TL 4, arrowtooth flounder and halibut. These patterns visible in aggregated food webs were confirmed in many subsequent analyses of biomass and consumption in each ecosystem.

In addition to broad energy flow descriptions, food web models were shown to provide both single species level and ecosystem level indicators and statistics. Single species indicators for walleye pollock (*Theragra chalcogramma*) in each ecosystem showed contrasts in mortality sources for this species. While fisheries for pollock in the three ecosystems had similar catch characteristics, during the early 1990s, AI pollock experienced more fishing mortality than predation mortality, unlike in the other two ecosystems. The key difference between the EBS and GOA is that the dominant pollock predation mortality came from different sources. In the EBS, pollock cannibalism is the dominant source of pollock mortality. In the GOA food web model, the overwhelming majority of explained pollock mortality is from predation by arrowtooth flounder, cod, and halibut, rather than pollock cannibalism or fishing. These results suggest different potential impacts of fishery management for pollock in each ecosystem; first, that fishery managers had control over the dominant source of AI pollock mortality during the early 1990s. In the EBS, a potentially complex interaction between fishing mortality on adult pollock and its affects on pollock cannibalism puts pollock mortality less under fishery management control. The dominance of predation mortality on GOA pollock suggests that reducing fishing mortality may have little impact on their population trajectory, contrary to conventional fishing theory. However, it also suggests that increased fishing mortality might have a greater than expected effect if the population collapses under the combined effects of high predation mortality and increased fishing mortality.

With respect to ecosystem indicators, we first presented an example where single species indicators suggest differences in ecosystem structure. We found that a commercially important predator, Pacific cod (*Gadus macrocephalus*), has relatively more fishing mortality than predation mortality in all three ecosystems. This suggests that changing fishing mortality is likely to affect cod population trajectories; therefore, we may ask what effects changes in cod mortality might cause in each ecosystem. Our results suggest that the regional level of management applied to Pacific cod should be modified to account for differences between the EBS and AI ecosystems. At present, cod are studied and assessed separately between the GOA and BSAI areas, but with similar management objectives. The impacts of cod predation are demonstrably different between the EBS, GOA, and AI ecosystems, with perhaps the largest contrast between the EBS and AI, where they are currently assessed and managed identically. The impacts of changing cod survival (and by extension, fishing mortality) differ by ecosystem as well, with the impacts felt most strongly and with highest certainty in the AI ecosystem according to this analysis. Therefore, it seems that the cod fishery in the AI should be managed separately from that in the EBS to ensure that any potential ecosystem effects of changing fishing mortality might be monitored at the appropriate scale.

A second set of ecosystem indicators derived from the food web models demonstrated differences in the consumption of key forage species between the three food webs, suggesting differences between ecosystems in energy flow supporting the predator species, including commercially fished groundfish. In the EBS, pollock, the primary forage fish, is also a primary commercially fish as an adult. Therefore, in the EBS, the sustainability of the pollock fishery as well as a large proportion of predator consumption depends on continued juvenile pollock production. Because pollock are both an important commercial species and an important forage species in the EBS, we may have a unique opportunity to study the ecosystem dynamics surrounding fluctuating forage fish availability there because pollock recruitment is closely monitored for stock assessment purposes. In the GOA and AI the primary forage fish, capelin and myctophids, are both given protected status by the NPFMC forage fish FMP amendment, which prohibits directed fishing for these species. While this regulation was designed to minimize any potentially negative direct effects of fishing on forage species in Alaska, there is also little information available to study the fluctuations in forage resources in these systems precisely because they are non-commercial species. Although similar form a management standpoint, the primary forage fish consumed in the AI and the GOA are different from a biological/physical standpoint. Capelin are primarily a coastal, continental shelf species, while myctophids are an oceanic, deepwater family of forage fish. This suggests that different climatic and oceanographic factors would affect production for the forage base in each ecosystem. Therefore, different climate and physical indicators might be appropriate signals of changing forage production in the AI as opposed to the GOA. This extends to all three ecosystems: consumption patterns confirm that the EBS is more self-contained shelf oriented ecosystem with equal benthic and pelagic energy inputs, with little oceanic influence. In contrast, the AI is mostly open ocean-influenced. Ecosystem boundaries may be more difficult to discern in an open, oceanic food web from an energetic perspective. The GOA food web seems intermediate, with an oceanic influence but also localized benthic and coastal pelagic forage base.

Finally, we present trophodynamic comparisons of biomass, predator consumption and fisheries catch, and the impacts of certain consumers on each ecosystem. Despite similar model structure and common assumptions for data-poor groups across ecosystems, clear differences in biomass and consumption at trophic level were apparent between the EBS, GOA, and AI. Biomass comparisons characterize the AI as a classic biomass "pyramid" with the highest densities of pelagic zooplankton in any system supporting extremely high densities of pelagic forage fish (myctophids) and high densities of commercial forage fish (Atka mackerel) and deepwater predators (grenadiers). In contrast, the EBS is characterized by biomass distribution as a pollock- and benthic-dominated ecosystem, with extremely high bivalve density and with pollock density similar to that estimated for large zooplankton groups in the EBS. The GOA biomass distribution departs from the classic pyramid where few predators subsist on many prey; here the analysis indicates a predator-dominated ecosystem, with far higher densities of arrowtooth flounder and halibut in proportion to the forage base than in either of the other food webs.

Consumption comparisons by trophic level confirmed these patterns but allowed evaluation of fishery catch on an equal footing with predator consumption, diversifying the suite of ecosystem indicators. In particular, this analysis confirmed that EBS pollock and GOA arrowtooth flounder are influential single species in each of these ecosystems in terms of consumption, standing out even in the context of whole ecosystem comparisons where consumption by high turnover groups (microbes and zooplankton) would be expected to swamp signals from higher trophic levels. In comparisons of consumption for high trophic level (TL>4) predators and fisheries, cod and grenadiers were influential consumers in all three ecosystems. However, arrowtooth flounder, halibut, and sablefish have much higher consumption in the GOA relative to the other ecosystems, while Alaska skates, fur seals and large sculpins have much higher consumption in the EBS. In the AI, Steller sea lions and Kamchatka flounder have relatively high consumption as well as porpoises and misc. deep fish. The EBS pollock trawl fishery is the fishery with the overall highest consumption rate in any ecosystem, and has the second highest consumption rate for groups over TL 4 in the EBS ecosystem (cod is first). The consumption comparisons showed that the EBS is the only ecosystem with fisheries among its most influential high TL consumers, although this does not necessarily indicate that fisheries are not influential in the other ecosystems, simply that predator consumption is higher in the AI and GOA.

Direct comparisons of the production required to support each ecosystem group (including fisheries) demonstrated contrasting fishery influence in the food web between the ecosystems. Fishery energy sinks appeared most prevalent in the AI relative to the other two ecosystems, mostly from NMFS managed groundfish fisheries which removed production at higher rates during the early 1990s than they do at present. The halibut longline fishery managed by IPHC is a large energy sink for many species only in the GOA. A small amount of the energy of many low TL species in the EBS exits the system as a result of the AK state managed salmon and crab fisheries. These results suggest that fisheries act as significant energy sinks throughout the food web in all three systems, but that the largest withdrawal of energy proportionally was in the AI during the early 1990s. In each ecosystem, fisheries “reach” all the way to primary producers, with an estimated range of 3.5% (GOA) to 16% (AI) of phytoplankton group production exiting the system via fisheries.

When directly compared with influential predators in each ecosystems, influential fisheries had distinctly different footprints in terms of production required to support them. Fishery footprints extend across more species and trophic levels than those of the predators due to incidental catch of species not eaten by the predators, such as birds, whales, sponges, and corals. Some fishery bycatch may have substantial impacts on nontarget species (e.g., the GOA halibut fishery’s incidental catch of skates and sharks). Of the three fisheries compared, the EBS pollock fishery has the largest impact on low trophic level production, while the GOA halibut fishery has the largest impact on high trophic level production. The AI Atka mackerel fishery appears to have a similar impact on low TL production as cod do in that ecosystem, and a similar range of effects (though on more and different species) on mid- to high-TL production. We suggest that a fishery removing high proportions of primary production compared with natural predators might have ecosystem level impacts through redirection of this basic energy flow, and that management should consider these ecosystem effects separately from those produced by fisheries removing high proportions of individual species, but lower proportions of primary production. The next step is to determine whether there is a threshold effect of redirecting low TL energy flow through fishery removals which can be translated into an indicator for fishery management.

All of our results are based on the best available scientific data and the detailed modeling methods presented here, but in complex ecosystems where many processes and components remain poorly known, considerable uncertainty remains. We have incorporated uncertainty in our estimates using the Sense routines, which suggest which influential species groups in each ecosystem are also the most data poor; in general these are forage species. These differences in data quality ultimately affect model-based prediction. While it is straightforward to demonstrate the sensitivity of other species in the ecosystem to each of these influential forage groups using a simulation analysis, the uncertainty in predictions for AI myctophids and GOA capelin are much higher than for EBS juvenile pollock. More generally, uncertainty appears higher in the AI and GOA analyses relative to the EBS analyses, due to a combination of data inequities and structural differences between ecosystems.

5. Recommendations

The models presented here for the EBS, AI, and GOA represent a substantial step forward in ecosystem modeling efforts for Alaskan systems to date. We recommend continued research to improve these modeling efforts and to incorporate them within fishery management in Alaska. Specifically, we recommend continued support for food habits sampling and continued improvement in data from multiple sources to make integration within future models and analyses more streamlined. Overall, we suggest updating food web models on a 5 year basis to evaluate changes in the food web from field data. Further specific recommendations are as follows:

1. Use alternative models to evaluate ecosystem roles for living substrates; trophic models are not appropriate. Corals, sponges, sea whips and sea pens, and other benthic structural organisms are potentially important ecosystem components where biomass is not well estimated by top down balance using EE=0.80 because they are not major prey of groundfish. Even trawl surveys are likely to produce severe underestimates of density for these groups as they are designed to catch fish, not benthic structure forming invertebrates. We again strongly caution that biomass estimates for these groups produced in these models should not be considered representative for analyses outside this narrow trophic context**.** Furthermore, the importance of these species to habitat quality cannot be evaluated within the food web modeling context. We in no way intend to suggest that these species are not important, rather, that they be considered using alternative analyses to those presented here.

2. Use these food web models alongside single species models for target species as a basic consistency check, because single species models are implemented together in the real world. For example, there are differences between the models in terms of data sources for Pacific cod. In the EBS, cod biomass based on the survey alone was inadequate to balance this group, so the cod stock assessment estimated biomass was substituted. In the GOA and AI models, survey biomass estimates for cod were used. Biomass estimates from the stock assessment are generally higher than survey estimates in all systems: in the GOA the difference is by a factor of 2. Furthermore, the GOA would likely not support a cod biomass as high as the assessment indicates as this would increase predation pressure on the already unbalanced pollock, which is not problem in the EBS. It may be useful to systematically include assessment biomass in balances and compare that to the survey biomass to see which are supported in all the models.

3. Address changing baselines in time and space: Climate and biological regime shifts likely affect food webs, so changes in feeding habits should be monitored both theoretically with dynamic ecosystem modeling, and by incorporating new food habits information as it becomes available. Updating these models is only a partial solution to the problem of ecosystem shifts; historically we have focused most sampling effort on groundfish, with less effort on other species demonstrated to be influential here. In the future, more balanced sampling across ecosystem components will help us identify when and if food webs have changed substantially and what the potential effects on fisheries might be. In addition, spatial scale for these models is large, but many important interactions happen at smaller scales. Future monitoring should have more flexibility with respect to the scale of sampling. The distribution as well as quantity of forage and predators should be considered in future modeling efforts.

4. Specific sampling improvements:

---Extend diet collection into spring and fall months to improve seasonal coverage for the all of the models.

---Improve biomass, consumption, diet, and distribution information for forage fish species in all models. Specifically, AI myctophids and GOA capelin are highly influential groups in each ecosystem which are extremely data poor.

---Improve bycatch accounting for seabirds in all fisheries.

---Improve bycatch accounting in the Pacific halibut fishery. The lack of bycatch information in halibut fisheries of equivalent quality to that available for groundfish fisheries represents a significant data gap in these models which should be considered a high priority for improvement.

---Improve diet information for the AI in general.

---Improve rockfish diet information in all ecosystems.

---Improve nontarget species biomass, consumption, and diet information in all ecosystems. Specifically, octopi and squid are monitored in federal groundfish fisheries and are important predators and prey with very poor diet information at present. Skates and sharks are important predators in Alaska which are receiving more fisheries interest, but which lack adequate biomass, and catch information for single species management. Diet information for sharks and skates is slowly improving, but is not at the level of quality for other managed groundfish.

---Improve forage and low trophic level sampling: Large zooplankton such as euphausiids, mysids and copepods comprise a very different proportion of the groundfish diets among the three systems. If data on zooplankton density were available it would be useful to compare relative densities between systems, and also look at differences in where or when groundfish were collected for stomach samples to further clarify these differences. Fluctuations in the abundance of prey resources are difficult to assess for most of these groups at present. Furthermore, we may be underestimating other components of the zooplankton community because we estimate biomass through diets collected during summer. Prey such as pteropods are rare during summer, and we lack diet information for forage fish which may consume pteropods. Finally, while our results suggest low trophic level differences between systems, and it is quite feasible to attribute differences to physical properties of the systems, we must keep in mind that full evaluation of differences between the EBS, GOA, and AI at low trophic levels is hampered by data gaps at present. Further investigation is necessary to determine what real differences in utilization of primary and secondary production exist between systems.

6. Appendix A: Description, Data Sources, and General Comparison for Each Species Group Across Ecosystems

In this appendix, we describe which species are in which groups in each model, and briefly document the input data to the models. We also give brief cross-system comparisons for each species group. In each description below, biomass density is reported to facilitate cross-system comparisons; this number is equal to the absolute biomass of a group divided by the area of each model: 495,218 km^2 for the EBS, 291,840 km^2 for the GOA, and 56,936 km^2 for the AI (Tables 1, 2, and 3 in Section 1). Detailed estimation methods for biomass, P/B, Q/B, and diets of Cetaceans, Otters and Pinnipeds, Seabirds, Fish, Invertebrates and Primary Producer groups are presented in Appendix B. Tables reporting all numeric values of parameters used in the models, including biomass, P/B, Q/B, diets, and pedigrees are presented in Appendix C, Table C1-C29.

6.1 Cetaceans

'Transient' killer whales are a subpopulation of killer whales (*Orcinus orca*) which are believed to feed exclusively on other marine mammals; therefore they represent an apex predator in the all three ecosystems. In recent years, transient killer whale predation has been hypothesized to cause observed declines in Steller sea lions (e.g., Springer et al. 2003), although the mechanisms supporting this hypothesis have been questioned (Mizroch and Rice 2006). Male killer whales grow to lengths of 9 m and weights exceeding 8 t; females are generally smaller at less than 7 m length and 4 t (Leatherwood et al. 1983).

Based on relative sighting rates, the population of transient killer whales is believed to be 10% of the 'resident' killer whales population (M. Dalheim, AFSC, pers. comm., 2003; Dalheim 1997). Therefore, based on resident killer whale population estimates (see below), at least 39 transient killer whales occupy the combined Bering Sea Aleutian Islands area (Waite et al. 2002), and 17 transient killer whales occupy the Gulf of Alaska (Dalheim 1997). The BSAI population was divided into 29 animals for the EBS and 10 for the AI (see Appendix B Section 7.2 for details). These numbers were multiplied by the average weight of 2.2 t each, resulting in a population density of 1.35E-4 t/km^2 in the EBS model, 3.91E-4 t/km^2 in the AI model, and 1.36E-4 t/km^2 in the GOA food web model.

In all modeled areas, the population production rate (P/B) of 0.0254 was estimated from the average survival of juveniles, male and female adults (Olesiuk et al. 1990), and the population consumption rate (Q/B) of 11.16 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Diet information for these important predators is lacking; therefore, Transient killer whales are assumed to feed on all marine mammal groups in proportion to each groups' biomass (equal "preference" for all EBS, GOA, and AI mammals; Dahlheim and Heyning 1999, Frost et al. 1992, Jefferson et al. 1991, Rice 1968).

The data pedigree for biomass was considered to be 7 (uncertain percentage of residents applied across the board). PB was given a pedigree of 3 in all systems because it is based on a species specific proxy (survival rate), while QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Transient killer whales have identical production and consumption parameters across systems by design; however, the density (biomass in t/km^2) in the AI is four times that in the EBS and GOA. Diet differences between systems reflect the local abundance of marine mammal prey, as we assumed that transient killer whales would consume any marine mammal in proportion to its abundance. Therefore, in the EBS transients rely primarily on fin whales (>70% of diet by weight), in the GOA they consume mostly fin and humpback whales (50 and 30%, respectively), and within the AI humpback and minke whales are their main prey items (65%, jointly). Under this assumption, transient killer whales have the most diverse diet in the AI and cause higher mortality on their prey than in other systems due to their higher density in the AI. There is no predation or fishing mortality on transient killer whales in any of the models.

Sperm and beaked whales are a combined group representing large offshore toothed whales, but sperm whales (*Physeter macrocephalus*) dominate the biomass. Other members of the group are Stejneger's beaked whale (*Mesoplodon stejnegeri*), Cuvier's beaked whale (*Ziphius cavirostris*) and Baird's beaked whale (*Berardius bairdii*). Sperm whales were heavily exploited in the North Pacific during the most recent period industrial pelagic whaling between 1960 and 1979 (Mizroch and Rice 2006), primarily for the high quality oil in the spermaceti organ found in their heads as well as for the ambergris found in their intestines. The size of the spermaceti organ makes the sperm whale's head account for up to one third of body length, which can range to a maximum of 18 m in males and 12 m in females. Maturity is reached between the ages of 8 and 11 years for females and over 10 years for males, at sizes of 8 to 12 m and 13 to 44 t (Leatherwood et al. 1983). Sperm whales range throughout the North Pacific, exhibiting gender-specific migratory behavior; in the EBS, GOA, and AI, adult male sperm whales are found foraging along the continental shelf and slope during the summer months (Rice 1989).

The North Pacific-wide sperm whale population estimate of 930,000 (Rice 1989) was multiplied by the fraction of the North Pacific represented by deep portions of the EBS (0.0011), GOA (0.0017), and AI shelves (0.0011) and scaled to reflect a residence time of half a year and the male proportion of the population (assuming a 50:50 sex ratio; see Appendix B Section B2 for details). This led to estimated sperm whale numbers of 265 (EBS), 399 (GOA), and 253 (AI). Biomass was estimated as the number of whales in each ecosystem times the adult male average body weight of 33 t, to give a density of 0.0177 t/km^2 in the EBS, 0.045 t/km^2 in the GOA and, 0.146 t/km^2 in the AI.

The P/B of 0.0469 for all ecosystems was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991); see Appendix B2 for details. Sperm whales were assumed to follow a human-like surrogate life table with an assumed longevity of 60 years to estimate P/B. The sperm whale Q/B of 6.61 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Sperm whale diets consist mainly of squids, with occasional consumption of octopus, salmon, skates, rockfish, and sablefish; the latter are sometimes removed from commercial longlines (Leatherwood et al. 1983, Hanselman et al. 2005). In the all three models, sperm whale diet is assumed to be 85% squids, with the remaining 15% of comprised of skates, rockfish, sablefish, sleeper sharks, adult cod, grenadiers and other miscellaneous deepwater fish in proportion to their biomass (Fiscus 1997, Kawakami 1980, Lowry et al. 1982, Nishiwaki 1972, Okutani and Nemoto 1964, Rice 1986, Tomilin 1957, Walker and Hanson 1999).

The data pedigree for biomass was considered to be 6 (historical estimate). The PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Sperm and beaked whales have the highest density in the AI, intermediate in the GOA, and lowest in the EBS. Energetics parameters were identical for all systems. These whales primarily prey on squid (85% of diet) and have no known sources of mortality in any of the three systems. Based on the proportionality assumption between consumption and abundance, it appears that the deep fish prey is more diverse in the GOA and the AI than it is in the EBS. This seems reasonable given the nature of the systems. The resulting estimated sperm whale mortality on adult sablefish is about 2% in the EBS and GOA systems (assuming neutral selection).

'Resident' killer whales are a subpopulation of killer whales (*Orcinus orca*) which are believed to feed primarily on fish and squid, and do not feed on other marine mammals. Male killer whales grow to lengths of 9 m and weights exceeding 8 t; females are generally smaller at less than 7 m length and 4 t (Leatherwood et al. 1983). They are social animals, occurring in "pods" of up to 30 related individuals including adult males and females with juveniles and calves. There is limited information on killer whale growth, reproduction, maturity and longevity (Leatherwood et al. 1983).

Approximately 174 individual resident killer whales are thought to occupy the Gulf of Alaska (Dahlheim 1997), and 391 are thought to occupy the combined Bering Sea Aleutian Islands area (Waite et al. 2002). Multiplying these numbers by an average weight of 2.2 t each, we estimate a population density of 1.36E-3 t/km^2 in the GOA food web model.

Because there is no information to distinguish the production and consumption rates of transient from resident killer whales, the same rates were used for both groups. The population production rate (P/B) of 0.0254 was estimated from the average survival of juveniles, male and female adults (Olesiuk et al. 1990), and the population consumption rate (Q/B) of 11.16 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Diet information for these important predators is lacking; therefore, Resident killer whales are assumed to feed on all continental shelf groundfish, salmon, and forage fish in proportion to each groups' biomass (Dahlheim and Heyning 1999; Frost et al. 1992; Yano and Dahlheim 1995; Rice 1968).

The data pedigree for biomass was considered to be 3 for the GOA, downgraded to 4 for the EBS and AI (mark recapture proxy data for GOA, higher coefficient of variation for BSAI). PB was given a pedigree of 3 in all systems because it is based on a species specific proxy (survival rate), while QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Resident killer whales have equal densities in the EBS and GOA, which are less than half that in the AI. Resident killer whales are assumed to prey on fish in proportion to abundance in each system, so that they eat more myctophids and squids in the AI, pollock and flatfish in the EBS, and arrowtooth, pollock, forage fish, halibut, and cod in the GOA. The only known source of mortality on this group in any model is from fishery bycatch. This is highest in the EBS, where it accounts for about 17% of total mortality; the pollock fishery alone contributes almost 7%. This bycatch mortality represents about 3 t, the average weight of an adult killer whale being 2.2 t. In the GOA only 2% of the total mortality is due to fishing, while in the AI there is none.

Porpoises are a combined group of small toothed whales. In the GOA food web model this group includes Dall's porpoises (*Phocoenoides dalli*), harbor porpoises (*Phocoena phocoena*), and Pacific white sided dolphins (*Lagenorhynchus obliquidens*). In the EBS food web model, the group includes harbor and Dall's porpoise, and in the AI model the group includes only Dall's porpoise because the other two species are not found there (See Appendix B Section 7.2 for details). Harbor porpoises are the smallest animals in the group, while Pacific white sided dolphins are largest. Harbor porpoises reach maximal lengths of 1.5 m, and are found in small groups or individually in nearshore areas of the EBS and GOA, where they feed on a variety of schooling fish species (Leatherwood et al. 1983). Dall's porpoises reach sizes up to 2.2 m, and are distributed throughout a variety of coastal and oceanic habitats where they feed primarily on squid and pelagic forage fishes. Unlike harbor porpoises, Dall's porpoises can be found in very large aggregations offshore, and often ride vessel bow waves (Leatherwood et al. 1983). Pacific white sided dolphins are the largest, most gregarious, and farthest offshore of the dolphins in this group. They grow to maximum lengths exceeding 2.3 m and can be found in groups numbering in the hundreds in waters over the continental slopes of the GOA, where they feed on squid and schooling pelagic forage fishes (Leatherwood et al. 1983).

There are an estimated 24,119 harbor porpoises in the EBS, and 31,012 in the Gulf of Alaska (Hobbs and Waite in review), so at an average body weight of 31 kg (Hunt et al. 2000) the estimated biomass of harbor porpoises is 6.04E-4 kg/km^2 in the EBS, and 3.29E-3 kg/km^2 in the GOA. The early 1990s population of Dall's porpoise in the GOA was estimated at up to 106,000, and the AI population was estimated at 302,000 (Hobbs and Lerczak 1993), but the actual population size may be only 20% of that estimate due to their attraction to the vessels used to count them (Turnock and Quinn 1991). Similarly, a recent EBS estimates of Dall's porpoise was 24,119 (Moore et al. 2002), but a similar 20% correction factor needs to be applied. Therefore, the EBS, GOA, and AI food web model Dall's porpoise biomass are estimated as 20% of 302,000, 106,000, and 24,119 respectively, times an average weight of 62 kg (Hunt et al. 2000) for a density of 6.04E-4 in the EBS, 4.50E-3 in the GOA, and 6.58E-2 t/km^2 in the AI. The early 1990s estimate of Pacific white sided dolphin population size was 26,880 in the Gulf of Alaska (Bukland et al. 1993), so multiplying that by an average weight of 79 kg (Hunt et al. 2000) we estimate a population density of 7.28E-3 t/km^2 . The sum of all porpoise biomass in the EBS is therefore 3.62E-3 t/km^2 , in the GOA is 0.0151 t/km^2, and in the AI is 0.0658 t/km^2. See Appendix B, Section B2 for further details.

Mortality rates are poorly known for porpoises in the North Pacific; therefore the P/B of 0.05 was estimated as an average of mortality rates for porpoises in other areas (Caswell et al. 1998). Consumption rates for porpoises were estimated for each group from average individual body weights and daily caloric requirements listed in Hunt et al. (2000); the Q/Bs estimated by this method were 27.5, 32.6, and 25.9, for Dall's porpoise, harbor porpoise, and Pacific white sided dolphins respectively. For the aggregate porpoise group a Q/B of 30 was used in all systems based on the average values for harbor and Dall's porpoises.

Food habits data for porpoises are lacking, but the generally described diets of all of these species are similar. The assumption made in the GOA model is that 69% of porpoise diet is squids, 18.5% is pelagic forage fish in proportion to each group's biomass, and the remainder is small benthic fish such as eelpouts, small sculpins, and miscellaneous shallow fish in proportion to each group's biomass (Crawford 1981, Fiscus and Jones 1999, Gearin et al. 1994, Walker et al. 1998).

The data pedigree for biomass was considered to be 3 for the EBS and GOA, downgraded to 4 for the AI (proxy data for EBS and GOA, higher CV for AI). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Porpoises have a higher proportion of total mortality caused by transient killer whales in the AI (23%) than in any of the other ecosystems; in both the EBS and GOA predation by transients is low and very similar (<6%). Dall's porpoises are the only species within the porpoise complex in the AI, making its diet composition heavily reliant on squid (90%), whereas in the GOA and EBS both Dall's and harbor porpoises are distributed, making the diet composition a lot more varied and less reliant on cephalopods in these two areas.

Beluga whales (*Delphinapterus leucas*) are distinctive white medium-sized toothed whales which inhabit Arctic waters. They are found in social groups numbering in the hundreds to thousands in a wide variety of habitats ranging from sea ice to open water to river mouths. Belugas reach ages of at least 25 years and lengths of 4.5 m for adult males, with females generally smaller and with substantial differences in size between regional stocks (Leatherwood et al. 1988). Five stocks of belugas are currently identified: Bristol Bay, Eastern Bering Sea, Chukchi Sea, Beaufort Sea, and Cook Inlet (Laidre et al. 2000).

In the EBS, the population estimates for the Bristol Bay and Eastern Bering Sea stocks for the years 1999-2000 were combined for a total EBS belugas population estimate of 20,025 animals (Angliss and Lodge 2002). An average body weight of 303 kg was applied to this population estimate to arrive at the biomass density for belugas in the EBS model, 3.01E-3 t/km^2 . Belugas were not included either in the AI or the GOA models. Belugas have not been sighted in the AI model area (Laidre et al. 2000). The inshore Cook Inlet population of belugas is outside the GOA model area, and Cook Inlet belugas are only rarely found outside Cook Inlet on the continental shelf of the GOA within the model area (Laidre et al. 2000, Hobbs et al. 2005).

The P/B of 0.112 was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991); see Appendix B2 for details. Beluga whales were assumed to follow a monkey-like surrogate life table with an assumed longevity of 30 years to estimate P/B. The beluga whale Q/B of 30 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Belugas reportedly feed on small forage fishes, crabs, and cephalopods ((Leatherwood et al. 1988). In the EBS model, belugas were assumed to feed on small forage fishes, including juvenile pollock, juvenile cod, and other juvenile commercial species, in proportion to those forage species abundance.

The data pedigree for biomass was considered to be 4 (a proxy with high variance, limited confidence or incomplete coverage). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Belugas' diet composition had all prey items with the same preference, but resulting proportions were highest for juvenile pollock, eelpouts, sand lance and other sculpins, which jointly contribute over 60% to the belugas' diet.

Gray whales (*Eschrichtius robustus*) are baleen whales which pass through the GOA on their annual migrations between the EBS and the Gulf of California, one of the longest migrations undertaken by any animal. The eastern Pacific gray whales may be the last of three historical gray whale stocks; the Atlantic stock was extirpated in the 1600-1700s, and the western Pacific stock is thought to be close to extinction. These whales grow to over 14 m and 35 t, reaching maturity somewhere between 5 and 11 years old (Leatherwood et al. 1983). Gray whales differ from other baleen whales in feeding primarily on benthic, rather than pelagic, invertebrates, especially benthic gammarid amphipods.

The eastern Pacific gray whale population is estimated to number 22,284 individuals (Rugh et al. 2005), which are estimated to spend ~5% of the year foraging in each of the EBS and GOA during their annual migration. Gray whales do not forage in the AI. For both the EBS and the GOA model, an estimated 1000 animals were assumed to occupy each model area in a given year, weighing an average of 16.2 t per animal (Hunt et al. 2000). This results in a total biomass density of .0.0327 t/km^2 in the EBS, and 0.0554 t/km^2 in the GOA. Details are given in Appendix B, section B2. .

The P/B of 0.0634 was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991); see Appendix B2 for details. Gray whales were assumed to follow a monkey-like surrogate life table with an assumed longevity of 60 years to estimate P/B. The gray whale Q/B of 8.87 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Gray whales are assumed to eat primarily benthic amphipods (90%) of diet, with the remaining 10% of diet allocated among other benthic invertebrate groups in proportion to their biomass (Lowry et al. 1982, Nerini 1984, Rice and Wolman 1971, Tomilin 1957, Zimushko and Lenskaya 1970).

The data pedigree for biomass was considered to be 5 for the EBS and GOA, with no biomass in the AI (uncertain scaling factors or extrapolation of migratory population by area). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Gray whales are almost identical for most characteristics between the GOA and EBS models, and are not distributed in the AI. Transient killer whales, their only predator, account for ~4% of the total mortality. Mortality due to fishing only occurs in the GOA subsistence fisheries, but in a negligible amount (<0.003%).

Humpback whales (*Megaptera novaeangliae*) also make long seasonal migrations between temperate feeding grounds and tropical breeding grounds in coastal areas, and are distributed in both the Atlantic and Pacific. The north Pacific populations were hunted extensively throughout the 19th and 20th centuries, especially as stocks of the larger blue and fin whales declined (Webb 1988). Humpback whales reach maximum sizes of 15-16 m, with adult females generally larger than males (Leatherwood et al. 1983).

Population size in the Gulf of Alaska has recently been estimated at 1,712 individuals, and in the AI at 268 individuals (Zerbini et al. 2006). Multiplied by an average body weight of 30.4 t (Hunt et al. 2000), the density estimate used in the GOA food web model is 0.178 t/km^2 , and in the AI model is 0.143 t/km^2. In the EBS, an older population estimate of 394 animals (Calambokidis et al. 1997) was reduced by 50% to account for time spent foraging in the EBS and was multiplied by the same average body weight for a density estimate of 0.0121 t/km^2. Details are given in Appendix B, section B2.

The P/B of 0.0377 was estimated using a survival rate estimated from repeated sightings of individual whales (Mizroch et al. in press). The humpback whale Q/B of 7.58 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Humpback whales feed on zooplankton (especially euphausiids) and small pelagic fishes, often employing a unique feeding behavior where the whales surround a school of prey by blowing bubbles which rise to the surface and concentrate the prey; the whale then swims vertically up through the concentrated prey with its mouth agape, often breaking the surface when its mouth snaps shut (Leatherwood et al. 1983). In the GOA food web model, humpback whales were assumed to have a diet composition of 60% euphausiids and other large zooplankton in proportion to their biomass, and the remaining 40% of salmon and small pelagic fishes such as capelin, eulachon, sand lance in proportion to their biomass (Kawamura 1980; Nemoto 1957, 1959, 1970; Nemoto and Kawamura 1977; Tomilin 1957).

The data pedigree for biomass was considered to be 4 for the AI and GOA, downgraded to 5 for the EBS (direct but uncertain estimates for AI and GOA, uncertain extrapolation in EBS). PB was given a pedigree of 2 in all systems (direct regional estimate) and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Humpback whales have a higher mortality from predation by transient killer whales in the AI (30% versus <10% in EBS and GOA); the EBS is the only ecosystem where bycatch occurs (4% of total mortality). Otherwise, the EBS and GOA are similar with transient killer whales contributing almost 4% to total mortality. The diets resulting from the preference method (proportionality assumption between consumption and abundance) have very similar proportions in all three ecosystems.

Fin whales (*Balaenoptera physalus*) are the second-largest living animals in the world, growing to a maximum size of 24 m in the Northern hemisphere (Leatherwood et al. 1983). Eastern North Pacific fin whales were extraordinarily heavily exploited throughout the 20th century. More whales were taken from the Gulf of Alaska and Eastern Bering Sea during 1961-1967 than during all previous 20th century whaling combined: the recorded removals in these seven years amount to 1.5 million t, and the majority of this catch was of fin whales (Mizroch and Rice 2006).

In the EBS, the current population estimate of fin whales is 4,051 animals (Moore et al. 2002). The current population of fin whales in the Gulf of Alaska is estimated at 1,397 individuals (Zerbini et al. 2006). There are an estimated 45 fin whales in the AI model area (Zerbini et al. 2006). Assuming that the average weight of a fin whale is 55.6 t (Hunt et al. 2000), the biomass density in the EBS food web model is estimated to be 0.0455 t/km^2 , in the GOA food web model is 0.2661 t/km^2, and in the AI model is 4.4E-2 t/km^2.

The P/B of 0.0267 was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991). Fin whales were assumed to follow a human-like surrogate life table with an assumed longevity of 105 years to estimate P/B. The fin whale Q/B of 6.52 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Fin whales are assumed to eat primarily large pelagic zooplankton (60%) in proportion to the biomass of each large zooplankton group, another 20% of their diet is copepods, and the remaining 20% of fin whale diet is allocated among pelagic forage fish groups in proportion to their biomass (Nemoto, 1957, 1959, 1970).

The data pedigree for biomass was considered to be 4 for all ecosystems (direct but uncertain estimates). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Fin whales have nearly identical mortality and diets in the EBS and GOA, except that fishery bycatch contributes a very small proportion to total mortality in the GOA (<1%). Transient killer whales are their only predator and they account for 10% of total mortality. In the AI, fin whales have no accounted sources of mortality either from fisheries or from predation.

Sei whales (*Balaenoptera borealis*) are named using the Norwegian word for pollock (which resemble pollock), "seje" (Leatherwood et al. 1983). Sei whales grow to a maximum size of 17-18.6 m, with females larger than males, and mature between 6 and 12 years of age. There is some evidence that age at maturity for sei whales decreased under heavy exploitation, and that their populations may have increased in the Southern hemisphere while their larger competitors blue, fin, and right whales were heavily exploited (Leatherwood et al. 1983). Sei whale exploitation increased in the North Pacific after fin whale stocks declined late 1960s (Mizroch and Rice 2006).

The most recent estimate of sei whale numbers in the entire North Pacific ranged from 7,260 to 12,620 individuals (Tilman 1977). Taking the midpoint of this range and assuming that the EBS model area represents 1.87% of the North Pacific, we estimate that 187 sei whales might occupy this area. Similarly, the GOA model area represents 1.1% of the North Pacific, so we estimate that 110 sei whales are in the GOA. The AI is 0.21% of the North Pacific, so 21 sei whales are estimated to occupy the AI. At an average of 16.8 t per animal, the estimated density for the EBS food web model is 0.00633 t/km^2 , is 0.00633 t/km^2 GOA food web model, and 0.00633 t/km^2 in the AI model.

The P/B of 0.0400 was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991). Sei whales were assumed to follow a human-like surrogate life table with an assumed longevity of 70 years to estimate P/B. The sei whale Q/B of 9.79 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

In the North Pacific sei whales are assumed to eat primarily copepods (Leatherwood et al. 1983; we assumed 80% of diet); another 5% of their diet is squids, 5% is large zooplankton in proportion to their biomass, and the remaining 10% of sei whale diet is allocated among pelagic forage fish groups in proportion to their biomass (Klumov 1963; Nemoto 1957, 1959, 1970; Nemoto and Kawamura 1977).

The data pedigree for biomass was considered to be 7 for all ecosystems (incomplete source with a wide range). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Sei whales have similar diets and sources of mortality in the EBS and GOA; transient killer whales are their only predator, accounting for ~7% of total mortality. They are not part of the bycatch in either system. The slightly more diverse diet in the GOA is due to the distribution of groundfish in prey preferences; for example the high biomass of

EBS pollock dominates the EBS Sei whale diet percentages, while prey items are more evenly proportioned in the GOA. Sei whales are not present in the AI.

Right whales (*Eubalaena glacialis*) are so called because they were the "right" whale to hunt; they historically inhabited relatively shallow nearshore areas, and floated when killed, yielding large quantities of oil and baleen. In the Gulf of Alaska, right whales were the main target of the first round of pelagic whaling in the North Pacific, and were heavily exploited from 1835 until 1848 (Scarff 2001, Shelden et al. 2005), and again illegally until 1967 (Mizroch and Rice 2006). Right whales are robust animals, growing to 17 m but weighing as much as 100 t each; this huge girth is supported by a nearly exclusive diet of copepods (Leatherwood et al. 1983).

Today, an estimated 100 right whales may exist in the entire North Pacific, with 59 of these animals thought to be in the EBS, 35 in the Gulf of Alaska, and 7 in the AI (Angliss and Lodge 2002, Wada 1973). Assuming that an average sized right whale might weigh 30 t today (Hunt et al. 2000), the biomass for the EBS, GOA, and AI models was estimated to be 0.0035 t/km^2.

The P/B of 0.0328 was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991). Right whales were assumed to follow a human-like surrogate life table with an assumed longevity of 85 years to estimate P/B. The right whale Q/B of 8 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Right whales were assumed to eat 95% copepods and 5% larger pelagic zooplankton, distributed in proportion to the biomass of those groups (Klumov 1962, 1963; Nemoto 1970; Omura et al. 1969; Omura 1958).

The data pedigree for biomass was considered to be 7 for all ecosystems (incomplete source with a wide range). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Right whales have very similar results to those of sei whales; transient killer whales account for ~8% of the total mortality which was identical in both systems. So was the diet, since 95% of it was assumed to be fixed consumption of copepods. Right whales are not present in the AI.

Minke whales (*Balaenoptera acutorostrata*) are the smallest whales in the large-rorqual whale genus *Balaenoptera*, growing to a maximum size of 9.2 m and less than 10 t, and maturing at the age of 7-8 years in the Northern hemisphere (Leatherwood et al. 1983).

An estimated population of 1,813 minke whales lives in the EBS (Moore et al. 2002). Approximately 105 minke whales are thought to occupy the Gulf of Alaska and an additional 846 live in the AI at present (Zerbini et al. 2006). With an average weight of 6.6 t (Hunt et al. 2000) the density of minke whales estimated in the EBS food web model is 0.024 t/km^2 , in the GOA is 0.0024 t/km^2, and in the AI is 0.0976 t/km^2.

The P/B of 0.0511 was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991). Minke whales were assumed to follow a monkey-like surrogate life table with an assumed longevity of 50 years to estimate P/B. The minke whale Q/B of 7.78 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Minke whales are thought to feed on the most abundant pelagic animals, which are euphausiids in Antarctic waters and are fish in the North Pacific (Leatherwood et al. 1983). Therefore, in the GOA food web model, a diet including 56% pelagic forage fish, and 40% pelagic zooplankton, proportioned by the biomass of each group in those categories, was assumed for minke whales. The remaining 4% of diet was divided equally between copepods and squids (Klumov 1963; Nemoto 1959,1970; Omura and Sakiura 1956; Tomilin 1957).

The data pedigree for biomass was considered to be 4 for all ecosystems (proxy with high variation). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Minke whales have an almost identical estimated total mortality in the EBS and GOA. Variations in the proportions of prey items in the diets among the models are again due to the differences in prey abundance distribution within each ecosystem. By design, forage fish, cephalopods and juvenile pollock are equally preferred and make up 56% of the minke's diet in all three ecosystems. However due to prey abundance, in the EBS, sand lance are second to juvenile pollock, whereas in the GOA capelin, followed by sand lance and several other forage fish are a higher percentage of Minke's diet, to which juvenile pollock contributes but a small portion. The AI minke whale's diet is evenly distributed among all forage fish groups and juvenile pollock.

Bowhead whales (*Balaena mysticetus*) are large baleen whales related to right whales which reach maximum lengths of 18 m and weights up to 50 t. They forage in icy habitats in groups of dozens, migrating along with seasonal changes in the ice edge from the Bering Sea to the Beaufort Sea (Leatherwood et al. 1988, Shelden and Rugh 1995). Bowheads were commercially harvested from 1848 to 1900 by "Yankee whalers" from New England, which severely depleted the stock (Bockstoce 1978, Shelden and Rugh 1995). Five stocks of Bowhead whales range throughout Arctic waters worldwide; the Bering Sea stock is the only one found in our model areas and it is distributed in the EBS only (Moore and Reeves 1993).

At present, an estimated 8,200 bowheads are thought to remain in the Bering Sea stock (IWC 1996, Zeh et al. 1995). One third of these animals feed within the EBS area; for these whales, the EBS model area is 10% of the full range of the stock, and they spend 5 months of the year or 42% of their time foraging in the model area (Moore and Reeves 1993, Lowry et al. 1993). Therefore, 8,200 times 0.33 times 0.1 times 0.42 gives 113 bowhead whales in the EBS model area. Averaging 31.506 t each, the resulting density estimate used in the model is 7.17E-3 t/km^2.

The bowhead whale PB of 0.01005 was derived from a survival estimate given in Zeh et al. (2003). The bowhead whale Q/B of 8.68 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Bowhead whales feed primarily on euphausiids, copepods, and other zooplankton, with some small proportion of the diet composed of benthic invertebrates (Lowry et al. 1993, Shelden and Rugh 1995). In the EBS, bowheads were assumed to feed on 40% copepods, 55% pelagic zooplankton including euphausiids, mysids, pelagic amphipods and chateognaths in proportion to their abundance. The remaining 5% of diet was composed of benthic invertebrates including all crabs, other epifauna and infauna.

The data pedigree for biomass was considered to be 5 for the EBS (highly uncertain scaling factors). PB was given a pedigree of 1 since it was derived from a direct independent method specific to this stock of bowheads. QB was given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Bowhead whales are distributed in the EBS only. Predation mortality by transient killer whales accounts for about one fourth of the total mortality. There is indigenous catch of these animals in the northern Bering Sea, however this was not included in the model because it is outside the bounds of the EBS ecosystem.

6.2 Sea Otters and Pinnipeds

Sea Otters (*Enhydra lutris*) are mustelids, most closely related to terrestrial weasels and skunks. These small carnivores live in nearshore areas of Alaska, and have recovered from heavy exploitation which began in the 18th century and continued until the beginning of the 20th. Sea otters have been shown to fundamentally structure nearshore ecosystems with their predation on sea urchins, which allows more growth of kelp, which provides habitat for a multitude of creatures (Reeves et al. 1992). The sea otter population in the Aleutian Islands and western Gulf of Alaska was estimated to decline at a rate of 17.5% per year during the 1990's (Doroff et al. 2003).

The EBS and AI ecosystems are thought to support approximately 15,000 sea otters each at present (Angliss and Lodge 2002), which translates into densities of 0.00075 t/km^2 in the EBS and 0.117 t/km^2 in the AI assuming that a sea otter weighs 25 kg on average (Hunt et al. 2000). In the Gulf of Alaska, a population of over 40,000 sea otters is thought to exist today (Angliss and Lodge 2002), which translates to a biomass density of 0.00345 t/km^2 using the same average weight.

For sea otters, the P/B was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991). Sea otters were assumed to follow a fur seal-like surrogate life table with an assumed longevity of 20 years to estimate a P/B of 0.117. The Q/B of 73 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate.

Sea otter diet changes radically between summer/autumn and winter/spring, and decadal diet changes have also been observed (Estes et al. 1981, Watt et al. 2000). In the AI model, otters consume 62% sea urchins, 19% miscellaneous shallow fish, 11% greenlings, sand lance, and managed forage in proportion to the abundance of these categories, and 8% selected benthic invertebrates in proportion to abundance (Watt et al. 2000). For the EBS and GOA food web models, only summer diets were considered (June- September average). Sea otters were estimated to derive 75% of their diet from sea urchins and crabs (allocated in proportion to those groups biomass), 20% of their diet from pelagic forage fish and juvenile groundfish, and 5% of their diet from squids (Watt et al. 2000).

The data pedigree for biomass was considered to be 4 for all ecosystems (proxy with high variation). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 5 in the AI (estimated using uncertain scaling factors/extrapolation) and 7 in the EBS and GOA (multiple incomplete sources with wide range).

Sea otters are preyed upon by transient killer whales in the AI more heavily than in the other systems. Sea otters comprise only 2% of AI transient killer whale diet, but this amounts to about 10% of the sea otters' total mortality in the AI. The higher density of transient killer whales in the AI (relative to the EBS and GOA), combined with less diversity and biomass of large cetaceans, increases their predation pressure on porpoises, sea otters, humpbacks, and minkes whales in the AI relative to other systems, hence the higher predation mortality rates for these groups. Diet preferences for sea otters are identical for the EBS and GOA; the composition was different for the AI so the greater proportion of echinoderms reflects the reported higher consumption of those benthic invertebrates there.

Walrus and Bearded Seals is a model group combining the two largest ice-associated pinnipeds in the Eastern Bering Sea, which both forage on benthic invertebrates during the winter months when sea ice extends across the Bering Sea shelf. Neither of these animals is found in the AI or GOA model areas, so this group is unique to the EBS model. The Pacific walrus, *Odobenus rosmarus rosmarus*, is the second largest pinniped in the world (after the elephant seals, *Mirounga* spp.), reaching average sizes of 3.15 m and 1215 kg for males and 2.6 m and 812 kg for females (Reeves et al. 1992). Females mature at 8 years, with first pupping around the age of 10 due to 4-5 months delayed implantation and long (15 month) gestation periods. Pups are nursed for over two years, hence females give birth only every other year. Males mature around 10 years, but generally do not breed successfully until the age of 15; walruses are thought to live to at least 40 years of age. Both male and female walruses have tusks, which are used to haul out on ice, to maintain breathing holes in ice, and for defensive displays. Floating sea ice provides important habitat for walruses, acting as both transportation during the annual migration between the Bering and Chukchi Seas and as a platform for breeding and for foraging in relatively shallow shelf waters. Walruses will haul out on land as well, but appear less likely to do so near human settlements, perhaps due to a long history of subsistence hunting (Reeves et al. 1992). Pacific walruses were hunted commercially for blubber and ivory during the 18th century by the Russian American Company on the Pribilof Islands, and then farther north in the EBS by whalers targeting bowheads during the 19th and early 20th century; commercial hunting ceased after 1991, at which point the north Pacific population was thought to number around 200,000 animals (Reeves et al. 1992, Angliss and Lodge 2002). The bearded seal, *Erignathus barbatus*, grows to large size as well, reaching an average of 2.1 to 2.4 m in length and 200-250 kg (which can range above 400 kg during spring) for both sexes. Females are mature at 3 years but may not reproduce until 8 years of age, after which they are thought to reproduce annually. Males mature at 6-7 years. It is thought that most bearded seals do not live past 25 years (Reeves et al. 1992). Bearded seals have similar migratory habits to walruses, wintering in Bering Sea pack ice and summering in Chukchi Sea pack ice, although they are more solitary animals and generally avoid walrus aggregations within this habitat. Like walruses, bearded seals are an important subsistence resource for coastal Alaskan natives, who take more than 5,000 animals annually; they were commercially exploited by Russian sealers in the Bering Sea as recently as 1989 at the rate of 1000-2000 animals annually (Reeves et al. 1992, Angliss and Outlaw 2005). The current number of bearded seals in the north Pacific is unknown, but was estimated at 250,000 to 300,000 animals in the late 1970s-early 1980s (Angliss and Outlaw 2005).

Because the current population size of both walrus and bearded seals is highly uncertain, we used the most recent total population estimates of 200,000 walrus and 250,000 bearded seals (Angliss and Lodge 2002, Angliss and Outlaw 2005). Both walrus and bearded seals use the Eastern Bering Sea model are during the winter only, when sea ice is at its full southern extent, so the combined population estimate of 450,000 animals was multiplied by 25% to account for the approximately 3 month residence time in the model area, and then multiplied by 87.5%, the approximate maximum coverage of sea ice in the model area during the period 1989-1998 (Stabeno et al. 2001). The average weight for the group was calculated as a weighted average by population size, assuming a 1:1 sex ratio for walrus and the average weights for females and males reported above and assuming an average weight of 225 kg for bearded seals, or (1215 + 812 + (225 * 2.5)) / 4.5 = 575 kg, resulting in the EBS biomass density estimate of 0.114 t/km^2.

The walrus and bearded seals group PB estimate of 0.0513 is based on a total annual mortality estimate of 5% (Perez 1990), where survivorship = 0.95, PB = -ln(0.95). The Q/B of 15.37 was estimated by scaling the average individual body weights and daily caloric requirements for walrus and bearded seals listed in Hunt et al. (2000) to an annual rate.

Both walrus and bearded seals forage on the continental shelf for benthic invertebrates. The walrus diet is dominated by bivalve mollusks, and supplemented by miscellaneous worms, snails, crabs, and shrimp. Bearded seals consume essentially the same prey, but in proportions less dominated by bivalves; especially in areas where they face competition for bivalves from walruses (Reeves et al. 1992). When proportioned by the mass of animals, the diet for the group most strongly resembles the diet of walruses; bivalves are over 70% of diet, miscellaneous worms are 18% of the diet, and various crustaceans make up the rest (Perez 1990). This group also feeds on wintering seals (0.10% of diet) because walruses are known to occasionally prey on other seals; the number was reduced from that reported in Perez (1990) to account for lower predation rates in the EBS model are relative to the Chukchi Sea.

The data pedigree for walrus and bearded seal biomass in the EBS model was considered to be 5 (highly uncertain scaling factors used). PB and QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 5 (correct species generalized from outside the model area).

Walrus are found only in the EBS. Their diet is dominated by bivalves, which have a high estimated abundance in the EBS, based on survey data. A small proportion of their total mortality (<1%) is due to bycatch mortality.

Northern Fur Seals (*Callorhinus ursinus*) are seasonal foragers in the Gulf of Alaska during their migrations to and from breeding areas in the Pribilof Islands (Eastern Bering Sea), where nearly three quarters of the world's population breed (Angliss and Lodge 2002). Fur seals are not thought to forage in the Aleutian Islands during the short time they spend migrating through island passes. Therefore, the EBS and GOA models have fur seal groups, but the AI model does not. The entire population forages in the EBS during the summer breeding and pupping season from May through November. Primarily adult female and juvenile fur seals forage in the GOA after they leave the Pribilofs each November and when they begin to return from wintering areas off the U.S. West Coast in March (Reeves et al. 1992). Fur seals were heavily exploited on their breeding grounds in Alaska from the late 1700s though the early 1900s by both Russian and American companies, as well as American, Japanese and Canadian pelagic sealers. Commercial harvests continued in a more regulated fashion after 1911 up until 1984. The population had increased to over a million individuals by the late 1960s, but declined thereafter through the early 1980s. After a period of relative stability through the early 1990s, the herd has been declining again in recent years (Angliss and Outlaw 2005).

The early 1990s population abundance of fur seals was estimated at 941,756 animals (Ream et al. 1999; Angliss and Lodge 2002). In the EBS model, this number was multiplied by 42.89% because fur seals forage only on the middle shelf and shelf break model areas during the summer, and then by an average weight of 40 kg (Perez 1990), resulting in a biomass density of 3.26E-2 t/km^2. Juvenile fur seal biomass in the EBS was estimated from pup counts conducted on the Pribilof Islands in the late 1980s and early 1990s, approximately 220,000 pups (Angliss and Outlaw 2005), multiplied by a 10 kg average juvenile body weight to result in an EBS juvenile fur seal biomass estimate of 1.91E-3 t/km^2. For the GOA model, the early 1990's total population abundance was scaled down by 93% to reflect the short residence time of the smaller (30-50 kg) female and juvenile fur seals spend foraging on the continental shelf of the Gulf of Alaska. (Adult male fur seals are much larger animals, reaching weights of 175-275 kg; Reeves et al. 1992). Therefore, 7% of the population with an average weight of 40 kg each resulted in a GOA model biomass density of 6.3E-3 t/km^2 for adult fur seals. Adult and juvenile fur seals were modeled separately to distinguish ontogenetic shifts in diet. Juvenile fur seal biomass is unknown in the Gulf of Alaska, so was assumed to be 10% of the juvenile fur seal biomass used in the Eastern Being Sea model, to reflect the short residence time in the GOA shelf region.

The P/B for northern fur seal groups was estimated by Siler (1979) using a competing risk model. The juvenile P/B of 0.116 and the adult P/B of 0.091 were estimated assuming a longevity of 25 and a fur seal survivorship curve (Siler 1979). The adult fur seal Q/B of 39.03 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate. Because data in Hunt et al. (2000) were inadequate to calculate a juvenile fur seal Q/B in a similar manner, juveniles were assumed to have the same growth efficiency (GE = P/B / Q/B = 0.002) as adults. Therefore, the juvenile fur seal Q/B of 49.5 was calculated as juvenile P/B divided by adult GE.

Diets for northern fur seals in the EBS were derived from Perez (1990) which reported food habits collections taken from pelagically foraging seals between 1958 and 1974. In the EBS, fur seals fed primarily on juvenile pollock (31% of diet) and squids (31%), and to a lesser extent on capelin (16%), juvenile herring (6%), myctophids (4%), and Alaska plaice (4%). Diets of fur seals in the GOA model were derived from Perez and Bigg (1986) which reported food habits collections taken from pelagically foraging seals in the 1970s. In the GOA, fur seals fed primarily on two forage species, sand lance (34%) and capelin (38%), and fed to a lesser extent on pollock (8.5%), squids (6.5%), salmon (2%), rockfish (2%), herring (3.5%), and other miscellaneous fish (5.5%). GOA Juvenile fur seals were modeled with diet preferences including both juvenile and adult groundfish, while adult fur seals fed more on the larger adult groundfish.

The data pedigree for adult northern fur seal biomass in the EBS model, and for both adult and juvenile fur seal biomass in the GOA model was considered to be 4 (direct estimate with high variation). In the EBS model, juvenile fur seal biomass data was rated 3 (proxy with known but consistent bias). Silers-model based PB values for both adults and juveniles were given a pedigree of 4 (proxy with known but consistent bias). Adult QB values were given a pedigree of 5 (general model specific to the area), while juvenile QB values were rated 7 (general relationship based on adult GE). Diets were given a pedigree of 5 (correct species but historical estimates).

Transient killer whales, the major mammal predator in these systems, account for only 2% of juvenile and 3% of adult northern fur seal mortality in both EBS and GOA. There are more sources of adult fur seal mortality in the EBS due to subsistence harvest combined with fishery bycatch relative to the GOA, where only subsistence harvest accounts for mortality. However, the bycatch contributes only about 1% of the total fur seal mortality in the EBS. Diet differences between systems are based on measured differences from foraging seals in each area, although the foraging data for both systems is historical.

Steller Sea Lions (*Eumetopias jubatus*) are apex predators which are resident year-round in the Eastern Bering Sea, Aleutian Islands, and Gulf of Alaska. They are the world's largest otariid pinniped, growing to over 3 m and 1 ton (males) or 2 m and 350 kg (females; Reeves et al. 1992). Two distinct stocks of Steller sea lions are recognized within U. S. waters: the eastern and western U. S. stocks. The first includes individuals east of Cape Suckling, Alaska (144°W), and the second includes those at and west of Cape Suckling (Loughlin 1997); the populations represented in the EBS, AI, and GOA food web models belong entirely to this last stock. Between 1998 and 2000, the western stock was estimated to decline 10.2% in the Bering Sea/ Aleutian Island region (Angliss and Lodge, 2004). There are some eight different hypotheses that have been proposed to explain the decline of Steller sea lions. Bottom-up forcing hypotheses include nutritional limitation due to either 1) fisheries removals of sea lion prey or 2) climate change/ regime shift reduction in sea lion prey or prey quality. Top-down forcing hypotheses include increased mortality due to 3) predation by killer whales, 4) purposeful killing, 5) subsistence uses, 6) bycatch, 7) infectious disease(s) and 8) toxic environmental substances (this last one may be bottom-up as well). Some have concluded the evidence is more consistent with a top-down forcing scenario and involves a combination of increased predation, illegal shooting in the early 1980's, bycatch mortality and subsistence harvest (NRC, 2003). The decline of the western stock prompted the listing of Steller sea lions as endangered under the ESA criteria (up from "threatened"). NMFS responded to the listing by implementing some changes to fishery management, most notably: 1) a more precautionary rule for setting harvest limits of major sea lion prey, 2) extension of 3 nautical mile protective zones around rookeries and haulouts not currently protected, 3) closures of many areas around rookeries and haulouts to 20 nmi, 4) establishment of 4 seasonal pollock catch limits inside critical habitat and two seasonal limits outside of critical habitat, and 5) establishment of a procedure for setting limits on removal levels in critical habitat based on the biomass of target species in critical habitat. A revised SEIS (Supplemental Environmental Impact Statement) was developed in 2001 and resulted in a preferred alternative that includes area-specific management measures designed to reduce direct and indirect interactions between the groundfish fisheries and Steller sea lions, particularly in waters within 10 nmi of haulouts and rookeries (Angliss and Lodge, 2004).

In all three food web models, Steller sea lion abundance was the average of 1991 and 1994 estimates for rookery/haulouts in the Gulf of Alaska as estimated by a spatial model (Fay, 2004). In the EBS and AI models, Steller sea lions were divided into adult and juvenile groups. In the GOA food web model, Steller sea lions were divided into both spatial and ontogenetic groups to capture different patterns in foraging by both juveniles and adults in the Central and Western GOA model areas. We first describe the division between adults and juveniles, and then describe the spatial groupings under the diet description below. Juveniles were defined as age 1 animals, called "yearlings" in the literature, whereas pups would be called "young of the year" or age 0 animals. Some studies consider 2-4 year old sea lions as juveniles, but we did not for the following reasons. While Steller sea lions do not reach sexual maturity until 3-8 years of age (Reeves et al. 1992), there is no information on how they distribute themselves for foraging purposes between ages 2 and 4, and therefore there is no way to separate them meaningfully from adults spatially or by diet. There is some telemetry data for the 1 year olds, which we are calling juveniles, and which do appear to forage closer to shore than their adult counterparts (NMFS 2003). This means our "adult" pool represents animals ages 2 and up. Since NMFS surveys of sea lion rookeries and haulouts regularly count both “pups” and “non-pups”, we can calculate the age 2+ biomass for a year following a survey as the previous year’s "non-pups” minus last years counted pups. The previous year’s pup count is used to estimate age 1 sea lion biomass by applying a mortality rate derived from a published life table (York 1994). Weight at age for female, male and pregnant female sea lions (Winship, 2001; York 1994) were averaged to get a juvenile (age 1) average weight of about 100 kg and an adult (ages 2-30) average weight of about 300 kg. These average weights were then used to convert abundance into biomass estimates. In the EBS model, adult sea lion biomass was 1.47E-3 t/km^2, and juvenile sea lion biomass was 1.5E-4 t/km^2. GOA central adult sea lion biomass was 1.08E-2 t/km^2 and central juvenile was 1.03E-3 t/km^2; GOA western adult biomass was 5.08E-3 t/km^2 and western juvenile biomass was 6.61E-4 t/km^2. AI adult sea lion biomass was 5.21E-2 t/km^2 and juvenile biomass was 5.45E-3 t/km^2.

For Steller sea lion juveniles and adults, the P/B was estimated using Siler’s competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991). Steller sea lions were assumed to follow a fur seal-like surrogate life table with an assumed longevity of 30 years to estimate a P/B of 0.109 for adults and 0.494 for juveniles. The adult Steller sea lion Q/B of 24 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate. Because data in Hunt et al. (2000) were inadequate to calculate a juvenile Steller sea lion Q/B in a similar manner, juveniles were assumed to have the same growth efficiency (GE = P/B / Q/B = 0.0046) as adults. Therefore, the juvenile Steller sea lion Q/B of 108 was calculated as juvenile P/B divided by adult GE.

In the EBS model, sea lion diets were derived from Perez (1990). Bering Sea Steller sea lions feed primarily on adult pollock (33%), followed by octopi (18%), juvenile cod (7%), sculpins (6%), and capelin (6%), and other fish, squids, and some benthic invertebrates. In the AI model, sea lion diets were derived from Merrick et al. (1997). Aleutian Islands Steller sea lions feed overwhelmingly on Atka mackerel (65% of diet), followed by adult pollock (9%), salmon (7%), squid (6%), cod (4%), and other fish and cephalopods. Steller sea lions display marked changes in diet between the central and western Gulf of Alaska (Sinclair and Zeppelin 2002). Therefore, we established separate model groups for sea lions in the Central GOA corresponding to marine mammal management areas in the eastern and central GOA (roughly fishery management areas 620 through 640 in Figure 1), and for sea lions in the Western GOA corresponding to marine mammal management areas in the western GOA and eastern Aleutian Islands (roughly fishery management area 610 in Figure 1). Diets for Central and Western Steller sea lions were reported in the 2000 Biological Opinion (NMFS 2000). We used summer diets reported for 1990-1994 to be most compatible with groundfish diets, also collected during summer surveys. The Central group of sea lions eats primarily adult pollock (40%) followed by salmon (20%) and arrowtooth flounder (16%), with the remainder of the diet comprised by various forage fish and cephalopods. The Western group has a slightly more diverse diet, but still eats primarily adult pollock (40%), followed by salmon (17%), herring (7%), Atka mackerel (7%), and sand lance (5%), followed by various fish and cephalopods.

The data pedigree for adult and juvenile Steller sea lion biomass in all models was considered to be 2 (direct estimate with limited corroboration for the spatial model’s interpolation of the count data). Silers-model based PB values for both adults and juveniles were given a pedigree of 4 (proxy with known but consistent bias). Adult QB values were given a pedigree of 5 (general model specific to the area), while juvenile QB values were rated 7 (general relationship based on adult GE). Diets were given a pedigree of 4 in the AI and GOA (direct estimates for correct time period but with high variation) and 5 in the EBS (correct species but historical estimates).

Steller sea lion juveniles have higher predation mortality from transient killer whales in the AI (about 2%) than in the EBS and GOA (less than 1% of total mortality), likewise in adult Steller sea lions (10% in AI vs. 2% in GOA and EBS). Diets were assigned independently for adults and juveniles in each system based on the best available data, but we made a consistent assumption between models that juvenile sea lions eat adult and juvenile pollock by preference (proportional to abundance), while adult sea lions eat only adult pollock (Sinclair, pers comm.). These models reflect what is already known about Steller sea lion diets, in that it is dominated by different prey in each system.

Resident Seals is a model group that includes only harbor seals (*Phoca vitulina*) in the GOA and AI models, and includes both harbor seals and ribbon seals (*P. fasciata*) in the EBS model. Harbor seals are distributed throughout the Northern hemisphere, but they grow to a larger size (1.7 to 1.9 m and 80 to 140 kg for females, males) in the North Pacific than in the North Atlantic (Reeves et al. 1992). They mature at 3-7 years and may live to 30 years. Three stocks of harbor seals are defined in the western Gulf of Alaska, in southeast Alaska, and in the Bering Sea for management purposes, but it is not clear whether they are distinct biological stocks. The overall harbor seal population appears to be stable to increasing (Small 1996). Ribbon seals are found primarily in the Bering, Okhotsk, and Chukchi Seas, where they are associated with the ice-edge, following its seasonal movements. These seals grow to average sizes of 1.75 m and 90 kg for both sexes, mature at 3-5 years of age, and live at least 20 years (Reeves et al. 1992). Population status is difficult to determine for ribbon seals; a mid-1970's estimate of 90,000 to 100,000 animals was given for the Bering Sea resident ribbon seals, with no more recent estimates available (Angliss and Outlaw 2005).

For the EBS resident seal biomass estimate, we used population estimates from Perez (1990): 45,000 harbor seals and 66,000 ribbon seals were estimated to occupy the region year round, so the total of 111,000 animals was multiplied by an average weight of 60 kg to arrive at a biomass density of 0.01345 t/km^2 for resident seals in the EBS. In the AI we used the estimated harbor seal number of 3,437 animals and multiplied that by the average body weight of 60 kg, resulting in an AI model biomass density of 3.62E-3 t/km^2. We took the early 1990s Gulf of Alaska population estimate of 16013 individuals (Angliss and Lodge 2002) and multiplied that by an average body weight of 60 kg to estimate the food web model density of 3.3E-3 t/km^2 .

For harbor seals, the P/B was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991). Harbor seals were assumed to follow a fur seal-like surrogate life table with an assumed longevity of 30 years to estimate a P/B of 0.082. The harbor seal Q/B of 17.4 was estimated by scaling the average individual body weights and daily caloric requirements listed in Hunt et al. (2000) to an annual rate. Lacking additional information for ribbon seals, the harbor seal parameters were applied to the entire resident seals group in the EBS model.

In the EBS, resident seal diet composition was estimated by averaging diet compositions for harbor seals and ribbon seals reported in Perez (1990). This results in a combined diet dominated by miscellaneous fish (15%), adult pollock (15%), octopi (11%), non-pandalid (10%) and pandalid shrimp (6%), and capelin (6%), followed by other fish and invertebrates. No diet information was available for harbor seals in the AI, so the EBS diet was modified to include higher proportions of Atka mackerel to replace 4% of the pollock in the diet from the EBS. Harbor seal food habits information was not available for the Gulf of Alaska, so we modified food habits from the Strait of Georgia (BC, Canada) reported by Olesiuk (1993). In the Strait of Georgia, harbor seals fed primarily on hake, so we assumed they would feed primarily on pollock in the Gulf of Alaska based on the functional similarity of the species in the two systems. All other species were common to the two ecosystems, so the final diet was pollock (42.6%), herring (32.4%), salmon (4%), miscellaneous shallow fish (12%), with the remainder of the diet comprised of small amounts of cod, rockfish, flatfish, cephalopods, and benthic invertebrates.

The data pedigree for resident seal biomass in all models was considered to be 5 (highly uncertain scaling factors/extrapolation). Silers-model based PB values were given a pedigree of 6 (general life history proxy). QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 5 in all models (same species in neighboring region).

Resident seals have similar sources of mortality between the AI and GOA, except that transient killer whales contribute a higher proportion to total mortality in the AI (14% versus 3% in GOA) and subsistence fisheries takes more than transients in the GOA (20% versus 10% in AI). In the EBS predation mortality by transients is around 3% and subsistence fisheries contribute a minimal amount to total mortality (1%). Differences across the systems in diet composition are partially the result of different seal species compositions in this category, and partially the result of prey preferences interacting with different groundfish abundances. For example, GOA diet composition is based on info from the Strait of Georgia, and based only on harbor seals; the diet composition for the EBS and the AI is similar but represents different species between the areas.

Wintering Seals are a model group combining ringed seals and spotted seals, which are found only in the EBS model area during the winter period of ice cover. These seals are separated from the walrus and bearded seal group because they are smaller and forage differently from walrus and bearded seals, even though they occupy the EBS model area during the same time of year. Ringed seals (*Phoca hispida*) are found throughout the Arctic Ocean, and range into the Bering Sea to Bristol Bay in the winter, where adults occupy land-fast ice and juveniles range into the pack ice at sea (Reeves et al. 1992, Angliss and Outlaw 2005). Ringed seals grow to maximum sizes 1.1 to 1.5 m and 50 to 70 kg, with considerable weight loss during the spring molt. Age at maturity varies by population, but most males and females are mature by age 5 to 7 years, and the maximum age may be up to 40 years. Ringed seals are unique among the pinnipeds in building a "birth lair" by tunneling into snow atop hard frozen ice, where the female nurses the pup and leaves it during foraging trips (Reeves et al. 1992). Ringed seals are an important subsistence resource for coastal Alaskan natives, who take an estimated 2,000 to over 9,000 seals annually from the entire population (mostly north of the EBS model area, Angliss and Outlaw 2005). Spotted seals (*P. largha*) range throughout the Beaufort, Bering, and Chukchi Seas and the Sea of Okhotsk, where they are also associated with the ice edge during winter (Reeves et al. 1992, Angliss and Outlaw 2005). Spotted seals reach maximum sizes of 1.6-1.7 m and 82-123 kg; they mature at 3-5 years with females maturing as much as a year earlier than males, and they live up to 35 years. Unlike ringed seals, which prefer land fast ice covered with snow to build birth lairs, spotted seals give birth on smaller ice floes at the ice edge (Reeves et al. 1992). Like ringed seals, spotted seals are important to Alaskan native communities for subsistence; recent estimates indicate that over 5,000 animals are taken annually (Angliss and Outlaw 2005).

The wintering seals group biomass for the EBS model was estimated using winter Bering Sea abundances of ringed and spotted seals reported in Perez (1990), which results in a category composition of approximately 75% ringed seals and 25% spotted seals. Because abundances reported in Perez (1990) included the population from the northern Bering Sea outside the EBS model area, the abundance was reduced by half to account for animals occupying only the southern model area. The resulting abundance of 348,838 animals was multiplied by an average body weight (including juveniles) of 43 kg, resulting in a biomass density of 3.029E-2 t/km^2.

For wintering seals, the P/B was estimated using Siler's competing risk model (Siler 1979) as modified using the surrogate life tables of Barlow and Boveng (1991). Ringed and spotted seals were both assumed to follow a fur seal-like surrogate life table with an assumed longevity of 40 and 35 years, respectively. A weighted average of each species P/B estimate (75% ringed, 25% spotted) resulted in a combined group P/B of 0.069. The wintering seal Q/B of 19.2 was estimated by scaling the average individual body weights and daily caloric requirements for ringed and spotted seals listed in Hunt et al. (2000) to an annual rate.

Both ringed and spotted seals forage on a wide range of prey including zooplankton, benthic invertebrates, and fish, which changes seasonally and varies by area (Reeves et al. 1992). Diet composition for wintering seals was estimated by taking a weighted average of ringed (75%) and spotted (25%) seal diets reported in Perez (1990). The resulting diet composition for the group is dominated by adult pollock (44%), followed by miscellaneous fish (10%), capelin (8%), other sculpins (8%), a variety of shrimp and worms (8%), eelpouts (6%), juvenile pollock (5%), juvenile herring (4%), and several flatfish and other species.

The data pedigree for wintering seal biomass in the EBS model was considered to be 5 (highly uncertain scaling factors/extrapolation). Silers-model based PB values were given a pedigree of 6 (general life history proxy). QB values were given a pedigree of 6 (general life history proxy). Diets were given a pedigree of 5 in all models (same species in neighboring region).

Wintering seals are only found in the EBS, where most of the mortality is caused by predation from walruses (85%) despite the fact they constitute a low percentage of the walrus' diet (0.1%) , This is one of the few predator-prey relationships that are exclusive to one of the systems, as both wintering seals and walruses are only found in the EBS.

6.3 Seabirds

Shearwaters (Procellariidae, genus *Puffinus*) includes at least two species in Alaska, the sooty shearwater (*P. griseus*) and the short-tailed shearwater (*P. tenuirostris*). These small seabirds (787g and 543 g body weight on average, respectively) are known to form some of the largest flocks of any seabird in areas of high food abundance. For example, short-tailed shearwaters migrate from breeding areas near Tasmania, around North Pacific to arrive in Alaskan waters during summer. Huge flocks (10,000 to 1 million individuals) aggregate to feed on euphausiids and forage fish in coastal and continental shelf regions. Unimak Pass in the eastern Aleutians (GOA model area) is regularly occupied by vast flocks of short-tailed shearwaters during summer (Piatt, 2005: photo and text available at http://www.absc.usgs.gov/research/seabird_foragefish/photogallery/Picture_of_Month/Dec05-STSH/Dec05-STSH.html).

The combined biomass of AI shearwaters is estimated at 1.8E-3 t/km^2 , which was derived from the Beringean Seabird Catalog colony counts for the North Pacific, multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). The combined biomass of shearwaters is poorly known in the EBS and GOA. In the EBS, a density of 4E-4 t/km^2 was assumed for shearwaters, and in the GOA shearwater density was assumed to be the same as the density of storm petrels in the GOA, 2.3E-4 t/km^2 .

P/B was estimated at 0.1 using an annual mortality rate estimated in Furness (1987). Q/B was estimated at 73, from daily energetic requirements (Hunt et al. 2000).

Shearwaters consume primarily forage fish and squids in the EBS, AI, and GOA. A generalized shearwater diet applied to both species in each area was derived from Hunt et al. (2000). In all three areas, capelin and squids are primary prey items at approximately 40% and 26% of diet, respectively, and in the AI myctophids are also important forage (20% of AI shearwater diet).

The data pedigree for shearwater biomass is 6 in all models (historical estimate/single study outside area). Shearwater P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

The majority of shearwater mortality in all models is unexplained, reflecting their position as apex predators in all systems. Fulmars account for the majority of predation mortality the AI and EBS. Small amounts of mortality (<5%) are attributable to fishery bycatch in the three ecosystems. One striking difference between models is the high proportion of shearwater's mortality (20%) in the GOA from Steller sea lions (juvenile and adult combined), this is the only system where seabirds have been reported as sea lion prey. The report appeared in the Steller Sea Lion Biological Opinion (NMFS 2000), and was incorporated into the model as a very low proportion of the diet preference (0.16%) distributed among all seabird groups; we are unable to determine how realistic this result is relative to the other systems.

Murres (Alcidae, genus *Uria*) includes two species in Alaska, the common murre (*U. aalge*) and the thick billed murre (*U. lomvia*). The common murre is a large alcid (body length 38–43 cm, wingspan 64–71 cm; 800–1,125 g) with circumpolar distribution from 68–33°N. It is found mostly at sea with significant breeding grounds throughout Alaska, including the Gulf of Alaska. The common murre breeds on cliff ledges, sloping island surfaces, or flat areas on rocky headlands and islands in full ocean view. In nonbreeding season they are often found close to shore, even up inlets and sounds. However, during breeding season they are most common where prey gets concentrated by oceanographic fronts, tidal sheers, and similar oceanographic features that are located within flight range of colonies. In warmer climate regimes, common murres feed further inshore from shelf break (Ainley et al. 1990, Oedekoven et al. 2001). The thick billed murre is one of the most numerous seabirds in the Northern Hemisphere. Thick billed murres are most often found farther offshore than common murres, in water >30 m deep (Springer 1991). In spring and early summer, these birds are strongly associated with margin of land-fast ice, especially where free-floating ice covered <50% of water adjacent to ice edge. Their distribution may be influenced by bottom topography and tidal phase, where strong tidal currents occur among islands and reefs (Cairns and Schneider 1990), also by the occurrence of oceanic fronts (Gaston and Hipfner, 2000).

The combined biomass of Murres was derived for each model area from the Beringean Seabird Catalog colony counts, multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). In the EBS, murre biomass density was estimated at 8.14E-3 t/km^2, for the Gulf of Alaska 4.8E-3 t/km^2, and for the AI 1.34E-3 t/km^2.

P/B was estimated at 0.169, equivalent to total mortality estimated by Schreiber and Burger, 2002) and QB was estimated at 72, from daily energetic requirements (Hunt et al. 2000).

General diet was also from Hunt et al. (2000). Their primary diet is comprised by midwater schooling fishes (cod, smelt, sand lance) and crustacea, especially pelagic amphipods and euphausiids; also benthic fishes (sculpins Cottidae, blennies Blennioidea, lumpsuckers), deepwater fishes (lanternfish), shrimps (Crangonidae), squid, and annelids. In all three models, the primary diet item is juvenile pollock (27%), followed by capelin in the GOA, Pacific ocean perch in the AI, and juvenile cod in the EBS.

The data pedigree for murre biomass is 4 in all models (direct estimate with high variation). Murre P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

Similar to other seabird groups, the majority of murre mortality in all models is unexplained, reflecting their position as apex predators in all systems. Fulmars account for the majority of predation mortality the AI and EBS. Small amounts of mortality (<3%) are attributable to fishery bycatch in the three ecosystems. One striking difference between models is the high proportion of murre mortality (11%) in the GOA from Steller sea lions (juvenile and adult combined), this is the only system where seabirds have been reported as sea lion prey. The report appeared in the Steller Sea Lion Biological Opinion (NMFS 2000), and was incorporated into the model as a very low proportion of the diet preference (0.16%) distributed among all seabird groups; we are unable to determine how realistic this result is relative to the other systems.

Kittiwakes (Laridae, genus *Rissa*) includes two species in Alaska, the red-legged (*R. brevirostris*) and black-legged (*R. tridactyla*) kittiwakes. The red-legged kittiwake is a small gull, with a mean total length of 372 mm (range 353–392 mm) which found nearly exclusively in Alaska, within 120–150 km of breeding islands. It is thought to engage in night feeding when vertically migrating prey like lampfish (Myctophidae), and squid become available to surface-feeding kittiwakes. This species is classified as Endangered in Russia which gives special protective status, such as restricted public access to nesting cliffs in the Commander Islands. The black-legged kittiwake is also a small gull, whose length averages 380–410 mm with mean body weight of 365–400 g. This bird usually nests on vertical sea cliffs, laying its eggs on narrow ledges—so narrow that most adults and chicks must face towards the cliff when on their nest, with their tails projecting over the edge. The black-legged kittiwake is one of the most widely distributed of our northern gulls, and one of the best studied. Ranging over the arctic, subarctic, and south, this species is also among the most pelagic of gulls. North American breeders winter offshore as far south as Florida and Baja California, and large numbers gather on the Grand Banks off Newfoundland and in ice-free waters off Alaska.

The combined biomass of kittiwakes in all three models was derived from the Beringean Seabird Catalog colony counts for the Gulf of Alaska multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). In the EBS and AI, both black-legged and red-legged kittiwakes are present, although black-legged kittiwakes outnumber red-legged by approximately 5:1. Kittiwake biomass density in the EBS was estimated at 6.6E-4 t/km^2, and in the AI was 4.8E-4 t/km^2. Kittiwake biomass in the Gulf of Alaska is based only on black-legged kittiwakes, with a density estimated at 8.9E-4 t/km^2 ,

P/B for the group in all models was estimated at 0.076, from survival rates measured in Alaska (Schreiber and Burger, 2002) and QB was estimated at 110, from daily energetic requirements (Hunt et al. 2000).

General diet was also from Hunt et al. (2000); kittiwakes feed on a variety of forage fishes, which varies by model area according to the biomass of those forage fish. In the EBS, sand lance and juvenile pollock were estimated to be the primary prey, while in the AI myctophids, POP, and other managed forage were primary prey, and in the GOA capelin, juvenile pollock and sand lance were dominant in estimated diet composition.

The data pedigree for kittiwake biomass is 4 in all models (direct estimate with high variation). Kittiwake P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

Similar to other seabird groups, the majority of kittiwake mortality in all models is unexplained, reflecting their position as apex predators in all systems. Fulmars account for the majority of predation mortality in the AI and EBS. Small amounts of mortality (<5%) are attributable to fishery bycatch in the three ecosystems. One striking difference between models is the high proportion of kittiwake mortality (27%) in the GOA from Steller sea lions (juvenile and adult combined), this is the only system where seabirds have been reported as sea lion prey. The report appeared in the Steller Sea Lion Biological Opinion (NMFS 2000), and was incorporated into the model as a very low proportion of the diet preference (0.16%) distributed among all seabird groups; we are unable to determine how realistic this result is relative to the other systems.

Auklets (Alcidae, genera *Ptychoramphus*, *Aethia*, and *Cerorhinica*) includes 6 species of auklets in the Gulf of Alaska: Rhinocerous, Least, Crested, Cassin’s, Parakeet and Whiskered auklets. They are plankton feeders and nest along rocky cliffs in the Gulf of Alaska. The Least auklet (*Aethia pusilla*) is the smallest alcid, with a total length of

12–14 cm, a wingspan of 33–36 cm, and a mean adult mass about 85 g. This tiny alcid is one of the most abundant seabirds in North America, with a total population of about nine million. This species has a low survival rate relative to other alcids, with a predicted average life expectancy of about 4.5 years. Least auklets dive for plankton, nest in huge colonies in rock crevices, lay just one egg each year, and eat almost 90% of their weight per day—reflecting the high energetic demands of their flight and foraging. The total North American population may be about 9,000,000 individuals (USFWS, 1988). Least auklet diet overlaps considerably with that of juvenile walleye pollock, and some Pacific salmon (*Oncorhynchus*) species. The crested auklet (*A. cristatella*) is a small, highly gregarious alcid; with a total length of 18–20 cm, a wingspan of 40–50 cm, and adult mass averages about 260 g. Breeding colonies are located on sea-facing talus slopes, cliffs, boulder fields, and lava flows, all of which provide abundant rock crevices suitable for nesting. Compared to the least auklet, the crested prefers areas with larger boulders and crevices, but also lays a single egg per clutch. The crested auklet dives for its food, primarily euphasiids, and often forages in large flocks, suggesting foraging is socially facilitated. Individuals in feeding concentrations dive beneath sea surface and pursue prey in rapid wing-propelled underwater flight (Jones, 1993). Cassin's auklet (*Ptychoramphus aleuticus*) is one of the most widely distributed of the Pacific alcids, and one of the best studied. It reaches an overall length 23 cm, and a mass 150–200 g. Found from Alaska south to Baja California, this small, abundant auklet nests in shallow burrows, which the birds excavate with their sharp toe nails, and also in rock crevices or under trees or logs on the ground. The total estimated population is believed to be at least 3.57 million individuals (Manuwal and Thorensen, 1993). Parakeet auklets (*A. psittacula*) grow to be 23–26 cm long and weigh 238–347 g. They have the widest range of any of the Alaskan auklets, spanning the northern Gulf of Alaska, most of the Bering Sea, the north Pacific south of the Aleutian Islands, and the Sea of Okhotsk in Siberia. Their preferred breeding sites are in crevices along rocky cliff faces, although small breeding colonies may be located on rocky beaches, talus slopes, lava extrusions, and even grassy slopes with scattered boulders. Parakeet auklets feed over stratified mixed and shelf waters, avoiding, or at least not concentrating at, areas of turbulence and upwelling, unlike other auklet species (Hunt et al. 1993, 1998). Parakeet auklets breed at 174 colonies in Alaska, compared to only 33 least auklet and 39 crested auklet colony sites, but populations at parakeet auklet colonies average much smaller (86% of parakeet auklet colonies contain <1,000 pairs breeding. Largest concentrations breed at St. George Island, Pribilof Island. (250,000 pairs) and King Island (Jones et al. 2001). The Whiskered Auklet (*A. pygmaea*) is a small alcid endemic to an arc of volcanic islands formed by the Aleutian, Commander, and Kuril Island chains. This small alcid (17–19 cm and 120 g) breeds in rock crevices on oceanic islands. It feeds in nearshore marine waters, usually within 10 km of colonies. Feeding flocks are associated with convergent tidal fronts year-round, usually within 16 km of islands, where zooplankton apparently concentrate. This habitat is characterized by well-mixed water with few gradients between surface and bottom. Dive depths are unknown, but the whiskered auklet is mostly found in areas where water < 100 m deep (Byrd and Willliams, 1993).

The combined biomass of auklets for all three models was derived from the Beringean Seabird Catalog colony counts multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). All auklet species were found in all ecosystems, except the rhinoceros auklet was absent from the EBS. In the EBS, estimated biomass density of auklets is 1.75E-3 t/km^2; in the AI, biomass density was estimated at 8.06E-3 t/km^2. In the GOA, biomass density was estimated at 2.9E-4 t/km^2 ,

P/B was estimated at 0.169, from survival rates measured in Alaska (Schreiber and Burger, 2002) and QB was estimated at 110, from daily energetic requirements (Hunt et al. 2000).

General diet was also from Hunt et al. (2000). Copepods and euphausiids are the primary diet items in all three model ecosystems, comprising more than 80% of the generalized auklet diet.

The data pedigree for auklet biomass is 4 in all models (direct estimate with high variation). Auklet P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

Similar to other seabird groups, the majority of auklet mortality in all models is unexplained, reflecting their position as apex predators in all systems. Fulmars account for the majority of predation mortality in the AI and EBS. Small amounts of mortality (<3%) are attributable to fishery bycatch in the three ecosystems. One striking difference between models is the high proportion of auklet mortality (12%) in the GOA from Steller sea lions (juvenile and adult combined), this is the only system where seabirds have been reported as sea lion prey. The report appeared in the Steller Sea Lion Biological Opinion (NMFS 2000), and was incorporated into the model as a very low proportion of the diet preference (0.16%) distributed among all seabird groups; we are unable to determine how realistic this result is relative to the other systems.

Puffins (Alcidae, genus *Fratecula*) are represented by two species in Alaska, the tufted (*F. cirrhata*) and the horned (*F. corniculata*) puffins. Adult tufted puffins are the most pelagic of the Alcids, ranging widely from colonies in summer to find fish for their young, but feeding themselves largely on invertebrates, especially squid and euphausiids. During the nonbreeding season, adults migrate far south to oceanic waters of the Central North Pacific, where their diet consists largely of squid, euphausiids, and pelagic fish. Juveniles migrate south to the Central North Pacific after fledging and may not return to coastal breeding areas for several years. Thus, the tufted puffin, even more so than the horned puffin (Piatt and Kitaysky, 2002), is a pelagic species that spends most of its life at great distances from land and has a diet more similar to shearwaters and petrels (*Pterodroma* spp.) than to most other alcids. Nests are typically excavated in deep, vegetated turf on steep slopes or plateaus, well above shoreline. Where mammalian predators (e.g., foxes) are present, or normal habitat absent, breeding is usually restricted to inaccessible cliff crevices or inside sea caves. Large feeding flocks are commonly observed near island passes in Aleutians where rip currents concentrate prey. Prey are captured underwater using wing-propelled "flight". The tufted puffin often forages in small groups of 10–20 individuals in association with other fish-feeding seabirds such as shearwaters, black-legged kittiwakes, glaucous-winged gulls, murres, horned puffins, and rhinoceros auklets (Piatt and Kitaysky, 2002). The horned puffin nests on coastline and offshore islands in British Columbia (rare), the Gulf of Alaska, Aleutians, Sea of Okhotsk, Kuril Islands, Bering and Chukchi Seas. This bird winters over a broad area of the central North Pacific, generally over deep oceanic waters; about 76% of colonies and 87% of the world population of horned puffins is found in Alaska. The largest colonies are concentrated in the Gulf of Alaska along the Alaska Peninsula near the Semidi, Shumagin, and Sanak Islands. Some remain near breeding colonies in Aleutians and Gulf of Alaska, but most undergo general postbreeding dispersal to overwintering grounds in central North Pacific where juveniles possibly remain for 1–2 years before returning to breeding areas. Adults return to colonies en masse in spring. The horned puffin forages in low densities (0.1–2.0 individuals/km^2) in bay, shelf, and shelf-edge habitats throughout Alaska, generally within 100 km of colonies (Piatt and Kitaysky, 2002a).

The combined biomass of puffins for all three models was derived from the Beringean Seabird Catalog colony counts multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). Both puffin species were found in all ecosystems. In the EBS, estimated biomass density of puffins is 4.7E-4 t/km^2; in the AI, biomass density was estimated at 4.1E-3 t/km^2. In the GOA, biomass density was estimated at 6.5E-3 t/km^2 ,

Puffin P/B was estimated at 0.04, from an annual mortality rate derived by Furness (1987), and QB was estimated at 73, from daily energetic requirements (Hunt et al. 2000).

General diet was also from Hunt et al. (2000). Puffins feed on a mix of small forage fish, so diets were estimated to be dominated by capelin in the GOA, sand lance in the EBS, and an equal mix of shallow water forage fish in the AI.

The data pedigree for puffin biomass is 4 in all models (direct estimate with high variation). Puffin P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

Unlike the other seabird groups, the majority of puffin mortality is unexplained only in the EBS model. Fulmars account for 51% of puffin mortality in the AI, and Steller sea lions account for 50% of puffin mortality in the GOA. The GOA is the only system where seabirds have been reported as sea lion prey. The report appeared in the Steller Sea Lion Biological Opinion (NMFS 2000), and was incorporated into the model as a very low proportion of the diet preference (0.16%) distributed among all seabird groups; we are unable to determine how realistic this result is relative to the other systems. Up to 10% of puffin mortality is attributable to fishery bycatch in the three ecosystems.

Fulmars (*Fulmarus glacialis*) are related to shearwaters, petrels, and albatross. This medium-sized bird (length 45–50 cm, wingspan 102–112 cm, mass 450–1,000 g) exhibits a generally pelagic distribution pattern with no true directed migrations, except possibly in high-arctic populations displaced by advancing sea ice in winter. Fulmars prefer to breed on precipitous sea cliffs of small to large islands or mainland promontories, often in mixed colonies with other cliff-breeders (murres [*Uria* spp.], kittiwakes [*Rissa* spp.], and cormorants [*Phalacrocorax* spp.]). However, fulmars use upper, more densely vegetated portions of cliffs, canyons, and gullies with less severe slopes and greater soil accumulation. Observations suggest that most foraging during chick-rearing occurs closer to colonies, probably <100 km away. Fulmars obtain food by dipping, surface-seizing, surface-plunging, pursuit-diving, and scavenging; apparently unable to pick up prey while on the wing. In Alaska, foxes (Alopex and Vulpes), rats (*Rattus norvegicus*), ground squirrels (*Spermophilus* spp.), and other mammals widely introduced in late 1800s and early 1900s (Bailey 1993) reduced or eliminated some former colonies. Heavy predation by fox also likely in the West Pacific, particularly Kuril Is., from animals introduced by Japanese fur farmers in early 20th century (Hatch and Nettleship, 1998).

The combined biomass of fulmars for all three models was derived from the Beringean Seabird Catalog colony counts multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). In the EBS, estimated biomass density of fulmars is 5.2E-4 t/km^2; in the AI, biomass density was estimated at 4.9E-3 t/km^2. In the GOA, biomass density was estimated at 8.2E-4 t/km^2 ,

P/B was estimated at 0.055, from an annual mortality rate derived by Furness (1987), and QB was estimated at 73, from daily energetic requirements (Hunt et al. 2000).

Fulmars are omnivorous, mainly feeding on fish, cephalopods (mainly squids), zooplankton (especially amphipods, copepods, and other crustaceans), offal, and carrion. Offal includes fish refuse (livers, entrails, and whole fish discarded by trawlers and factory ships), as well as remains of whales, walruses, and seals, especially blubber. General diet was also from Hunt et al. (2000). In all three models, fulmars are estimated to feed on squid for a majority (59%) of their diet, followed by juvenile pollock in the GOA and EBS (26-30%) and POP in the AI (15%).

The data pedigree for fulmar biomass is 4 in all models (direct estimate with high variation). Fulmar P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

The majority of fulmar mortality is unexplained in the EBS and AI models, with fulmars themselves accounting for the majority of predation mortality on fulmars in these systems. As with other seabird groups, Steller sea lions cause the majority of fulmar predation mortality in the GOA, based on a very low proportion of the diet preference (0.16%) distributed among all seabird groups. Less than 8% of mortality is attributable to fishery bycatch in the three ecosystems. Within the Aleutians, fulmars overall contribute at least 10% to the predation mortality of all seabird groups, reaching up to 50% for puffins. In the GOA and EBS fulmars account for a lower percentage of predation mortality 4 to 15% and 3 to 12%, respectively. By design, all seabird group diet preferences are identical between areas, and all models have seabirds jointly comprising 0.15% of the fulmars diet. The resulting effects of fulmars on predation mortality are the combined result of seabirds' density, which in the AI happen to be all higher than in the other systems. Its worth noting that fulmars eat chicks and chick productions rates are not accounted in the models, so predation mortality of fulmars on other seabirds may be overestimated.

Storm Petrels (Hydrobatidae) are represented by at least two species in Alaska, Leach's storm petrel (*Oceanodroma leurcorhoa*), and the fork-tailed storm petrel (*O. furcata*). Leach's storm petrel breeds mainly in the Aleutian Islands, although there are also many colonies off Alaska Peninsula; the northernmost are small ones at Wooded Island, off Prince William Sound at 59°52'N, 147°25'W. Nesting habitat consists of islands far enough offshore to avoid predatory mammals. Foraging habitat is in the open sea, wherever zooplankton and nekton of suitable size are available. Leach's storm petrel feeds by pecking at individual organisms while hovering over the surface, occasionally pattering on the surface, as Wilson's Storm-Petrel commonly does, or sitting on water. Some surface fishes (e.g., rockfish [*Sebastes* sp.]) are prominent in storm petrel diets, but deep-water fish, especially myctophids, are even more so. These and vertically migrant plankton in the diet imply nocturnal feeding, but fish considered midwater species (e.g., *Vinciguerria lucetia*) come to the surface often enough in daylight to be taken as prey, sometimes in great numbers. Other prey include cephalopods (squids, octopuses), crustaceans (euphausiids, decapods, amphipods, isopods, mysids, copepods), and jellyfish (Scyphozoa) (Huntington et al. 1996). The fork-tailed storm petrel is the second most abundant and widespread of storm-petrels breeding in the North Pacific. The core of fork tailed petrel distribution is offshore islands of Alaska, particularly in the Eastern Aleutian Islands. In Alaska there are some 60 colonies of fork-tailed storm-petrels, 39 of these are in the Gulf of Alaska. Individuals use different breeding habitats, ranging from talus slopes to crevices under large trees or rocks. Nesting habitat of majority of populations characterized by subarctic maritime tundra, comprising grasses (*Elymus* sp., *Festuca* sp.), sedges (*Carex* sp.), and umbelliferae (*Heracleum* sp., *Angelica* sp.) among or under which burrows may be found. In general, nests are crevices among rocks, sod, or roots where birds can stay dry. Nests distributed from sea level to island tops. Fork tailed storm petrels are surface feeders, seizing prey while hovering over, or landing briefly on, ocean surface. In eastern populations, primary prey include amphipods; Myctophid and other deep-water fish, shallow-water fish, rockfish, greenling, sablefish, copepods, euphausiids, decapods, and squid comprise other main prey items (Boersma and Silva 2001).

The combined biomass of storm petrels for all three models was derived from the Beringean Seabird Catalog colony counts multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). In the EBS, estimated biomass density of storm petrels is 1.75E-6 t/km^2; in the AI, biomass density was estimated at 3.5E-3 t/km^2. In the GOA, biomass density was estimated at 2.3E-4 t/km^2 ,

P/B was estimated at 0.12, from an annual mortality rate derived by Furness (1987), and QB was estimated at 144, from daily energetic requirements (Hunt et al. 2000).

General diet was also from Hunt et al. (2000) and the references listed above. The major prey items in the storm petrel diets are estimated to be squids (61%), copepods (16-18%), and euphausiids (12-15%) in all three models.

The data pedigree for storm petrels biomass is 4 in all models (direct estimate with high variation). Storm petrel P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

Similar to other seabird groups, the majority of storm petrel mortality in all models is unexplained, reflecting their position as apex predators in all systems. Fulmars account for the majority of predation mortality in the AI and EBS while Steller sea lions cause the majority of storm petrel predation mortality in the GOA, based on a very low proportion of the diet preference (0.16%) distributed among all seabird groups. Small amounts of mortality (<4%) are attributable to fishery bycatch in the three ecosystems.

Cormorants (Phalacrocoracidae) include at least three species in Alaska, the double crested (*Phalacrocorax auritus*), the pelagic (*P. pelagicus*) and the red-faced (*P. urile*). The double crested cormorant is the most common cormorant in North America, ranging from freshwater to saltwater habitats across the continent; it is also longer but lighter than either of the other cormorants found in Alaska, with a length up to 80 cm but a weight of about 1700 g (Sibley 2000). The pelagic cormorant is smaller, reaching lengths of 51–76 cm, with males larger than females (average mass: male, 1,750–2,034 g; female, 1,531–1,702 g). This cormorant is the most widely distributed of six cormorant species inhabiting the North Pacific, ranging from the Arctic waters of the Chukchi and Bering Seas south through temperate waters along the North American Pacific Coast to Baja California and along the Asian coast to southern China. It is among the least gregarious or social of the cormorants, nesting on steep cliffs along rocky and exposed shorelines, either in loose colonies or far from nearest neighbors. Migration occurs primarily in northern populations. Nesting colonies are located on suitable cliffs of forested, grassy, and rocky islands and headlands, but it also uses ledges of sea caves, beached driftwood logs, sand spits, and human-made structures such as navigation beacons, bridges, wharves, empty ship hulls, and abandoned towers. It forages in waters in Gulf of Alaska to about 36 m; it is often found in waters up to 100 m deep, but foraging depths have not been confirmed in these waters. The red-faced cormorant may be the least known of all North American species. It is a medium-sized cormorant (length 75–100 cm; males larger than females: average mass for males, 2,400 g; females, 1,850 g) which breeds in a narrow, latitudinally compressed band from the northern Sea of Japan, along the Kuril and Aleutian Island chain, and far east into the southeastern Gulf of Alaska. Possibly owing to its shy habits and inaccessible colony sites, it is one of the least studied and least known birds of the North Pacific: little is known beyond distribution and rudiments of ecology. The red-faced cormorant is exclusively marine and ventures onto land only to breed or roost, never intruding more than a few meters from the edge of the sea. It sometimes is observed flying far out to sea, but is more commonly associated with the inshore and coastal waters of islands and continental shelves. Cormorants are generalist feeders; their diet consists predominantly of medium-sized fish, but they also consume invertebrates, marine worms, and crustaceans. In Alaska, black-legged kittiwakes and cormorants compete for nest space. Red-faced cormorants arrive early to occupy nesting cliffs and possibly dominate and exclude pelagic cormorants from the best nesting sites. Gulls and double-crested cormorants also compete with pelagic cormorants for nesting habitat (Hobson, 1997).

The combined biomass of cormorants for all three models was derived from the Beringean Seabird Catalog colony counts multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). All three cormorant species listed above are found in the EBS and GOA model areas, but the double crested cormorant was absent from the AI model area. In the EBS, estimated biomass density of cormorants is 1.5E-4 t/km^2; in the AI, biomass density was estimated at 1.07E-3 t/km^2. In the GOA, biomass density was estimated at 3.5E-4 t/km^2 .

P/B was estimated at 0.159, from survival rates measured in Alaska (Schreiber and Burger, 2002), and QB was estimated at 73, from daily energetic requirements (Hunt et al. 2000).

General diet was also from Hunt et al. (2000). In all three models, cormorant diets were estimated to be dominated by sand lance (42-50% of diet), with capelin, juvenile herring, and other managed forage fish next in importance depending on the system.

The data pedigree for cormorant biomass is 4 in all models (direct estimate with high variation). Cormorant P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

Similar to other seabird groups, the majority of cormorant mortality in all models is unexplained, reflecting their position as apex predators in all systems. Fulmars account for the majority of predation mortality the AI and EBS while Steller sea lions cause the majority of cormorant predation mortality in the GOA, based on a very low proportion of the diet preference (0.16%) distributed among all seabird groups. Small amounts of mortality (<3%) are attributable to fishery bycatch in the three ecosystems.

Gulls (Laridae, genus *Larus*) include many species worldwide, but are dominated by a single species in Alaska, the glaucous winged gull (*Larus glaucescens*). Another species, the mew gull (*L. canus*) is found in the Gulf of Alaska but is far less abundant. The glaucous winged gull generally nests at high densities in large or small colonies on off-shore islands, although it has recently begun nesting on roofs of waterfront buildings. It is an abundant resident along the northwestern coast of North America; bold and omnivorous, it is a familiar sight in coastal cities and towns. Although generally an inshore species, it does venture away from the coast where it is often seen around fishing vessels at sea. This species has steadily increased in numbers in the last few decades, particularly around urban centers, mainly owing to environmental changes and to the availability of garbage and fish offal. It feeds by seizing food from the water surface or just below it in flight or while swimming; it also plunges from a floating position, by jumping into the air, to become partially or totally submerged. Chit and limpets are pulled off rocks during ebbing tides while they are still submerged, and barnacles are grasped and broken off. Fish are obtained when stranded in tide pools, in shallow water along the shore, or when they come near the surface off shore. Gulls are known for stealing food from both members of its own species, and others, and for killing and eating its own species' chicks, and those of other birds. Glaucous winged gulls rarely live beyond 15 years, and the average life expectancy is 9.5 years, with breeding starting at age 4 (Verbeek, 1993).

The combined biomass of gulls for all three models was derived from the Beringean Seabird Catalog colony counts multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). Different gull species are present in the different model areas: In the AI, only the glaucous-winged gull was present; in the GOA the glaucous-winged and mew gulls were present; in the EBS, glaucous-winged gulls, mew gulls, herring gulls, glaucous gulls, and Sabine's gull were present. In the EBS, estimated biomass density of gulls is 1.0E-4 t/km^2; in the AI, biomass density was estimated at 5.8E-4 t/km^2. In the GOA, biomass density was estimated at 5.7E-4 t/km^2 ,

P/B was estimated at 0.166, from order-level survival rates measured in Alaska (Schreiber and Burger, 2002), and QB was estimated at 73, from daily energetic requirements (Hunt et al. 2000).

General diet was also from Hunt et al. (2000). The diet compositions estimated for gulls showed similar prey in each ecosystem, with different rankings: capelin (54%) and sand lance (19%) dominated in the GOA, sand lance (47%) and other managed forage (19%) were prevalent in the EBS, and other managed forage (21%), sand lance (20%), and capelin (19%) were the top prey in the AI.

The data pedigree for gull biomass is 4 in all models (direct estimate with high variation). Gull P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

Similar to other seabird groups, the majority of gull mortality in all models is unexplained, reflecting their position as apex predators in all systems. Fulmars account for the majority of predation mortality in the AI and EBS while Steller sea lions cause the majority of gull predation mortality in the GOA, based on a very low proportion of the diet preference (0.16%) distributed among all seabird groups. Small amounts of mortality (<3%) are attributable to fishery bycatch in the three ecosystems.

Albatross and Jaegers is a composite seabird group containing all species of albatross (Diomedeidae, genus *Phoebastria*) and jaegers (Laridae, genus *Stercorarius*). Three species of albatross forage (but none breed) in Alaska: short-tailed, Laysan and black-footed albatross. Short-tailed albatross (*Phoebastria albatrus*) is the largest seabird in the North Pacific. Historically millions of birds nested in the western North Pacific, but now only two breeding colonies remain active: Torishima Island and Minami-kojima Island. Short-tailed albatross live up to 40 years and begin breeding at about 7 or 8 years of age. During the late 1800s and early 1900s, feather hunters killed an estimated five million and the species became nearly extinct. The world population is now about 1,200 birds, and is listed as Endangered under ESA; hence bycatch in Alaskan longline fisheries is of great concern. Black-footed albatross (*Phoebastria nigripes*) are the most common albatross in the North Pacific, and range into the Gulf of Alaska and the Bering Sea during summer. They feed mainly during the day by seizing prey at the surface. Flying-fish eggs are the principal component of the diet, followed by squid and crustacea. Some 50,000 pairs of Black-footed albatross nest in the Northwestern Hawaiian Islands (Whittow, 1993a). Laysan albatross (*Phoebastria immutabilis)* are seen regularly in Gulf of Alaska during spring and in the southern Bering Sea in summer. Birds are farther north in summer than during the breeding season, and nonbreeders concentrate near the Aleutians and in the Bering Sea. Laysan albatross feed by sitting on the water and seizing prey; they also scavenge natural carrion or refuse from ships, but not as extensively as the black-footed albatross. Laysans often feed in flocks with other albatross but rarely with other species. Squid make up the bulk of the diet. Fish eggs constitute the largest fraction of the "fish" part of the diet, followed by sunfish. Colonies of Laysan albatross nest on Johnston, Wake, and Marcus Islands, and on the Izu Islands were decimated by Japanese feather hunters at the turn of the century and have never recovered. Marcus once had an estimated population of one million birds. Midway and Laysan Island populations also greatly reduced by feather hunters (on Laysan Island, more than 300,000 birds were killed in 1909 alone) but have largely recovered. The Lisianski population has remained depressed apparently because the vegetation was altered by introduced rabbits, destroying nesting habitat. Nearly all of the 400,000 breeding pairs nest in the Northwestern Hawaiian Islands (Whittow, 1993b).

The combined biomass of AI albatross and jaegers is estimated at 8.2E-5 t/km^2 , which was derived from an estimate of 1500 albatross in that area (Hunt et al. 2000), multiplied by the average weight for each species to convert abundance to biomass estimates (Appendix B Table B5). Body weights were taken from Hunt et al. (2000). The combined biomass of albatross is poorly known in the EBS and GOA. In the EBS, a density of 1E-4 t/km^2 was assumed for albatross and jaegers, and in the GOA albatross and jaeger density was assumed to be the same as the density of storm petrels in the GOA, 2.3E-4 t/km^2 .

P/B was estimated at 0.0676, from order-level survival rates measured in Alaska (Schreiber and Burger, 2002), and QB was estimated at 75, from daily energetic requirements (Hunt et al. 2000).

General diet was also from Hunt et al. (2000). Half of the albatross and jaeger diet in all three ecosystems is squid. The remainder of the diet is estimated to come from the forage fish present in each ecosystem in proportion to their estimated abundance, so that capelin are ranked next in GOA diet, while juvenile pollock are next in the EBS and myctophids are next in the AI albatross and jaeger diet.

The data pedigree for albatross and jaeger biomass is 6 in all models (historical or single study). Albatross and jaeger P/B and Q/B estimates were rated 6 (general life history proxies from literature). Diet compositions were rated 6 (mix of species across regions).

Similar to other seabird groups, the majority of albatross and jaeger mortality in all models is unexplained, reflecting their position as apex predators in all systems. Fulmars account for the majority of predation mortality in the AI and EBS while Steller sea lions cause the majority of gull predation mortality in the GOA, based on a very low proportion of the diet preference (0.16%) distributed among all seabird groups. Generally less than 7% of albatross and jaeger mortality is attributable to fishery bycatch in the three ecosystems.

6.4 Fish (Includes Cephalopods and Forage Fish)

Pacific sleeper sharks (*Somniosus pacificus*) are considered common in boreal and temperate regions of shelf and slope waters of the north Pacific. Sleeper sharks are found in relatively shallow waters at higher latitudes, and in deeper habitats in temperate waters. Little biological information is available for Pacific sleeper sharks. Pregnant females have not been found, so reproductive mode is unknown, although ovoviviparity is suspected. One individual mature female sleeper shark had 300 eggs. Sleeper sharks grow to large sizes; individuals have been measured to 4.3 m, and lengths to 7 m have been observed under water (Compagno, 1984).

The EBS sleeper shark biomass is the sum of 1991 shelf survey biomass and 2002 slope survey biomass, as full slope survey data were not available prior to 2002. GOA biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. AI biomass is 96.45% of the average for years 1991 and 1994 (average estimate of 1991 and 1994 is 750 t). This is because total biomass for “sleeper sharks” was split between dogfish and sleeper sharks, based on the cumulative biomass percentage of each species from 1980-2002 trawl surveys (with 1986 excluded due to unusually high numbers of sleeper sharks). The total number of sharks reported in the trawl surveys is 22 and 33 for dogfish and sleeper sharks respectively with cumulative biomasses of 56.92 kg and 1420.29 kg, respectively.

It seems likely that sleeper sharks display slow growth and relatively low natural mortality rates, so we assumed that P/B was 0.1 for this group, and for all other sharks, until better information is available. Likewise, consumption rates are unknown, so a Q/B of 3.0 was adapted from a model of an adjacent area, Prince William Sound (Hulbert 1999).

Sleeper shark diet composition for the GOA and AI was estimated from 11 animals collected in the GOA during 1996 (Yang and Page 1999). Diet composition for the EBS was taken from a study conducted in the western Bering Sea (Orlov and Moiseev 1999), which showed more pollock and flatfish oriented diets than the GOA data and is thus expected to be more representative of the Bering Sea.

The data pedigree for biomass was considered to be 4 (survey with limited catchability) but downgraded to 5 for the EBS and AI as the main deepwater concentrations were not surveyed in the model years. PB and QB values were given a pedigree of 7 (general literature review from wide range of species), while diets were given a pedigree of 6 (species sampled in neighboring regions/limited coverage).

Sleeper sharks are estimated to have rather high bycatch mortality (accounting for almost 60% of the total mortality) in the GOA due to the halibut longline fishery. Bycatch rates for the halibut longline fishery were estimated based on the non-halibut species caught during halibut longline surveys. It was necessary to reduce the estimate of sleeper shark bycatch from that observed on the halibut longline survey to balance sleeper sharks in the GOA model. While biomass estimates from trawl surveys are uncertain for sleeper sharks, the high mortality estimated even after reducing mortality from the halibut fishery indicates that further investigation may be necessary to determine whether there is a cause for concern. A majority of sleeper shark mortality is also caused by longline fishery bycatch in the AI, from the turbot and sablefish longline fisheries; however, the AI sleeper shark biomass estimated by surveys may be an underestimate, therefore the bycatch mortality may be an overestimate. In the EBS, sleeper shark bycatch mortality appears low; the inclusion of a slope survey biomass estimate here which was not available in the AI may account for this difference. The EBS sleeper shark diet is adapted from the western Bering Sea, and is more diverse than in other regions.

Salmon sharks (*Lamna ditropis*) range in the north Pacific from Japan through the Bering Sea and Gulf of Alaska to southern California and Baja. They are considered common in coastal littoral and epipelagic waters, both inshore and offshore. Like other lamnid sharks, salmon sharks are active and highly mobile, maintaining body temperatures well above ambient water temperatures (Anderson and Goldman 2001). Salmon sharks have been both considered a nuisance for eating salmon and damaging fishing gear (Macy et al. 1978; Compagno 1984) and investigated as potential target species in the Gulf of Alaska (Paust and Smith 1989), although little was known about their life history locally. In the western Pacific, females are estimated mature at 8-10 years and males at 5 years (Tanaka 1980). The reproductive mode for salmon sharks is ovoviviparous and with uterine cannibalism (Gilmore 1993), and litter size in the western North Pacific is up to 5 pups, with a ratio of male to female of 2.2 (Tanaka 1980). Maximum size has been reported at 3.0 m, but average size range seems to be between 2.0 and 2.5 m. This species lives at least 25 years in the western North Pacific (Tanaka 1980). Salmon sharks have different population dynamics in the eastern North Pacific, with maximum ages of 20 years (females) and 17 years (males), and maturing at 6 to 9 years (females) and 3 to 5 years (males) (Goldman and Musick 2006).

EBS salmon shark biomass was considered to be 0 (trace, not modeled). GOA biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. Given that bottom trawl surveys are not efficient at catching large pelagic predators, the biomass may be underestimated. AI biomass was estimated by assuming a density of 0.003725 t/km^2 applied to shallow subareas only. Note this is not the density calculated by Ecopath as this last one calculates density based on the entire area, which includes the middle and deep strata where they are not really distributed. The calculation was as follows: The average minimum stock size of salmon sharks in the North Pacific (NP) during 1989 was estimated to be 1.92 million individuals (Nagasawa 1998). The mean body weight considered was 103 kg; the area of the NP was 26, 542,000 Km^2. Thus, ((1.92*10^6)*0.103)/ 26,542,000 = 0.007451 t/km^2. To account for migration, density was divided by 2, resulting in 0.003725 t/km^2. Because salmon sharks are found mainly in shallow waters, mostly 0-100 m (Nagasawa 1998), it was assumed the density would only be applicable to shallow strata (but note Campagno 1984 mentions depth range may go down to 150 m). Only two salmon sharks have been reported in the AI bottom trawl surveys between 1980 and 2002, probably due to the survey's poor performance for sampling large pelagic predators.

It seems likely that salmon sharks have a slow growth and relatively low natural mortality rates, so we assumed that P/B was 0.1 for this group, and for all other sharks, until better information is available. Likewise, consumption rates are unknown, so a Q/B of 6.0 was adapted from a model of an adjacent area, Prince William Sound (Hulbert 1999).

Salmon shark diet composition was estimated from 11 animals collected in Prince William Sound during 1998 (K. Goldman, ADF&G, pers. comm. 2003). The percentage of spiny dogfish in salmon shark diet was lowered from 7% to 1% in order to balance spiny dogfish; the percentage of squid in salmon shark diet was increased to 7% to compensate; the rationale being that spiny dogfish may be more common prey for salmon sharks in Prince William Sound relative to the continental shelf of the Gulf of Alaska and Aleutian Islands, where they are likely to encounter more squids.

The data pedigree was for biomass was considered 5 for both GOA and AI, due to limited catchability in surveys. PB, QB, and diet data were all from general studies only and were all graded 7.

Salmon sharks are present only in the AI and GOA models. In the GOA, there appear to be no significant sources of mortality for salmon sharks, as there are no natural predators and bycatch appears very low. In the AI, mortality caused by the pollock fishery appears quite high, although this may reflect an inadequate biomass estimate as much as high bycatch. Salmon sharks eat primarily salmon, sablefish, halibut and squid in the GOA; while identical diet data from Prince William Sound (GOA) was used in the AI, actual diets there require further study.

Spiny dogfish (*Squalus acanthius*) are small demersal sharks, occupying shelf and upper slope waters from the Bering Sea to the Baja Peninsula in the north Pacific, and worldwide in non-tropical waters. They are considered more common off the U.S. West Coast and British Columbia than in Alaska (Hart 1980). This species is commercially fished worldwide, and may be the most abundant living shark. Complex population structure characterizes spiny dogfish stocks in other areas; tagging shows separate migratory stocks that mix seasonally on feeding grounds in the UK, and separate stocks in BC and Washington state, both local and migratory, that don't mix (Compagno, 1984). Dogfish form large feeding aggregations, with schools often segregated by size, sex, and maturity stage. Male dogfish are generally found in shallower water than females, except for pregnant females which enter shallow bays to pup. This species is ovoviviparous with small litters of 1-20, and gestation periods of 18-24 months. While all parameters may vary by population, British Columbia female spiny dogfish are reported to mature at 23 years, and males at 14. Maximum age estimates range from 25-30 up to 100 years. Eastern north Pacific spiny dogfish stocks grow to a relatively large maximum size of 1.6 m (Compagno, 1984). Directed fisheries for spiny dogfish are often selective on larger individuals (mature females), resulting in significant impacts on recruitment (Hart 1980; Sosebee 1998).

Eastern Bering Sea biomass was considered to be 0 (trace, not modeled). Gulf of Alaska biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. The AI original biomass estimate was 3.5% of the average "shark" survey biomass for years 1991 and 1994. However this estimate was insufficient to satisfy predation by salmon sharks and incidental mortality in fisheries, hence the biomass was doubled. The total biomass for "sleeper sharks" (750 t) was split between dogfish and sleeper sharks based on the cumulative biomass percentage of each species from 1980-2002 trawl surveys (with 1986 excluded due to unusually high numbers of sleeper sharks).

The total number of sharks reported in the trawl surveys is 22 and 33 for dogfish and sleeper sharks respectively with cumulative biomasses of 56.92 kg and 1,420.29 kg, respectively.

Stock assessments of Atlantic spiny dogfish use a natural mortality rate of 0.09 (Sosebee 1998), so we assumed that P/B was 0.1 for this group, and for all other sharks, until better information is available. Likewise, consumption rates are unknown, so a Q/B of 3.0 was adapted from a model of an adjacent area, Prince William Sound (Hulbert 1999). Spiny dogfish diet compositions are not well studied in the GOA, so diet preference was based on information from British Columbia collected in the 1970s (Jones and Geen 1977).

The data pedigree was for biomass was considered 6 for both GOA and AI, due to extremely limited catchability in surveys. PB, QB, and diet data were all from general studies only and were all graded 7.

Spiny dogfish are present only in the AI and GOA models. The only significant sources of mortality for dogfish are salmon sharks, the halibut fishery, and dogfish themselves in the GOA, and salmon sharks, the cod longline fishery, and sea lions in the AI, where halibut fishery bycatch is unknown. Still, predation and bycatch mortality account for 80% or more of total mortality. The percentage of dogfish in both salmon shark diets and halibut fishery bycatch had to be reduced in the GOA for balance. Diet compositions used for dogfish are identical between the GOA and AI, and was adapted from a 1970's sampling off the coast of British Columbia.

Walleye pollock (*Theragra chalcogramma*) are medium-sized schooling groundfish in the family Gadidae (cod family). Pollock range throughout the north Pacific from Japan through the Bering Sea and down the U.S. West Coast as far south as California, but their center of abundance is in the Bering Sea (Ianelli et al. 2005). Pollock form massive schools over relatively shallow continental shelf habitats throughout their range (Browning 1980). They migrate annually between spawning and feeding grounds, with migrations driven by a combination of temperature, prey availability, currents, and day length (Kotwicki et al. 2005). Pollock display the relatively high fecundity and rapid growth associated with all members of this family of groundfish. Pollock may reach maximum lengths of up to 1m and ages of 17 years, with fish maturing between 3-6 years and at 40+ cm (Dorn et al. 2003). Though historically viewed as an undesirable species for its "soft" flesh quality (Eschmeyer et al. 1983), the development of at-sea processing capability eventually made pollock fishing more desirable. Alaskan pollock produced the highest single species landings in the United States in 2003 at 35% of total U.S. landings. The Alaskan pollock fishery comprised more than two thirds of the tonnage and half the value of the combined Alaskan groundfish fishery valued at over $590 million in 2004 (National Marine Fisheries Service, Fisheries Statistics Division, Silver Spring, MD; Hiatt 2005). Due to its importance as a forage fish as well as a commercial species, pollock was modeled as two functional groups (juveniles and adults) in all three models. The split between juveniles and adults was taken to be age 2, which was assumed to correspond to 20 cm for calculating diets. We describe the model parameters for each age group separately below.

Adult pollock

EBS adult pollock biomass is the 1991 stock assessment estimated biomass for ages 2 through 10+ (Ianelli et al. 2003). This estimate is approximately equivalent to summing the primary survey biomass estimates for pollock from the bottom trawl survey and hydroacoustic survey conducted in the EBS, so was considered to be a better estimate than either raw survey alone. GOA adult biomass is the average of 1990-1993 stock assessment estimated biomass for age 2 through 10+ (Dorn et al. 2003). Bottom trawl survey estimates of adult Pollock biomass are approximately half of those estimated by the stock assessment, which incorporates information from three surveys in addition to the bottom trawl survey. Because pollock are a schooling species distributed throughout the water column, bottom trawl surveys might underestimate biomass. Because of the apparent high demand on adult pollock in the GOA during the early 1990s, a biomass accumulation (BA) term of -1.35 t/km^2 was used to balance the model. This BA is within the range of estimated annual declines from the pollock stock assessment (Dorn et al. 2003), although it is greater than the maximum annual decline during the 1990s. AI adult biomass is the average of 1991 to 1994 AI stock assessment biomass estimates for Age 3+ (Barbeaux et al. 2003). AI Biomass was proportioned according to the percent in trawl survey biomass for each subarea. The biomass estimated from the trawl survey was not only about one third that of the stock assessment, it also has an opposite trend. So while the AI stock assessment estimates an increase in biomass between 1991 and 1994, the AI survey estimates show a decline of about 40% between 1991 and 1994. AI Trawl surveys are limited to within the 500 m isobath, thus they exclude midwater pollock and pollock located offshore from the 500 m isobath. This renders the estimates as an unknown proportion of the total biomass subject to annual variability in depth distribution, age composition, and other factors.

The EBS P/B ratio of 0.67 for adults is derived from the age structure estimated for 1991 in the stock assessment (Ianelli et al. 2003), where production equals growth in size plus recruitment for a given year (see Appendix B for methods). The GOA P/B ratio of 0.41 for adults is derived from the age structure estimated for 1990-1993 in the stock assessment (Dorn et al. 2003), with the additional assumption that the mortality rate for age 2 fish is 0.8 instead of 0.3, the assumption for all other age classes in the assessment. This adjustment is supported by previous multispecies modeling efforts specific to GOA pollock (Hollowed et al. 2000b). The AI adult P/B ratio of 0.37 was derived from the estimated age structure for 1991 in the AI stock assessment (Barbeaux et al. 2003). In the EBS, the Q/B of 3.17 was estimated using weight at age data fit to a generalized von Bertalanffy growth function (Essington et al. 2001) and scaled to the 1991age structure from the stock assessment (Ianelli et al. 2003). In the GOA, the Q/B of 3.78 was estimated using the same methods but scaled for the 1990-1993 age structure from the stock assessment (Dorn et al. 2003). The AI Q/B of 4.4 was estimated using the same method and scaled to the 1991 age structure from the stock assessment (Barbeaux et al. 2003).

Diet composition for adult pollock was estimated from food habits collections made during the 1991 bottom trawl survey of the EBS shelf, from 1990 and 1993 bottom trawl surveys of the GOA, and from 1991 and 1994 bottom trawl surveys for the AI.

The adult pollock biomass data pedigree was 1 for the EBS and GOA models (data established and substantial, including more than one independent method). This rating was downgraded to 3 for the AI model (proxy with known and consistent bias) because the AI stock assessment area and the trawl survey area did not fully overlap. P/B and Q/B parameters were rated differently by system: 3 in the EBS model (proxy with known and consistent bias), 4 in the GOA model (proxy with high variation), and 5 in the AI model (general model specific to area). Diet composition data rated 1 in all systems (data established and substantial, with resolution on multiple spatial scales).

Adult pollock is the only group in all three systems where the survey biomass estimate was not enough to satisfy the consumptive demand within the ecosystem, hence assessment biomass estimates were used. The EE in the EBS and GOA indicates that adult pollock are fully to over-utilized when predation is also considered, while in the AI almost 20% of the biomass is "unused" in the system. In the GOA, adult pollock remains out of balance even when using the biomass estimates from the stock assessment. A negative biomass accumulation term representing a population decline is necessary to balance the model. We found widely different sources of mortality between the systems: the fishery dominates in the AI (though pollock still appear "underutilized" there), while fishery mortality is lower than cannibalism and cod predation in the EBS but still an important factor, and by contrast fishing mortality is a minor source of pollock mortality compared to groundfish predation in the GOA. Specifically, in the AI, the fishery (48%) and predation by Pacific cod (13%) account for half of pollock total mortality. In the EBS, it is cannibalism (40%), followed by the fishery (13%) and Pacific cod (5%), while in the GOA predators account for 70% of the total mortality, arrowtooth flounder (33%), halibut (23%), and cod (16%);the fishery itself is only responsible for 7% of the total mortality.

Juvenile pollock

In all three models, juvenile pollock were defined as fish less than 20 cm in length, which roughly corresponds to 0 and 1 year old fish. There is no survey information available to estimate biomass for this age group of pollock in any of the systems. In the EBS, and AI, juvenile pollock biomass was estimated assuming an EE of 0.8. This was also initially assumed in the GOA, but to make the juvenile pollock biomass estimate more consistent with the stock assessment information used for adults, juvenile mortality rates were estimated that resulted in enough production to meet system predation demands (based on the initial P/B and top down biomass estimate achieved by assuming EE = 0.8, and the resulting biomass was estimated as production / P/B = biomass.

In the EBS and AI, P/B for juvenile pollock was estimated using the same method described above to estimate adult P/B. This resulted in and EBS juvenile pollock P/B of 2.35 and AI juvenile pollock P/B of 1.97. In the GOA an initial P/B estimate derived from the age structured stock assessment method described above for adults was used first, then modified according based on a top down balance. This estimated juvenile mortality rate was used to adjust the P/B ratio to 2.67 for 1990-1993 based on stock assessment age structure and to estimate a juvenile biomass given the production demand. (Later adjustments to the model made juvenile EE vary slightly from the 0.8 it is designed to be, because juvenile P/B and biomass were not re-adjusted In all three models, we used the same Q/B estimation methodology as described above for adults. The resulting EBS juvenile pollock Q/B was 5.51, the AI Q/B was 6.96, and the GOA Q/B was 6.83.

Juvenile pollock diet composition was estimated from food habits collections made during the bottom trawl surveys in each ecosystem. The EBS used the 1991 shelf survey data, the GOA used the 1990 and 1993 bottom trawl surveys, and the AI used the 1991 and 1994 bottom trawl surveys.

The juvenile pollock biomass data pedigree was 8 for all three models (no estimate available, top down balance). P/B and Q/B parameters were rated differently by system: 4 in the EBS and GOA models (proxy with high variation), and 6 in the AI model (general life history proxy). Diet composition data rated 1 in all systems (data established and substantial, with resolution on multiple spatial scales).

Juvenile pollock mortality sources differ greatly between systems, with 71% from Atka mackerel in the AI, 40% from adult pollock in the EBS, and 47% from arrowtooth flounder in the GOA. In the AI, adult pollock cause less than 1% of mortality on juvenile pollock, while adult pollock are second to arrowtooth in the GOA, accounting for 11% of juvenile pollock mortality.

Pacific cod (*Gadus macrocephalus*) is a large predatory groundfish in the family Gadidae which is common in the Aleutian Islands, Bering Sea, and Gulf of Alaska, and ranges from the Yellow Sea in China to Santa Monica, CA on the U.S. West Coast. Cod are found in both benthic and pelagic habitats from surface waters to depths of 875 m (Love et al. 2005). Pacific cod commonly reach lengths over 1 m and live up to 18 years, with females maturing between ages 5-7 and about 60-70 cm (Thompson et al. 2003). This one species is responsible for most of the diversity of species codes required in the NMFS food habits database, including such delectables as scorpions, wood, and cow parts (Bovidae). The first commercial fishery recorded in the American territory of Alaska took place in the Shumagin Islands in the Gulf of Alaska, and the target species was Pacific cod. According to the first census of American Alaska in 1880, the cod fishery started by 1865, a shore station was established in 1876 at Popof Island, and an average of 10 boats per year fished cod in the Gulf of Alaska and Bering Sea between 1865 and 1892 (Mohr 1979). This fishery changed little in character throughout its 85 year duration, remaining on a relatively small scale in terms of vessel numbers. However, the fishery shifted over time from its early center the Gulf of Alaska to be conducted almost entirely in the Bering Sea after 1915, where the highest landings were taken (Shields 2001). Overall the landings from the Gulf of Alaska are estimated to have ranged from 1,000 to 3,000 t annually between 1865 and 1900, increasing to a maximum of 6,800 t in 1906 and remaining in the range of 2,000 to 4,000 t annually until the fishery shifted to the Bering Sea (where annual catches ranged from 10,000 to 20,000 t at the height of the fishery from 1915-1935; Shields 2001, Paulson, WDF&G, pers. comm., 2006). At present, cod support substantial and diverse commercial fisheries in Alaska, where they are fished with trawls, longlines, jigs and pot gear. Catch of Pacific cod accounted for about 12% of all groundfish catch in Alaska in 2005 (second to pollock at 78% of groundfish catch, AFSC website http://www.afsc.noaa.gov/species/catch_value.htm).

Adult Pacific cod

In the EBS model, adult cod biomass is the stock assessment estimated biomass of fish over 20 cm in length from 1991 (Thompson and Dorn 2005). GOA biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. In the AI adult biomass is the average of 1991 and 1994 estimates from the AI bottom trawl survey. The biomass was proportioned across the model subareas according to survey estimates in each one.

In the EBS, the P/B ratio of 0.41 was estimated from the 1991 age structure in the EBS cod stock assessment (Thompson and Dorn 2005),and weight at age data collected on NMFS bottom trawl surveys for the EBS (see Appendix B for methods). The GOA P/B ratio of 0.42 was estimated using the same methods with the 1990-1993 age structure in the GOA cod stock assessment (Thompson et al. 2003) and weight at age data collected on NMFS bottom trawl surveys. The EBS Q/B ratio of 2.28 and GOA Q/B ratio of 2.19 were estimated using weight at age data fit a generalized von Bertalanffy growth function (Essington et al. 2001) and scaled to the 1991 age structure from EBS the stock assessment and the 1990-1993 age structure from the GOA stock assessment, respectively. The AI model used the P/B ad Q/B ratios estimated for the EBS model.

Adult cod diet composition was estimated from food habits collections made during bottom trawl surveys in each ecosystem. The EBS diet was derived from 1991 collections, the GOA diet was derived from the 1990 and 1993 bottom trawl surveys of the GOA, and in the AI it comes from stomachs collected in 1991 and 1994 as part of the bottom trawl surveys.

The adult cod biomass data pedigree was 2 for all three models (data is a direct estimate from surveys in AI and GOA or assessments in EBS but the two sources disagree in these areas). P/B and Q/B parameters were rated differently by system: 3 in the EBS and GOA models (proxy with known and consistent bias), and 5 in the AI model (general model specific to area). Diet composition data rated 1 in all systems (data established and substantial, with resolution on multiple spatial scales).

Pacific cod adult mortality is dominated by fishing in all systems. In the EBS total cod directed fishing represents about 35% of the total mortality, in the AI about 33%, and in the GOA, 38%. In contrast, there is no sole predator that has even half the same impact on total mortality. In the EBS the most important predator is adult pollock which causes 4% of total mortality; Steller sea lions (adult and juvenile jointly) in the AI account for 7% and halibut in the GOA, contributes 4%. Cod diets are diverse in all systems, with between 15 and 30% of them comprised by the dominant fish in each system (pollock in the EBS and GOA, Atka mackerel in the AI), 10-20% by shrimp, and then various benthic groups.

Juvenile Pacific cod

In all three models, juvenile cod were defined as fish less than 20 cm in length, which roughly corresponds to 0 and 1 year old fish. In the EBS and AI models, biomass of juvenile cod was estimated by assuming an EE of 0.80 for the group. Biomass in the GOA was first estimated using an EE of 0.8, but then juvenile mortality rates were estimated that resulted in enough production to meet system predation demands (based on the initial P/B and top down biomass estimate). The juvenile mortality was used to adjust the PB and estimate the biomass given the production demand.

The EBS P/B ratio of 1.08 for juvenile cod was estimated by the same method described above for adult cod. In the GOA, the estimated juvenile mortality rate described above was used to estimate a P/B ratio of 2.02 for 1990-1993 based on stock assessment age structure. In the EBS and GOA, juvenile cod Q/B was estimated using the same method as described above for adults, resulting in estimates of 5.58 and 4.59, respectively. The AI model used the same P/B and Q/B estimates derived for EBS juvenile cod.

Diet composition was estimated from food habits collections made during NMFS bottom trawl surveys in all ecosystems. In the EBS, 1991 data was used, in the GOA, the 1990 and 1993 bottom trawl surveys were used, and in the AI, 1991 and 1994 surveys were used.

The juvenile cod biomass data pedigree was 8 for all three models (no estimate available, top down balance). P/B and Q/B parameters were rated differently by system: 4 in the EBS and GOA models (proxy with high variation), and 6 in the AI model (general life history proxy). Diet composition data rated 1 in all systems (data established and substantial, with resolution on multiple spatial scales).

Pacific cod juveniles have diverse sources of mortality between systems, most notably cannibalism by adult cod in the AI, which accounts for 48% of the total mortality followed by resident seals (16%) and arrowtooth flounder (12%). In the GOA and EBS, cannibalism is not nearly as relevant, as it only contributes 3% to the total mortality in the EBS and less than 1% in the GOA. In contrast, in these last two systems, murres contribute the most (~30%) to juvenile cod total mortality, followed by the group other sculpins (25%); arrowtooth flounder (19%) are also important predators in the GOA. Juvenile cod diets are diverse in all systems, consisting primarily of benthic invertebrate groups with some zooplankton. Diets are dominated by benthic amphipods and mysids which comprise 60-70% of it in the EBS and GOA; but in the AI non-pandalid shrimps are the most common prey, making up 33% of the diet as opposed to 17% in the EBS and GOA. Benthic amphipods are consumed in the similar amounts as in the EBS and GOA (19%), but mysids are almost absent (<1%); instead polychaetes are about 18% of the diet in the AI, a prey item that contributes little in the other two systems (0.5-4%).

Pacific herring (*Clupea pallasi*) are small, relatively short-lived fish in the family Clupeidae that range from Japan to Baja California in Mexico and north through the Arctic Ocean in Canada. They are pelagic, occupying surface waters shallower than 250 m (Love et al. 2005). Herring grow to sizes of 30-40 cm and live up to 8 years, reaching maturity at 3-4 years (Hart 1980). They are known for their large spring spawning aggregations in nearshore coastal waters, where eggs are laid on submerged aquatic vegetation and milt turns nearby waters white. Spawning occurs earlier in the southern portions of the range and as late as July in the EBS. EBS herring are generally larger, longer lived, and migrate more extensively than GOA herring, which are genetically distinct stocks (Woodby et al. 2005). There is a long history of fishing for herring in Alaska. The first commercial herring venture in Alaska produced oil and fertilizer from the fish in 1882 at Killisnoo in Southeast Alaska (Macy et al. 1978). By 1906, herring fisheries were established in the western Gulf of Alaska at Chignik and the Shumagin Islands, in Prince William Sound by 1913, in Cook Inlet by 1914, and off Kodiak by 1916. These fisheries produced a variety of products between 1912 and 1922, but salted herring quickly became a dominant product alongside canned herring after large salteries were established in Prince William Sound in 1918 (Macy et al. 1978). During World War I, Alaskan herring was able to compete as a food fish, but after war's end the superior European Atlantic herring products again dominated the food market (Browning 1980). After World War I, the Alaskan herring fishery returned to its roots and began producing oil, fish meal, and fertilizer from herring. This "reduction" fishery peaked in 1937 with over 100,000 t processed by 17 plants, and it accounted for over 90% of all Alaskan herring catch between 1929 and 1966 (Macy et al. 1978). Bering sea herring stocks were heavily exploited by Japan and the Soviet Union in the early 1960's with over 200,000 t removed at the fishery peak in 1964 (Murai et al. 1981, Fredin 1985). Herring catches from the Alaska peninsula, Kodiak, and Prince William Sound were nonexistent in the early 1960s, and the end of the reduction fishery in Southeast Alaska saw declines from over 35,000 t in 1960 to under 2000 t in 1968 (Macy et al. 1978). However, the fishery was revitalized with a new product for a Japanese market: herring sac-roe and eggs on kelp fisheries developed in the late 1960s and 1970s and remain the current major products of the Alaskan herring fishery (Macy et al. 1978, OCSEAP 1986, Rigby et al. 1995). Sac-roe fisheries catch herring just prior to spawning, while eggs on kelp fisheries harvest spawned eggs sticking to kelp. In some fisheries, herring are captured and put in "pounds" or enclosures to spawn within the enclosed area for later harvest of the eggs (Rigby et al. 1995). Gulf of Alaska sac-roe herring fishery catch increased from about 300 t in 1969 to nearly 10,000 t by 1975, and to an initial peak of nearly 25,000 t in 1981 (Woodby et al. 2005).

Adult Pacific herring

In the EBS model, adult herring biomass is the stock assessment estimated biomass of fish over 20 cm in length from 1991 (Fred West, ADF&G, pers. comm., 2002). The biomass was proportioned across the model subareas according to survey estimates in each one. GOA adult biomass is the average of 1990 through 1993 ADF&G stock assessment biomass estimates for Kamishak Bay (Ted Otis ADF&G, 2004 personal communication) and Prince William Sound (Steve Moffitt and Rick Merizon ADF&G, 2004 personal communication), proportioned to have equal density in all model areas. This assumption of equal density in the GOA was intended to represent the dispersal of spawning herring throughout the model area in non-spawning seasons; in addition, there is no better information on herring distribution in the GOA. Because of the apparent high demand on GOA Pacific herring in the early 1990's, a biomass accumulation (BA) term of -0.11 t/km^2 was used to balance the model. This rate of decline is within the range of herring stock declines estimated for this period from the two GOA Pacific herring stock assessments. In the AI model, adult herring biomass was estimated assuming an EE of 0.8 in all model strata.

In the EBS, the P/B ratio of 0.32 was estimated from the 1991 age structure in the EBS herring stock assessment and weight at age data collected by ADF&G (Fred West, ADF&G, pers. comm., 2002) (see Appendix B for methods). The EBS Q/B ratio of 3.52 was estimated using weight at age data fit a generalized von Bertalanffy growth function (Essington et al. 2001) and scaled to the 1991 age structure from the EBS stock assessment. No age structure information was available from GOA stock assessments aside from annual recruitment estimates (Williams and Quinn 2000), so the P/B ratio and Q/B ratio were adapted from those estimated using the Pacific herring assessment for the Eastern Bering Sea (Fred West, ADF&G, pers. comm., 2002). The GOA herring P/B of 0.4 was adjusted upward from the value of 0.32 calculated from the Bering Sea herring stock assessment to account for a large 1988 year class recruiting in the GOA during the 1990-1993 model period. The Q/B ratio of 3.52 was estimated from the 1990-1993 age structure in the Bering Sea herring stock assessment. EBS production and consumption parameters were used for AI adult herring because there is no data on herring for the AI that allows any improvements on these estimates.

Herring diet composition in the EBS was estimated from food habits collections made during the 1991 EBS bottom trawl survey. Diet composition information was unavailable for GOA and AI Pacific herring, so diet composition was estimated from food habits collections made during the 1990-1993 EBS bottom trawl surveys.

The adult herring biomass data pedigree was 3 for the EBS and GOA models (proxy data from assessed stocks applied to entire area which includes unassessed stocks), and 8 for the AI model (top down balance). P/B and Q/B parameters were rated differently by system: 3 in the EBS model (proxy with known and consistent bias), and 6 in the GOA model (general life history proxy based on information within the region), and 7 in the AI model (general and outside the region). Diet composition data rated 4 in the EBS (direct estimate from trawl surveys but with high variability due to poor selectivity of herring), and 5 in the GOA and AI models (same species, same time period, different area).

Pacific herring adult mortality is dominated by groundfish predation in all systems, despite directed fishing for herring in the EBS and GOA. The most important source of mortality is predation by arrowtooth flounder (30% of total mortality) in the GOA, followed by the herring fleet (24%). In the EBS pollock cause the most herring mortality (27%), followed the fishery (11%). Herring are estimated to be "underutilized" in the EBS, with a high flow to detritus, especially in comparison to the GOA where it was necessary to add a negative biomass accumulation, representing a declining population, to balance the model. There is no herring fishery in the AI, where arrowtooth flounder and eelpouts are the dominant sources of mortality, contributing 46% and 20%, respectively.

Juvenile Pacific herring

In all three models, juveniles were defined as fish less than 20 cm in length, which roughly corresponds to 0 through 3 year old herring. In the EBS and AI models, biomass of juvenile herring was estimated by assuming an EE of 0.80 for the group. In the GOA, the biomass was estimated by assuming that EE was 0.8 for the group, with an initial estimate of juvenile P/B. To make this estimate more consistent with the estimated recruitments and adult biomass from GOA stock assessments, juvenile mortality rates were estimated that resulted in enough production to meet system predation demands (based on the initial P/B and top down biomass estimate). The juvenile mortality was used to adjust the PB and estimate the biomass given the production demand.

The EBS juvenile herring P/B ratio of 2.37 was estimated by the same method described above for adult herring; this parameter was also used in the AI model. In the GOA, the juvenile mortality rate estimated by the method described above was used to adjust the P/B ratio to 1.42 for 1990-1993 based on stock assessment biomass and recruitment. The EBS Q/B ratio of 7.24 for juvenile herring was estimated by the same method described above for adult herring; this parameter was also used in the AI model. The GOA juvenile herring Q/B of 4.33 was estimated assuming that GOA juvenile herring have the same growth efficiency as EBS juvenile herring (0.327), where age structured stock assessment information was sufficient to estimate this parameter.

Diet composition information for EBS juvenile herring was estimated from food habits collections made during early 1990s EBS bottom trawl surveys; however, juvenile herring were collected only in a single trawl survey stratum (middle NW). Diet data were unavailable for GOA and AI juvenile Pacific herring, so the EBS diet composition was substituted.

The juvenile herring biomass data pedigree was 8 for all three models (top down balance). P/B and Q/B parameters were rated differently by system: 4 in the EBS and GOA models (proxy with high variation and incomplete coverage), and 6 in the AI model (general life history proxy). Diet composition data rated 5 in the EBS (direct estimate from trawl surveys but with incomplete coverage, downgraded for small sample size), and 6 in the GOA and AI models (same species, neighboring region).

Pacific herring juvenile mortality comes from different predators in each system. In the EBS, pinnipeds are responsible for most juvenile herring total mortality (68%), while in the GOA arrowtooth flounder cause more mortality than any other source (65%). In the AI, pollock followed by resident seals are responsible for most juvenile herring mortality (60% jointly).

Arrowtooth flounder (*Atheresthes stomias*) are relatively large, piscivorous flatfish in the family Pleuronectidae (right-eyed flounders) which range from Kamchatka, Russia in the Bering Sea through the Gulf of Alaska to Santa Barbara, CA on the U.S. West Coast. It is found in benthic habitats from less than 10m to over 1000 m depth (Love et al. 2005). Arrowtooth flounder are currently the most abundant groundfish in the GOA (Turnock et al. 2003a). They exhibit differential growth by sex, with females reaching a maximum size of 1 m and age of 23, and males growing to 54 cm and 20 years. Females reach 50% maturity at 47 cm in the GOA, and display exponentially increasing fecundity with length, with large females producing over 2 million eggs annually (Zimmerman 1997). Until recently, arrowtooth flounder were not a desirable commercial species because their flesh quality was considered poor; however recently developed processing techniques have allowed a moderate commercial fishery to develop around Kodiak Island (AFSC website http://www.afsc.noaa.gov/species/Arrowtooth_flounder.php).

Adult arrowtooth flounder

In the EBS model, adult arrowtooth biomass is the NMFS bottom trawl survey estimate from 1991. GOA adult biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. In the AI biomass is the average of 1991 and 1994 estimates from the AI bottom trawl survey. The biomass was proportioned across the subareas according to survey estimates in each one.

In the EBS, the P/B ratio of 0.18 was estimated from the 1991 age structure in the EBS arrowtooth/Kamchatka flounder stock assessment (Wilderbuer and Sample 2003), and weight at age data collected on NMFS bottom trawl surveys for the EBS (see Appendix B for methods). The EBS Q/B ratio of 1.16 was estimated using weight at age data fit a generalized von Bertalanffy growth function (Essington et al. 2001) and scaled to the 1991 age structure from the EBS stock assessment. The GOA P/B ratio of 0.26 and Q/B ratio of 1.44 were estimated using the same methods as in the EBS from the 1990-1993 age structure in the GOA arrowtooth flounder stock assessment (Turnock et al. 2003a) and weight at age data collected on NMFS bottom trawl surveys. Values for the AI P/B and Q/B ratios of 0.297 and 2.61 were estimated using the age structure for 1991 in the BSAI stock assessment for arrowtooth/ Kamchatka flounder (Wilderbuer and Sample 2003), and weight at age data collected on NMFS bottom trawl surveys for the Gulf of Alaska.

Adult arrowtooth diet composition was estimated from food habits collections made during bottom trawl surveys in each ecosystem. The EBS diet was derived from 1991 collections, the GOA diet was derived from the 1990 and 1993 bottom trawl surveys of the GOA, and in the AI it comes from stomachs collected in 1991 and 1994 as part of the bottom trawl surveys.

The adult arrowtooth biomass data pedigree was 2 for the EBS and AI models (data is a direct estimate from surveys in AI and EBS but the assessment is conducted for the combined area), and 1 for the GOA model (direct estimate from surveys which agrees with the GOA assessment). P/B and Q/B parameters were rated differently by system: 3 in the GOA model (proxy with known and consistent bias), 4 in the EBS model (proxy for combined BSAI with some species mixing), and 5 in the AI model (proxy for combined BSAI with some species mixing plus weight at age from adjacent area). Diet composition data rated 1 in all systems (data established and substantial, with resolution on multiple spatial scales).

Arrowtooth flounder adults have a significantly higher density in the GOA (5.7 t/km^2) than in either the EBS or AI (<1 t/km^2). They are preyed upon by pollock, Alaska skates and sleeper sharks which jointly account for 60% of the total mortality in the EBS, but have relatively few predators in the AI; sleeper sharks are the only significant ones (16% of total mortality). In the GOA, there are no major predators on arrowtooth, as sleeper sharks, cod, pollock and cannibalism barely account for 11% of the total mortality. The fisheries in aggregate cause 15%-17% of the mortality in the EBS and AI respectively, while only 4% in the GOA. In all three systems adult arrowtooth flounder eat primarily pelagic prey. In the GOA they eat mostly capelin (22% of diet) and euphausiids (17%), followed by adult pollock (14%), and juvenile pollock (10%). In the EBS, arrowtooth flounder eat primarily juvenile pollock (47% of diet), followed by adult pollock (20%) and euphausiids (10%). In the AI, arrowtooth mostly prey on myctophids (27%), juvenile Atka mackerel (16%), and pandalid shrimp (16%).

Juvenile arrowtooth flounder

In all three models, juveniles were defined as fish less than 20 cm in length, which roughly corresponds to 0 through 1 year old arrowtooth. In the AI, juvenile arrowtooth biomass is based on an EE of 0.8. In the EBS and GOA models, initial attempts at estimating juvenile biomass using top-down methods were not successful because there are apparently few predators of juvenile arrowtooth flounder in either ecosystem. Therefore, in the EBS juvenile arrowtooth flounder biomass in each model stratum was assumed to be 10% of adult arrowtooth biomass in that stratum. In the GOA, we estimated juvenile arrowtooth mortality to be 0.5, a rate comparable to those estimated by MSVPA model runs in the EBS (Jurado-Molina 2001). This mortality rate was used to estimate juvenile biomass given the numbers and weight at age estimated for those years.

In the EBS, the P/B ratio of 1.58 was estimated by the same methods as described above for adults. In the GOA, the estimated juvenile mortality rate of 0.5 was used to estimate the P/B ratio to 0.90 for 1990-1993 based on stock assessment age structure. The juvenile arrowtooth P/B in the AI was estimated using the same method as that described above for adults, resulting in a value of 1.01. In all three ecosystems, Q/B ratios were estimated by the same method and using the same information as for adults. The EBS juvenile arrowtooth Q/B was therefore 3.31, the GOA juvenile arrowtooth Q/B was 2.45, and the AI Q/B ratio was 3.77.

Juvenile arrowtooth flounder diet composition was estimated from food habits collections made during bottom trawl surveys in each ecosystem. The EBS diet was derived from 1991 collections, the GOA diet was derived from the 1990 and 1993 bottom trawl surveys of the GOA, and in the AI it comes from stomachs collected in 1991 and 1994 as part of the bottom trawl surveys.

The juvenile arrowtooth biomass data pedigree was 8 for the EBS and AI models (no estimate available, top down balance), and 4 for the GOA (proxy with limited confidence). P/B and Q/B parameters were rated differently by system: 4 in the GOA model (proxy with limited confidence), 5 in the EBS model (downgraded from adult rating of 4), and 6 in the AI model (downgraded from adult rating of 5). Diet composition data rated 1 in all systems (data established and substantial, with resolution on multiple spatial scales).

Arrowtooth flounder juveniles have a low fraction of total mortality due to predation in the EBS and GOA, so the assumption of an EE=0.8 in the AI model to top down balance this group might be re-examined in revisions to that model. The major source of mortality in the EBS and GOA are adult arrowtooth (3-5%, respectively), but they are preyed upon mostly by Pacific cod (20%) in the AI. Juvenile arrowtooth flounder appear to eat from different sections of the food web in each system. They eat primarily benthic invertebrates (pandalids and benthic amphipods) in the AI, show approximately equal feeding from benthic and pelagic groups (non pandalids and juvenile pollock) in the EBS, but feed predominantly on pelagic euphausiids and capelin in the GOA.

Kamchatka flounder (*Atheresthes evermanni*) are relatively large, piscivorous flatfish in the family Pleuronectidae (right-eyed flounders) which range from the northern Japan Sea through the western Bering Sea and Aleutian Islands into the far western Gulf of Alaska. They are found in benthic habitats from 25 m to 1,200 m depth (Love et al. 2005). Because it is extremely rare in the Gulf of Alaska, the Kamchatka flounder is not modeled there and is only included in the EBS and AI models. The Kamchatka flounder bears a strong resemblance to the arrowtooth flounder, but is less well studied in Alaskan waters. The stock assessment for arrowtooth flounder also includes Kamchatka flounder due to its spatial coverage and the inability to separate catch histories for these species historically (Wilderbuer and Sample 2003). Therefore, there is unavoidably considerable parameter overlap between these two species in the EBS and AI ecosystem models.

Adult Kamchatka flounder

In the EBS model, adult Kamchatka flounder biomass is based on the 2002 estimate from the NMFS EBS bottom trawl survey to ensure correct identification of this species. In the AI model, adult biomass is the average of 1991 and 1994 estimates from the AI bottom trawl survey. The biomass was proportioned across the subareas according to survey estimates in each one.

The P/B and Q/B ratios for EBS and AI Kamchatka flounder are identical to those calculated for arrowtooth flounder in each area because the stock assessment makes no distinction between the species. Therefore, the EBS P/B ratio of 0.18 was estimated from the 1991 age structure in the EBS arrowtooth/Kamchatka flounder stock assessment (Wilderbuer and Sample 2003), and weight at age data collected on NMFS bottom trawl surveys for the EBS (see Appendix B for methods). The EBS Q/B ratio of 1.16 was estimated using weight at age data fit a generalized von Bertalanffy growth function (Essington et al. 2001) and scaled to the 1991 age structure from the EBS stock assessment. The AI P/B and Q/B of 0.297 and 2.61 were estimated using the age structure for 1991 in the BSAI stock assessment for arrowtooth/ Kamchatka flounder (Wilderbuer and Sample 2003), and weight at age data collected on NMFS bottom trawl surveys for the Gulf of Alaska.

Adult Kamchatka flounder diet composition was estimated from food habits collections made during bottom trawl surveys in each ecosystem. The EBS diet was derived from 1991 collections, the AI diet was based on stomachs collects in the AI during 1991 and 1994 as part of NMFS bottom trawl surveys.

The adult Kamchatka flounder biomass data pedigree was 3 for the EBS and AI models (proxy with a known bias due to species identification problems). P/B and Q/B parameters were rated 5 in the both models (proxy for combined BSAI with some species mixing plus weight at age from adjacent area). Diet composition data rated 2 in both systems (direct estimate with poor subregional resolution).

Adult Kamchatka flounder goes “unutilized” within both systems as the model explains less than 1% of the total mortality in either of them. In the EBS, adult Kamchatka flounder rely on pollock as prey, as 80% of their diet is a mix of adult and juvenile pollock while in the AI there seems to be a switch to myctophids which make up over 90% of their diet.

Juvenile Kamchatka flounder

In both the EBS and AI models, juvenile Kamchatka flounder are defined as fish no longer than 20 cm which corresponds approximately to ages 0 and 1. In the EBS, the biomass was assumed to be 10% of adult Kamchatka flounder biomass in each survey stratum. In the AI, the estimated juvenile biomass is based on top down balance with an EE 0f 0.8.

In the EBS and AI, the juvenile Kamchatka P/B ratios of were estimated by the same methods as described above for adults, resulting in values of 1.58 and 1.01, respectively. In both ecosystems, Q/B ratios were estimated by the same method and using the same information as for adults. The EBS juvenile Kamchatka flounder Q/B was therefore 3.31, and the AI Q/B ratio was 3.77.

The EBS juvenile Kamchatka flounder diet was estimated from food habits sampling conducted aboard NMFS trawl surveys in the EBS. In the AI, no Kamchatka flounder juveniles were sampled for stomach contents; the diet composition was assumed to be the same as that of arrowtooth flounder juveniles sampled in the AI during 1991 and 1994 as part of NMFS bottom trawl surveys.

The juvenile Kamchatka flounder biomass data pedigree was 8 for the EBS and AI models (no estimate available, top down balance). P/B and Q/B parameters were rated 6 in the both models (downgraded from adult rating of 5). Diet composition data rated 2 in the EBS (direct estimate with poor subregional resolution), and 6 in the AI (similar species in same region).

Juvenile Kamchatka flounder have no significant sources of mortality in the EBS, sleeper sharks being their main predator causing 11% of the total mortality. The juveniles are however preyed upon heavily by adult halibut (46% of total mortality) and Atka mackerel (32%) in the AI (but are top down balanced with an EE=0.80, so the same caveat applies here as that described above for juvenile arrowtooth flounder). Juveniles prey mostly on pollock and non-pandalid shrimp (both make up 80% of diet) in the EBS.

Greenland turbot (*Reinhardtius hippoglossoides*; also called Greenland halibut) are large predatory flatfish in the family Pleuronectidae which range from the North Atlantic through the Arctic Ocean to the North Pacific. Within the North Pacific, they are found from the Sea of Japan to northern Baja California in Mexico, but they are most common in the Bering Sea and Aleutian Islands. Because it is extremely rare in the Gulf of Alaska, the Greenland turbot is not modeled there and is only included in the EBS and AI models. Greenland turbot are benthic fish found in depths ranging from 14 m to 2,000 m (Love et al. 2005). Adults inhabit deeper continental slope waters, while juveniles up to ages 3 or 4 years are found in shallower continental shelf waters; all turbot move to shallower parts of their habitat in spring and summer and return to deeper portions of their habitat during fall and winter (Love 1996, Ianelli et al. 2006). Greenland turbot reach a maximum size of 1.3 m and a maximum age of over 30 years (Love et al. 2005, Gregg et al. 2006). Greenland turbot are a valuable commercial species in the EBS; peak catches between 1972 and 1976 ranged from 63,000 t to 78,000 t, but declined throughout the 1980s to less than 10,000 t annually in the 1990s, and less than 5,000 t since 2004 (Ianelli et al. 2006).

Adult Greenland turbot

Adult Greenland turbot biomass in the EBS model is age 1+ biomass for 1991 as estimated in the stock assessment (Ianelli et al. 2002). Adult biomass in the AI is the average of 1991 and 1994 AI biomass estimates from the AI bottom trawl survey. The biomass was proportioned across the subareas according to survey estimates in each one.

In both the EBS and AI, the P/B and Q/B ratios of 0.18 and 1.16, respectively, were assumed to be the same as those estimated for arrowtooth flounder in the BSAI region. These values were chosen to maintain consistency among the ecosystem models for the Alaska regions in data-poor situations. Alternatively, one could use the values estimated for the arrowtooth flounder in the AI. The values for the AI arrowtooth flounder are higher, and we chose to assume the Greenland turbot had lower production and consumption values than the arrowtooth flounder given its lower abundance in the AI.

The diet composition was based on stomachs collected in the EBS during the 1991 survey and in the AI during 1991 and 1994 as part of the bottom trawl surveys.

The adult Greenland turbot biomass data pedigree was 2 for the EBS and AI models (direct regional estimate with poor subregional resolution). P/B and Q/B parameters were rated 5 in the both models (proxy for combined BSAI with some species mixing plus weight at age from adjacent area). Diet composition data rated 1 in both systems (data established and substantial, with resolution on multiple spatial scales).

Adult Greenland turbot total mortality is almost exclusively accounted for (97%) by the fisheries in the AI, whereas in the EBS adult mortality is caused by pollock (30%), then sleeper sharks (11%), then fisheries (turbot trawl, flatfish trawl, turbot hook and line) which jointly account for 12% of the mortality (in descending order). Adult Greenland turbot eat primarily squids (30%) and pollock (adult and juvenile, 30% of diet) in the EBS and myctophids (50%) and squid (30%) in the AI.

Juvenile Greenland turbot

Juvenile Greenland turbot are defined as fish no longer than 20 cm which corresponds approximately to ages 0 and 1. In the EBS, the juvenile biomass was assumed to be 10% of adult Greenland turbot biomass in each survey stratum. Juvenile Greenland turbot have not been found during trawl surveys of the AI. Rather than estimating biomass assuming an EE of 0.8 in the AI, a biomass of 1 ton was assumed in each area, giving a total biomass of 9 t. Assuming a value of 0.8 for the EE gives a biomass estimate of less than 0.3 t.

In the EBS and AI models, the juvenile P/B and Q/B ratios were estimated using the data and methods described above, the values were 1.58 and 3.31 respectively.

The juvenile turbot diet composition was based on stomachs collected in the EBS during the 1991 survey. No Greenland turbot juveniles were sampled in the AI for stomach contents; the diet composition was assumed to be the same as that of arrowtooth flounder juveniles sampled in the AI during 1991 and 1994 as part of NMFS bottom trawl surveys.

The juvenile Greenland turbot biomass data pedigree was 8 for the EBS and AI models (no estimate available, top down balance). P/B and Q/B parameters were rated 6 in the both models (downgraded from adult rating of 5). Diet composition data rated 2 in the EBS (direct estimate with poor subregional resolution), and 6 in the AI (similar species in same region).

There are few significant sources of mortality for juvenile turbot in either model, except for adult pollock in the EBS which account for 15% of the total mortality. Juveniles eat almost exclusively euphausiids (>95% of diet) in the EBS while a more diverse diet of myctophids, Atka mackerel and pandalid shrimp was assumed for the trace juvenile group in the AI.

Pacific halibut (*Hippoglossus stenolepis*) are very large predatory flatfish in the family Pleuronectidae which range from Japan to Baja California in benthic North Pacific habitats from 6 to 1,100 m deep (Love et al. 2005). Halibut are one of the largest teleost fishes, growing to 2.7 m and ages of 42 and 55 years for females and males, respectively, and maturing at a size of 90 cm – 1 m, or 8 years for males and 12 years for females. During spring and summer, adult halibut feed in continental shelf waters less than 200 m depth; they migrate during winter to deeper (300 m) spawning grounds, where they release pelagic eggs. Eggs hatch and larvae develop over 6 months until the eye migrates over the head and juvenile halibut settle to a benthic life in shallow habitats (IPHC 1998). Pacific halibut were first commercially fished in 1888 off British Columbia by a sailing vessel from Maine, the *Oscar and Hattie*, that had made the long trip to the Pacific to participate in the pelagic seal fishery, but arrived too late for the fur seal migration. Fishing continued off Washington and British Columbia until populations there were depleted. After 1913, the majority of halibut catch was taken in Alaskan waters (Bell 1981). The fishery developed rapidly, with coastwide catch declining throughout the 1920s from a peak in 1915. Pacific halibut were first managed by the IPHC starting in the 1920s and displayed stock recovery after regulations were applied in the 1930s. Landings had reached new heights of 20,000 t annually in the Gulf of Alaska from the 1940s through the 1960s, and reached a coastwide peak of 31,752 t in 1962 (IPHC 1998). Catches dropped again during the 1970s, but have since been maintained at over 20,000 t in the Gulf of Alaska (the most productive area) throughout much of the 1980s, 1990s, and since 2000 (IPHC website http://www.iphc.washington.edu/halcom/commerc/catchbyreg.htm).

Adult Pacific halibut

In the EBS model, adult Pacific halibut biomass is the 1991 NMFS bottom trawl survey estimate for the EBS shelf. GOA adult biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. In the AI adult biomass is the average of 1991 and 1994 biomass estimates from the AI bottom trawl survey. The biomass was proportioned across the subareas according to survey estimates in each one.

Pacific halibut are not formally assessed by the IPHC in the EBS or AI areas, but are assessed in the GOA (IPHC Areas 3A and 3B). For all three models, the P/B ratio of 0.19 and Q/B ratio of 1.1 were estimated from the 1990-

1993 age structure in the halibut stock assessment for Area 3A (Clark and Hare 2003) and weight at age data collected on IPHC longline surveys (and summarized on the IPHC website, http://www.iphc.washington.edu/halcom/research/sa/sa.html). Because Pacific halibut weight at age has varied significantly over time (Clark et al. 1999), we used weight at age relationships from the early 1990s surveys only to estimate parameters for this model.

Adult Pacific halibut diet composition was estimated from food habits collections made during bottom trawl surveys in each ecosystem. The EBS diet was derived from 1991 collections, the GOA diet was derived from the 1990 and 1993 bottom trawl surveys of the GOA, and in the AI it comes from stomachs collected in 1991 and 1994 as part of the bottom trawl surveys.

The adult Pacific halibut biomass data pedigree was 2 for all three models (direct regional estimate with poor subregional resolution). P/B and Q/B parameters were rated 3 in the GOA (proxy with known but consistent bias) and 5 in the EBS and AI models (general model specific to area). Diet composition data rated 1 in all three systems (data established and substantial, with resolution on multiple spatial scales).

Halibut adults are true top predators in each system, in that only the fisheries “consume” them. The fisheries account for 34% of the total mortality in the GOA, with 29% explained by the halibut fishery alone. In the AI fisheries jointly cause 41% of the total mortality; 35% is from the halibut fishery. The EBS bycatch is more of an issue; total fisheries mortality is 46% however the halibut fishery accounts only for 20%. The trawl fisheries, primarily that for cod and pollock (9% and 6% of total mortality, respectively) account for the rest. In the GOA and EBS, half of the halibut diet is adult pollock, in the GOA this is complemented by hermit crabs and miscellaneous crustaceans (20% of diet jointly), whereas in the EBS it highly diverse with no other preferred prey. In the AI the diet is comprised by squids (22%) and Atka mackerel (15%), followed by octopi and miscellaneous crabs (10% each). While all crabs jointly account for 20 and 25%of the diets in the AI and in the GOA respectively, in the EBS they are less than 10% of the diet; rather, mixed flat and forage fish contribute small percentages each to their diet.

Juvenile Pacific halibut

In all three models, juveniles were defined as fish less than 20 cm in length, which roughly corresponds to 0 through 1 year old halibut. In the AI, juvenile halibut biomass is based on an EE 0f 0.8. In the EBS and GOA models, initial attempts at estimating juvenile biomass using top-down methods were not successful because there are apparently few predators of juvenile halibut in either ecosystem. Therefore, in the EBS juvenile halibut biomass in each model stratum was assumed to be 10% of adult halibut biomass in that stratum. In the GOA, we estimated juvenile mortality to be 0.5, a rate comparable to those estimated by MSVPA model runs in the EBS (Jurado-Molina 2001). This estimated juvenile mortality rate was used to estimate juvenile biomass given the numbers and weight at age estimated for those years. For comparison with the EBS, the method applied in the GOA resulted in an estimated juvenile halibut biomass which was 12% of adult halibut biomass.

In the GOA, the estimated juvenile mortality rate of 0.5 was used to estimate the P/B ratio to 0.38 for 1990-1993 based on stock assessment age structure. No data was available for the EBS or the AI, hence the values PB values estimated for the GOA were assumed in both models. The GOA juvenile halibut Q/B of 1.42 was estimated by the same method and using the same information as for adults and was assumed to be the same for the EBS and the AI models.

Juvenile Pacific halibut diet composition was estimated from food habits collections made during the 1991 bottom trawl survey of the EBS and the 1990 and 1993 bottom trawl surveys of the GOA. No stomach samples were available from the AI, so the juvenile Pacific halibut diet composition was assumed to be the same as for the GOA.

The juvenile Pacific halibut biomass data pedigree was 4 in the GOA (proxy with limited confidence) and 8 in the EBS and AI (no estimate available, top down estimate). P/B and Q/B parameters were rated 4 in the GOA (proxy with known limited confidence) and 6 in the EBS and AI models (same species in neighboring area). Diet composition data rated 1 in the EBS and GOA (data established and substantial, with resolution on multiple spatial scales), and 6 in the AI (same species in neighboring region).

Halibut juveniles show similar mortality patterns to other flatfish juveniles across systems. Given the low estimated EE for juvenile halibut in the EBS and GOA (0.40), we might in the future assume a value lower than 0.8 to top down balance this group in the AI. Predators in the GOA include salmon sharks (32% of total mortality), and in the EBS skates (20%) and yellowfin sole (8%). In the AI, Atka mackerel account for the most mortality (35% of total mortality), followed by southern rock sole and salmon sharks each of which explain 15% of the total mortality.

Yellowfin sole (*Limanda aspera*) are small flatfish in the family Pleuronectidae which range from the Japan Sea to Barkley Sound in British Columbia in shallow benthic habitats from 2 to 425 m (Love et al. 2005). Yellowfin sole are most common in the EBS in shallow water (<50 m), and they are found only in the Western and Central GOA (Turnock et al. 2003b). They reach a maximum size of about 40 cm in the EBS, maturing at about 11 years and living over 26 years (Wilderbuer and Nichol 2004a). A large commercial fishery targeting yellowfin sole developed in the EBS in 1954, and the stock was rapidly overexploited when Japanese and then Soviet fishing fleets took over 400,000 t annually between 1959 and 1962. Catches declined during the 1960s and 1970s, but increased again during the 1980s, when the fishery transitioned from a foreign fleet to a domestic fleet. Current catches averaged 78,000 t between 1998-2005 (Wilderbuer and Nichol 2006a). The stock is managed as a one joint stock for the BSAI region; yellowfin sole are managed within the shallow water flatfish complex in the GOA.

Adult yellowfin sole

In the EBS model adult yellowfin sole biomass was the 1991 EBS bottom trawl survey estimate. In the AI adult biomass was estimated by assuming an EE of 0.8. Biomass estimates based on the AI bottom trawl surveys are only available for those strata north of Umak and Unalaska (which fall within the EBS model). In the rest of the Aleutians biomass is estimated as “zero”, and considered negligible for stock assessment purposes. However, yellowfin sole is reported in some diets (sharks and marine mammals) and more importantly, as bycatch in several fisheries in the AI; particularly those trawling for “other groundfish”. It was therefore assumed that yellowfin biomass was too low to be sampled adequately by the survey.

This group was not split into adult and juvenile pools in the GOA model due to lack of age structured stock assessment information. GOA Biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates.

The EBS adult yellowfin P/B of 0.174 was estimated from the 1991 age structure in the EBS yellowfin sole stock assessment (Wilderbuer and Nichol 2004a), and weight at age data collected on NMFS bottom trawl surveys for the EBS (see Appendix B for methods). The EBS Q/B ratio of 0.93 was estimated using weight at age data fit a generalized von Bertalanffy growth function (Essington et al. 2001) and scaled to the 1991 age structure from EBS the stock assessment. The AI P/B and Q/B ratios were assumed to be the same as those estimated for the EBS stock. The GOA P/B ratio of 0.2 and Q/B ratio of 2.0 for the entire yellowfin stock (adults and juveniles) were adapted from those estimated for the only small flatfish in the GOA with age structured stock assessment information, the Flathead sole (see below).

Yellowfin sole diet composition was estimated from food habits collections made during the 1991 EBS bottom trawl survey and 1990 and 1993 bottom trawl surveys of the GOA. AI diets were estimated from stomachs collected in the EBS during surveys in 1991.

The adult yellowfin sole biomass data pedigree was 2 for the EBS and GOA models (direct regional estimate with poor subregional resolution), and 8 for the AI model (top down balance). P/B and Q/B parameters were rated 3 in the EBS (proxy with known but consistent bias), 5 in the AI (general model specific to area), and 6 in the GOA (different species, same area). Diet composition data rated 1 in the EBS and GOA (data established and substantial, with resolution on multiple spatial scales), and 6 in the AI (same species in neighboring region).

Mortality sources for adult yellowfin sole are primarily fisheries in the EBS and AI (19% and 79%, respectively, but note yellowfin adults were top down balanced assuming an EE of 0.8), whereas large sculpins (10% of total mortality) and other groundfish explain most of the mortality in the GOA, where yellowfin are not an important commercial species. Yellowfin sole does not appear to be over exploited in the context of the EBS model; despite the fact that the fisheries are the main source of mortality, primarily the trawl fishery for yellowfin and small flatfish which accounts for 16% of the total mortality. Almost two-thirds of the estimated production is not accounted for within the system. Yellowfin sole adult diets from the EBS were used for the AI as well, and these were made up predominantly by polychaetes, miscellaneous worms and clams, whereas in the GOA miscellaneous worms are absent from their diet. This apparent discrepancy may in part be due to smaller sample sizes in the GOA, but this is not certain.

Juvenile yellowfin sole

Juvenile yellowfin sole were defined in the EBS and AI models as fish less than 20 cm in length, corresponding to ages 0 through 5 years. No juvenile group was defined for the GOA model. Juveniles were kept in the AI model (out of sheer stupidity) to maintain the same structure as in the EBS model. Juvenile yellowfin sole biomass was assumed to be 10% of adult yellowfin sole biomass in each survey stratum for the EBS model. In the AI model, a juvenile biomass of 1 ton was assumed in each area, giving a total biomass of 9 t.

In the EBS, the juvenile yellowfin sole P/B and Q/B ratios of were estimated by the same methods as described above for adults, resulting in values of 0.6 and 1.74, respectively. Identical parameters were used in the AI model

Yellowfin sole diet composition was estimated from food habits data collected aboard trawl surveys of the EBS shelf in 1991. Diet composition in the AI was assumed to be the same as in the EBS.

The juvenile yellowfin sole biomass data pedigree was 8 in the EBS and AI (no estimate available, top down estimate). P/B and Q/B parameters were rated 4 in the EBS (proxy with known limited confidence) and 6 in the AI model (same species in neighboring area). Diet composition data rated 1 in the EBS (data established and substantial, with resolution on multiple spatial scales), and 6 in the AI (same species in neighboring region).

Yellowfin sole juveniles have few predators in the AI and EBS. The diet was based on EBS collections where they consume mainly miscellaneous crustaceans, benthic amphipods and polychaetes (80% of diet).

Flathead sole (*Hippoglossoides elassodon*) are relatively small flatfish in the family Pleuronectidae which range from the Okhotsk Sea to Monterey Bay, CA, in shallow benthic habitats from intertidal waters to 1,050 m deep (Love et al. 2005). Flathead sole grow to a size of 45 cm and a maximum age of 25 years, maturing at 27 cm or age 8. Growth in the GOA is somewhat faster than in the EBS (Turnock et al. 2003c). Flathead sole are commercially important in Alaska, with catches in the BSAI ranging from 14,000 to 20,000 t since 1990 (Stockhausen et al. 2006), and GOA catches ranging from 1,000 to 3,000 t (Stockhausen et al. 2005).

Adult flathead sole

In the EBS model, adult flathead sole biomass is the 1991 EBS NMFS bottom trawl survey estimate. GOA adult biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. AI biomass for adults was based on estimates from the AI bottom trawl surveys for 1991 and 1994.

The EBS adult flathead sole P/B of 0.26 was estimated from the 1991 age structure in the EBS yellowfin sole stock assessment (Wilderbuer and Nichol 2004a), and weight at age data collected on NMFS bottom trawl surveys for the EBS (see Appendix B for methods). The EBS Q/B ratio of 1.97 was estimated using weight at age data fit to a generalized von Bertalanffy growth function (Essington et al. 2001) and scaled to the 1991 age structure from EBS the stock assessment. The GOA P/B ratio of 0.18 and Q/B ratio of 1.69 were estimated from the 1990-1993 age structure in the flathead sole stock assessment (Turnock et al. 2003c) and weight at age data collected on NMFS bottom trawl surveys. Flathead sole is managed as one stock for the joint BSAI region so in the AI the Q/B ratio was assumed to be the same as in the EBS, 1.97; the P/B was assumed slightly lower at 0.20, as the biomass is less than 1% of that in the EBS.

EBS adult flathead sole diet composition was estimated from food habits collections made during the 1991 bottom trawl survey of the EBS. GOA diet composition was estimated from food habits collections made during the 1990 and 1993 bottom trawl surveys of the GOA. AI diets were estimated from stomachs collected during AI bottom trawl surveys for 1994 (no data from the 1991 survey were available).

The adult flathead sole biomass data pedigree was 2 for all three models (direct regional estimate with poor subregional resolution). P/B and Q/B parameters were rated 3 in the GOA (proxy with known but consistent bias), 4 in the EBS (proxy with high variation) and 5 in the AI (general model specific to area). Diet composition data was rated 1 in all three models (data established and substantial, with resolution on multiple spatial scales).

Adult flathead sole have relatively low mortality, with flow to detritus dominating total mortality at 60-70% in each system. Major predators include cod, halibut, and the fishery in the GOA and AI which account for 20% and 30% of the total mortality in each system; but the fishery is the leading cause of mortality in the EBS (10%), followed by pollock and cod (7% jointly). In the GOA and EBS juvenile diets seem to switch from being one third euphasiids and mysids to shrimp (primarily pandalids in GOA) and brittle stars, as well as juvenile pollock (this last in the EBS only), jointly making up 60-70% of the diet. In the AI the sample size is small (<15 stomachs), this may in part explain the lack of diversity in this system as non pandalid shrimps (82%) and miscellaneous worms (11%) make up most of the diet.

Juvenile flathead sole

In all three models, juvenile flathead sole were defined as fish less than 20 cm in length, which roughly corresponds to ages 0 through 3 years. In the EBS model, juvenile flathead sole biomass was assumed to be 10% of adult flathead sole biomass in each survey stratum. GOA biomass for this juvenile group was estimated by assuming that EE was 0.8 for the group. In the AI the biomass was estimated assuming all subareas had 1 (one) ton; therefore the total biomass was 9 t.

The EBS juvenile flathead sole P/B of 0.93 and Q/B of 3.13 were estimated by the same method and using the same information as for adults. GOA juvenile flathead sole P/B of 1.10 and Q/B of 3.13 were estimated by the same method and using the same information as for GOA adults. AI P/B and Q/B ratios were assumed to be the same as in the EBS 0.93 and 3.13 respectively.

EBS juvenile flathead sole diet composition was estimated from food habits collections made during the 1991 bottom trawl survey of the EBS. GOA diet composition was estimated from food habits collections made during the 1990 and 1993 bottom trawl surveys of the GOA. AI diets were estimated from stomachs collected during AI bottom trawl surveys for 1994 (no data from the 1991 survey were available).

The juvenile flathead sole biomass data pedigree was 8 in all three models (no estimate available, top down estimate). P/B and Q/B parameters were rated 4 in the GOA (proxy with known limited confidence), 5 in the EBS (general model specific to area), and 6 in the AI model (same species in neighboring area). Diet composition data was rated 1 in all three ecosystems (data established and substantial, with resolution on multiple spatial scales).

Flathead sole juveniles have virtually no known predators in the AI (EE of 0.009 even with only 9 t in the system), and few in the EBS (EE 0.3) such as adult arrowtooth and miscellaneous shallow fish which jointly account for 25% of total mortality, besides some cannibalism (3%). In the GOA, flathead juveniles were top down balanced assuming an EE of 0.8, consequently predators cause a higher portion of total mortality lead by arrowtooth flounder (28%), and followed by other sculpins (24%), adult pollock (13%), and adult cod (11%). As with other flatfish species, the available data from the EBS indicates that the flow to detritus is 50%, so again a value for EE lower than the default 0.8 might be used in future iterations. Predation on juvenile flatfish is an important data gap in these systems right now. Diet differences between systems appear to reflect middle shelf versus inner shelf benthic prey distributions in the EBS.

Northern rock sole (*Lepidopsetta polyxystra*) are small flatfish in the family Pleuronectidae which range from the Japan Sea to Puget Sound, WA in shallow benthic habitats from 3 to 517 m deep (Love et al. 2005). This species was first described as separate from Southern rock sole by AFSC scientists (Orr and Matarese 2000). The ranges of the two species overlap significantly in the Western and Central GOA, but in the EBS nearly all rock soles are northern rock soles. The northern rock sole grows to about 43 cm in the GOA and lives over 20 years, maturing at 33 cm and 7 years of age (Turnock et al. 2003b); a larger maximum size of 69 cm was reported for the EBS (Orr and Matarese 2000). This small flatfish is the target of an economically important fishery in the EBS during its spawning season in the winter; catches have averaged nearly 50,000 t annually from 1989-2005 (Wilderbuer and Nichol 2006b). GOA catches of northern rock sole have ranged from 500 to 3000 t between 2001 and 2005 (Turnock et al. 2005).

In the EBS, northern rock sole were split into adult and juvenile pools. Adult northern rock sole biomass in the EBS is the 1991 NMFS bottom trawl survey biomass estimate for each model stratum. Juveniles were defined as fish less than 20 cm in length, corresponding to 0 through 3 year old fish. Juvenile northern rock sole biomass in the EBS was assumed to be 10% of the adult biomass in each model stratum. In the GOA and AI models, northern rock sole were not split into adult and juvenile pools due to lack of stock assessment information. GOA biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates for general rock sole, proportioned by the ratio of northern rock sole to total rock sole observed in the 1996 GOA trawl survey (the first survey where the species were reliably identified separately). As in the GOA, prior to 1997, northern and southern rock sole AI biomass was estimated as “general rock sole” in the bottom trawl surveys. Starting 1997 onwards, the two species have been addressed separately. The average proportion of northern to southern rock sole in 1997 and 2000 was used to proportion the biomass of 1991 and 1994 of “general rock sole” biomass. According to these data, 99% of the rock sole biomass corresponds to northerns.

The EBS adult northern rock sole P/B of 0.232 was estimated from the 1991 age structure in the EBS northern rock sole stock assessment (Wilderbuer and Nichol 2004b), and weight at age data collected on NMFS bottom trawl surveys for the EBS (see Appendix B for methods). The EBS Q/B ratio of 1.14 was estimated using weight at age data fit a generalized von Bertalanffy growth function (Essington et al. 2001) and scaled to the 1991 age structure from EBS the stock assessment. The EBS juvenile northern rock sole P/B of 0.94 and Q/B of 2.31 were estimated by the same method and using the same information as for adults. In the GOA, the whole northern rock sole population's P/B ratio of 0.2 and Q/B ratio of 2.0 were adapted from those estimated for the only small flatfish in the GOA with age structured stock assessment information, the Flathead sole (see above). AI values for the entire population for the P/B and Q/B ratios were estimated by fitting a von Bertalanffy growth function to data from the 1991 age structure in the BSAI stock assessment, and weight at age data from the AI, giving P/B and Q/B values of 0.25 and 1.70, respectively.

Northern rock sole diet composition was estimated from food habits collections made during the 1991 bottom trawl survey of the EBS, and during the 1996 bottom trawl survey of the GOA (the first year where Northern and Southern rock sole were identified separately).The AI diet composition was an average from GOA subareas west shelf, gully, and slope from the 1996 GOA bottom trawl survey.

The adult northern rock sole biomass data pedigree was 2 for the EBS model (direct regional estimate with poor subregional resolution), while the EBS juvenile rock sole biomass data pedigree was 8 (no estimate available). The northern rock sole biomass pedigree was 3 in both the GOA and AI models (proxy with known but consistent bias). P/B and Q/B parameters were rated 3 for adults (proxy with known but consistent bias) and 4 for juveniles (proxy with high variation) in the EBS, 6 for the whole population in the GOA (similar species in same region), and 5 for the whole population in the AI (general model specific to area). Diet composition data for northern rock sole rated 1 in the EBS and GOA models (data established and substantial, with resolution on multiple spatial scales), and 6 in the AI model (same species in neighboring region).

Northern rock sole show similar patterns across systems to those of yellowfin sole and other flatfish, where the amount of mortality due to predation and fishing is relatively low (<40% for GOA and EBS, <10% in AI) compared to the unexplained mortality (flow to detritus); this applies to both the adult and juvenile groups in the EBS. However it does not mean fisheries have no impact at all, since in the GOA, ~30% of the total mortality is caused by fisheries, primarily the flatfish fisheries with trawls and in the EBS 15% of the total mortality (for adults) comes from predation by Alaska skate. In terms of diet, in the EBS juveniles feed primarily on polychaetes (54%) and benthic amphipods (35%), extending their diet to include sand lance and more miscellaneous worms when they are adults. In contrast in the GOA the primary prey items are polychaetes, urchins (jointly 65%) and a variety of benthic invertebrates; in the AI diets are a subsample of those in the GOA as they were based on the west GOA where the preferred preys are pteropods, snails, and miscellaneous crustaceans (jointly 30%). The diet appears to include fish in a larger proportion as both sand lance and other sculpins comprise 10% of the diet while in the GOA these prey are not even 1% of the diet.

Southern rock sole (*Lepidopsetta bilineata*) are small flatfish in the family Pleuronectidae which range from the Bering Sea to Southern California in shallow benthic habitats from 13 to 339 m deep (Love et al. 2005). This species was first described as separate from northern rock sole by AFSC scientists (Orr and Matarese 2000). The ranges of the two species overlap significantly in the Western and Central GOA, but in the EBS nearly all rock soles are northern rock soles. Therefore, southern rock sole are not modeled in the EBS. In contrast to the northern rock sole (see above), the southern rock sole reaches a larger maximum length of about 52 cm in the GOA (max age was not reported), and matures at 35 cm or 9 years old (Turnock et al. 2003b). GOA catches of southern rock sole have ranged from 1400 to 2400 t between 2001 and 2005 (Turnock et al. 2005).

This group was not split into adult and juvenile pools in any model due to lack of stock assessment information. Biomass for the GOA population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates for general rock sole, proportioned by the ratio of southern rock sole to total rock sole observed in the 1996 GOA trawl survey (the first survey where the species were reliably identified separately). Prior to 1997, northern & southern rock sole AI biomass was estimated as “general rock sole” in the bottom trawl surveys. Starting in 1997, the two species have been addressed separately. The average proportion of northern to southern rock sole in 1997 and 2000 was used to proportion the biomass of 1991 and 1994 of “general rock sole” biomass. The biomass for southern rock sole is much lower, ~ 1% that of northerns.

The P/B ratio of 0.2 and Q/B ratio of 2.0 were adapted from those estimated for the only small flatfish in the GOA with age structured stock assessment information, the Flathead sole (see above). AI values for the P/B and Q/B ratios were estimated by fitting a von Bertalanffy growth function to data from the 1991 age structure in the BSAI stock assessment, and weight at age data from the AI. The P/B and Q/B values are 0.25 and 1.70, respectively.

Southern rock sole diet composition was estimated from food habits collections made during the 1996 bottom trawl survey of the GOA (the first year where Northern and Southern rock sole were identified separately). The AI diet composition was an average from GOA subareas west shelf, gully, and slope from the 1996 GOA bottom trawl survey.

The southern rock sole biomass data pedigree was 3 in both the GOA and AI models (proxy with known but consistent bias). P/B and Q/B parameters were rated 6 for the whole population in the GOA and AI (similar species in same region and same species in different region), Diet composition data for northern rock sole rated 1 in the GOA model (data established and substantial, with resolution on multiple spatial scales), and 6 in the AI model (same species in neighboring region).

Southern rock sole are similar to northern rock sole in the AI and GOA in that predation and fishing explain less than 30% of the total mortality. For this group, fishing explains 17% of the total mortality in the GOA; again the flatfish trawl fishery contributes a major portion of that at 14% of total mortality. Diets also show a similar pattern having the same caveat as northern rock sole: the diets for the AI were based on those from the western GOA. As with northern rock sole, fish comprise a larger portion of the diet including other sculpins, sand lance and managed forage (jointly 14% of diet); benthic invertebrates prevail in the GOA with polychaetes, benthic amphipods, urchins, clams and brittle stars making 70% of the diet versus clams, urchins and benthic amphipods contributing 10% each in the AI.

Alaska plaice (*Pleuronectes quadrituberculatus*) are relatively small flatfish in the family Pleuronectidae which range from the Sea of Japan to southeast Alaska in shallow benthic habitats from 5 m to 1,050 m deep (Love et al. 2005). Alaska plaice are found in the Western and Central GOA, but their center of abundance is in the EBS with only a minor portion in the AI. In the EBS, plaice reach sizes of 46 cm and ages of over 22 years, with maturity estimated to occur at ages 8-9. Annual catches of Alaska plaice have generally ranged from 10,000 to 20,000 t in the EBS since 1990; the highest catch reported for this species was 61,000 t there in 1988 (Spencer et al. 2004). Alaska plaice is reported within the shallow flatfish category in the GOA, where catches have been less than 100 t since 1991 (Turnock et al. 2005).

Alaska plaice were not split into adult and juvenile pools in any model. Biomass for the EBS population is the 1991 NMFS bottom trawl survey estimate. Biomass for the whole GOA population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. The AI value for biomass was estimated assuming an EE 0.8; though no biomass estimate is available Alaska plaice is a prey item in the diets of several marine mammals, and sharks but mostly of adult yellowfin sole

The GOA P/B ratio of 0.2 and Q/B ratio of 2.0 were adapted from those estimated for the only small flatfish in the GOA with age structured stock assessment information, the Flathead sole (see above). Because these values are close to those estimated for small flatfish species with more information in the EBS as well, we made a common assumption across all models for data poor flatfish species in the EBS, GOA, and AI models. .

Alaska plaice diet was estimated from food habits collections aboard NMFS bottom trawl surveys in 1991 in the EBS. Diet composition information was unavailable for GOA and AI Alaska plaice, so diet composition estimated from food habits collections made during the 1990-1993 EBS bottom trawl surveys were substituted.

The Alaska plaice biomass data pedigree was 2 for the EBS and GOA models (direct regional estimate with poor subregional resolution), while the AI biomass data pedigree was 8 (no estimate available, top down balance). P/B and Q/B parameters were rated 6 for all three models (similar species in same region). Diet composition data for northern rock sole rated 1 in the EBS model (data established and substantial, with resolution on multiple spatial scales), and 6 in the GOA and AI model (same species in neighboring region).

Alaska plaice have at least 60% of the total mortality unexplained (flow to detritus) in the GOA and EBS; Alaska plaice was top down balanced in the AI assuming an EE of 0.8. There is some significant mortality from seals in the EBS (35% of total mortality), but only small amounts of groundfish predation apparent in the GOA (7% by large sculpins). In the AI the main predator is yellowfin sole (76% of total mortality) but note its diet comes from the EBS data. Likewise, diet information for the Alaska plaice was only available for the EBS, and thus it was modified for the GOA and AI. Polychaetes, clams and miscellaneous worms are the main components of the diet in the EBS (80% of diet).

Dover sole (*Microstomus pacificus*) are relatively small flatfish in the family Pleuronectidae which range from the western Bering Sea to southern Baja California, Mexico in benthic habitats from 2 to 1,372 m deep (Love et al. 2005). Dover sole grow to over 60 cm and 54 years (Turnock and Amar 2004a), maturing at 44 cm and 12-13 years of age (Abookire and Macewicz 2003). This is an important commercial species in Alaska as well as on the U.S. West Coast. Prior to 2000, Dover sole catches in the GOA ranged from 2,000 to over 9,000 t annually; however recent catches have remained below 1,000 t (Turnock et al. 2005).

Dover sole were not split into adult and juvenile pools in any model. Biomass for the EBS population is the 1991 NMFS bottom trawl survey estimate, as supplemented by the 2002 EBS slope survey for deeper strata. GOA biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. AI biomass is the average of the 1991 and 1994 AI bottom trawl survey estimates.

The P/B ratio of 0.2 and Q/B ratio of 2.0 were adapted from those estimated for the only small flatfish in the GOA with age structured stock assessment information, the Flathead sole (see above). Because these values are close to those estimated for small flatfish species with more information in the EBS as well, we made a common assumption across all models for data poor flatfish species in the EBS, GOA, and AI models. However, a stock assessment is in development for GOA Dover sole which may allow improvements in these parameters for that area.

Dover sole diet composition was estimated from food habits collections made during the 1990 and 1993 bottom trawl surveys of the GOA. Diet composition in the EBS was derived by averaging diet compositions for miscellaneous flatfish and rex sole (which occupy similar areas in the EBS to Dover sole). AI was assumed to be the average stomach content from samples collected in the GOA west shelf, gully, and slope subareas during 1990 and 1993 GOA bottom trawl surveys.

The Dover sole biomass data pedigree was 2 for the EBS and AI models (direct regional estimate with poor subregional resolution), while the GOA biomass data pedigree was 3 (proxy with known but consistent bias). P/B and Q/B parameters were rated 6 for all three models (similar species in same region). Diet composition data for Dover sole rated 2 in the GOA model (direct estimate but limited coverage), and 6 in the EBS and AI model (similar species in same region, and same species in neighboring region).

Dover sole have different mortality sources between ecosystems. In the EBS and AI, they are mostly consumed by fisheries and seals; mortality is estimated to be very low in the AI, with over 90% of the flow to detritus, in the EBS flow to detritus is about 30%. In the GOA, pollock and the fisheries account for 26% of the total mortality each (22% by the flatfish trawl fishery). Diet for the AI comes from the western GOA, and is dominated by benthic amphipods and polychaetes (jointly 80% of diet) whereas in the GOA the diet is more diverse, comprised by brittle stars, polychaetes and miscellaneous worms (jointly 75% of diet). In contrast, the diet for Dover sole in the EBS is based on polychaetes and shrimp (both pandalids and non pandalids) which make up 75% of their diet.

Rex sole (*Glyptocephalus zachirus*) are relatively small flatfish in the family Pleuronectidae which range from the northern Kuril Islands and western Bering Sea to central Baja California, Mexico in benthic habitats from 0 to 1,145 m deep (Love et al. 2005). Rex sole reach sizes exceeding 45 cm and a maximum age of 27 years. Size and age at maturity are still being studied, but may be 35 cm and 5-6 years (Turnock and Amar 2004b). Rex sole are commercially important in Alaska, with catches ranging from 700-2000 t annually in the EBS from 1996 through 2005 (Wilderbuer et al. 2006) and higher annual catches in the GOA from ~1,000 to 5,874 t since 1990 (Turnock and A'mar 2005).

Rex sole were not split into adult and juvenile pools in any model. Biomass for the EBS population is the 1991 NMFS bottom trawl survey estimate, as supplemented by the 2002 EBS slope survey for deeper strata. GOA biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the

1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. AI biomass was estimated assuming an EE of 0.8 for balancing purposes; the average of 1991-1994 biomass estimates from the AI bottom trawl surveys was not enough to satisfy assumed consumption within the ecosystem.

The P/B ratio of 0.2 and Q/B ratio of 2.0 were adapted from those estimated for the only small flatfish in the GOA with age structured stock assessment information, the Flathead sole (see above). Because these values are close to those estimated for small flatfish species with more information in the EBS as well, we made a common assumption across all models for data poor flatfish species in the EBS, GOA, and AI models. However, an age structured stock assessment is in development for GOA rex sole which may allow improvements in these parameters for that area.

GOA Rex sole diet composition was estimated from food habits collections made during the 1991 bottom trawl survey of the EBS and the 1990 and 1993 bottom trawl surveys of the GOA. The AI diet composition was assumed to be the average stomach content from samples collected in the GOA west shelf, gully, and slope subareas during 1990 and 1993 GOA bottom trawl surveys.

The rex sole biomass data pedigree was 2 for the EBS model (direct regional estimate with poor subregional resolution), while the GOA biomass data pedigree was 3 (proxy with known but consistent bias), and the AI biomass data pedigree was 8 (no estimate available, top down balance). P/B and Q/B parameters were rated 6 for all three models (similar species in same region). Diet composition data for rex sole rated 2 in the EBS and GOA models (direct estimate but limited coverage), and 6 in the AI model (similar species in same region, and same species in neighboring region).

Rex sole have different mortality sources between systems, with the longnose skate being the primary predator in the GOA (40% of total mortality), cod in the AI, (75% of total mortality, but note rex sole is top down balanced) and seals (30%) in the EBS. Overall mortality is lower in the EBS with a larger proportion flowing to detritus (44%) than in the GOA (33%). Diet for the AI was based on the western GOA, polychaetes, miscellaneous worms and euphasiids make up 85% of the diet in the both the AI and GOA, albeit in different proportions and in the EBS non pandalid shrimp contribute 50% of the diet with an additional 30% being comprised by polychaetes and benthic amphipods.

Miscellaneous flatfish is a composite group containing all remaining small flatfish species in each model area. In the EBS model, this group primarily includes longhead dab (*Limanda proboscidea*), Sakhalin sole (*Limanda sakhalinensis*), butter sole (*Isopsetta isolepis*), and starry flounder (*Platichthys stellatus*). In the GOA model this group includes butter sole, English sole (*Parophrys vetulus*), sand sole (*Psettichthys melanostictus*), slender sole (*Eopsetta exilis*), and starry flounder. In the AI, it includes butter sole, starry flounder and English sole. Other, more rare flatfish species in Alaska are also included in this group, but have little influence over the composite group characteristics due to low biomass. These species include Arctic flounder (*Pleuronectes glacialis*), Bering flounder (*Hippoglossoides robustus*), curlfin sole (*Pleuronichthys decurrens*), deepsea sole (*Embassichthys bathybius*), Pacific sanddab (*Citharichthys stigmaeus*), petrale sole (*Eopsetta jordani*), and roughscale sole (*Clioderma asperrimum*). All but one of these small flatfish is in the family Pleuronectidae; the exception is the Pacific sanddab which is in the family Paralichthyidae (Love et al. 2005). These species may be retained by commercial fishing operations in Alaska, but generally are not the targets of those operations at present.

This category was not split into adult and juveniles in any model. In the EBS, trawl survey biomass estimates for all flatfish in this category were inadequate to meet consumption needs within the ecosystem (primarily due to Pacific cod predation), Therefore, the category was top-down balanced using an EE of 0.80. Biomass for the whole GOA complex is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. In the AI biomass estimates from the AI bottom trawl surveys were only available for English sole in 1994 (~1.9 t). This biomass was not enough to satisfy the consumption of miscellaneous flatfish within the ecosystem and was therefore an EE of 0.8 was used to estimate the final biomass in the model.

The P/B ratio of 0.2 and Q/B ratio of 2.0 were adapted from those estimated for the only small flatfish in the GOA with age structured stock assessment information, the flathead sole (see above). Because these values are close to those estimated for small flatfish species with more information in the EBS as well, we made a common assumption across all models for data poor flatfish species in the EBS, GOA, and AI models.

Miscellaneous flatfish diet composition was estimated from food habits collections made during the 1991 bottom trawl survey of the EBS and the 1990 and 1993 bottom trawl surveys of the GOA. Diet composition in the AI was assumed to be the same as GOA.

The miscellaneous flatfish biomass data pedigree was 3 for the GOA model (proxy with known but consistent bias), and the EBS and AI biomass data pedigree was 8 (no estimate available, top down balance). P/B and Q/B parameters were rated 6 for all three models (similar species in same region). Diet composition data for miscellaneous flatfish rated 2 in the EBS and GOA models (direct estimate but limited coverage), and 6 in the AI model (similar species in same region, and same species in neighboring region).

Miscellaneous flatfish have a majority of mortality is by the fisheries (75% of total mortality) in the AI model. In the EBS 33% of the total mortality is caused by fisheries, the rest being caused by predation by seals (20%) and halibut (11%). Polychaetes, mysids and non-pandalid shrimp constitute 50% of the diet in the EBS. The diets for the AI were based on those for the western GOA, yet the proportion of the prey items is quite distinct: in the GOA miscellaneous crustaceans comprise 93% of the diet while in the AI miscellaneous crustaceans are only 30% of the diet which is complemented by octopi and brittle stars (23% each).

Alaska skate (*Bathyraja parmifera*) is the most common skate on the EBS shelf (and therefore in Alaska as a whole), but is relatively uncommon in the GOA. In the AI, the skate now identified as *B. parmifera* is likely a separate species (J. Orr, AFSC, pers. comm., 2004). In the GOA, the maximum observed size of the Alaska skate is 135 cm (Gaichas et al. 2003). Using an empirical regression method (Frisk et al. 2001), length at maturity would be about 96 cm based on that maximum size. At present, there is no age and growth information for any skate species in Alaska. Age, growth, and maturity studies of the Alaska skate were initiated in the EBS in 2003, and may provide information helpful to management of GOA species in the future.

EBS biomass is the sum of 1991 shelf survey biomass and 2002 slope survey biomass, as full slope survey data were not available prior to 2002. GOA biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. AI biomass comes from AI bottom trawl survey estimates for 1991 and 1994. The estimates are a combined average of direct biomass estimates and the corresponding proportion of AK skates from the total biomass for “unidentified skates”. Bycatch estimates were cut in half because the biomass of skates has doubled from 1991-94 to 97-00. Thus we considered the bycatch extrapolated from 1997-2000 to be too high. The reduction by half reflects the fact that the biomass of skates was half at the time.

Frisk et al. (2001) estimated that on average, medium sized (100-199 cm) elasmobranchs have a potential rate of population increase around 0.21. We used this as a proxy for Z or P/B = 0.20 for a population at equilibrium, lacking other data. A growth efficiency intermediate between sharks and large teleost predators (arrowtooth and halibut) seemed a reasonable assumption for skates; we assumed a GE of 0.1, which led to a Q/B estimate of 2.0 for all skate species until better information becomes available. These P/B and Q/B values were assumed to be representative across Alaskan ecosystem models (AI, GOA, and EBS).

EBS diets were estimated from the food habits database. Their diet consisted primarily of pollock (40%), secondarily small flatfish and eelpouts (16% combined) with the remainder coming from shrimp, crabs, other crustaceans, and a range of benthic animals. Food habits information specific to GOA and AI is currently lacking. Diet preference for GOA and AI Alaska skates was based on information from the Kuril Islands and Kamchatka collected in the early 1990s (Orlov 1998, Orlov 1999).

Pedigree for biomass in all systems was considered to be 2 (well-sampled by surveys, but downgraded from 1 due to species identification issues). PB and QB were considered 7 (general literature review from range of species). Diet for EBS was considered 1 (direct sampling with reasonable sample size) while GOA and AI diets were considered 6 (measured from same species, but in Russian waters).

Fisheries are the largest source of explained Alaska skate mortality in the EBS and the GOA (15% and 20%, respectively). In all systems unexplained mortality is high, 55% in GOA, 83% in EBS, 92% in the AI. Mortality in this last system is caused by sperm and beaked whale predation as well as fisheries. Diet information was available for the EBS and AI, but in the GOA Russian diet data had to be substituted. Diet diversity appeared lowest in the AI with Atka mackerel as the dominating prey comprising 65% of the diet, followed by pollock. The low diversity might be partly explained by the low sample size, about 45 stomachs. In the EBS, pollock (40%), northern rock sole, and eelpouts (8% each) are the main prey, followed by a variety of other fish and crustaceans. In the GOA, the diet was mostly benthic amphipods and Atka mackerel, as well as cephalopods, which together constitute half the skate's diet.

Bering skate (*Bathyraja interrupta*) is found in all three Alaskan ecosystems, but may represent several species (J. Orr, AFSC, pers. comm., 2004). The Bering skate is the second most common species on the EBS shelf (after Alaska skates), where it is distributed on the outer continental shelf and upper slope.

EBS biomass is the sum of 1991 shelf survey biomass and 2002 slope survey biomass, as full slope survey data were not available prior to 2002. GOA biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. Bering skates are rare in the AI and were assumed to have a biomass of 0 in this model.

Frisk et al. (2001) estimated that on average, medium-sized (100-199 cm) elasmobranchs have a potential rate of population increase around 0.21. Because little is known about *Bathyraja* species anywhere, a precautionary approach was applied in estimating P/B for this species; it is estimated to be the same as for other skates at 0.20 until further information can be collected, although it is possible that these species are slightly more productive than the larger *Bathyraja* and *Raja* species. A growth efficiency intermediate between sharks and large teleost predators (arrowtooth and halibut) seemed a reasonable assumption for skates; we assumed a GE of 0.1, which led to a Q/B estimate of 2.0 for all skate species until better information becomes available.

EBS food habits were estimated from the food habits database, but few fish were collected during the model time period. Food habits information specific to GOA skates is currently lacking. Diet preference for Bering skates was based on information from the Kuril Islands and Kamchatka collected in the early 1990s (Orlov 1998, Orlov 1999).The diet composition was derived from one stomach collected in the Eastern Aleutians during the 1995 bottom trawl survey for AI.

Biomass pedigree for all regions was considered 3: while surveys sampled the species, their deeper distribution had limited coverage by the surveys. PB and QB were considered 7 (general literature review from range of species). Diet for EBS and AI were considered 4 (direct sampling but with low sample size) while GOA diet were considered 6 (measured from same species, but in Russian waters).

Bering skates have higher unexplained mortality than predation or fishing mortality in the EBS and AI (90-70%, respectively); in the EBS, fisheries explain 25% of the total mortality. In the GOA, 60% of the total mortality is caused by the fisheries (37%) and predation by dogfish (10%). The diets are dominated by one main prey item, which might be a function of low sample sizes. Main prey are polychaetes and miscellaneous crustaceans in the AI (70 and 13%, respectively), benthic amphipods in the GOA (80%), and pollock in the EBS (84%). The diet for the GOA was adapted from the Russian diets.

Aleutian skate (*Bathyraja aleutica*) is the most common Bathyraja skate species in the GOA and on the EBS slope, where is dominant in deeper strata. Despite its common name, it is second in abundance in the Aleutian Islands to the whiteblotched skate. In the GOA, the maximum observed size of the Aleutian skate is 150 cm (Gaichas et al. 2003). Using an empirical regression method (Frisk et al. 2001), length at maturity would be about 107 cm based on that maximum size. At present, there is no age and growth information for any skate species in Alaska.

EBS biomass is the sum of 1991 shelf survey biomass and 2002 slope survey biomass, as full slope survey data were not available prior to 2002. GOA biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. AI biomass comes from AI bottom trawl survey estimates for 1991 and 1994. The estimates are a combined average of direct biomass estimates and the corresponding proportion of AK skates from the total biomass for "unidentified skates". Bycatch estimates were cut in half because the biomass of skates has doubled from 1991-94 to 97-00. Thus we considered the bycatch extrapolated from 1997-2000 to be too high. The reduction by half reflects the fact that the biomass of skates was half at the time.

Frisk et al. (2001) estimated that on average, medium sized (100-199 cm) elasmobranchs have a potential rate of population increase around 0.21. We used this as a proxy for Z or P/B = 0.20 for a population at equilibrium, lacking other data. A growth efficiency intermediate between sharks and large teleost predators (arrowtooth and halibut) seemed a reasonable assumption for skates; we assumed a GE of 0.1, which led to a Q/B estimate of 2.0 for all skate species until better information becomes available.

EBS food habits were estimated from the food habits database, but few fish were collected during the model time period. Food habits information specific to GOA skates is currently lacking. Diet preference for Aleutian skates was based on information from the Kuril Islands and Kamchatka collected in the early 1990s (Orlov 1998, Orlov 1999).AI diet composition was estimated from less than 5 stomachs collected in 1994 and 1997during the AI bottom trawl survey.

Biomass pedigree for all regions was considered 3: while surveys sampled the species, their deeper distribution had limited coverage by the surveys. PB and QB were considered 7 (general literature review from range of species). Diet for EBS and AI were considered 4 (direct sampling but with low sample size) while GOA diet were considered 6 (measured from same species, but in Russian waters).

Aleutian skate mortality is estimated to be primarily from the halibut fishery in the GOA, but we lack accurate information on skate species composition in that fishery. In the AI, where we also lack information, halibut fisheries were assumed to have no bycatch, so there appears to be less skate mortality in AI. In the AI, skate diets consist of pandalid shrimp (60%) and pollock (40%) but note this was based on 3 stomach samples. In the EBS, hermit crabs predominate in diets (35%), followed by non-pandalid shrimp (20%) and pollock (16%). In the GOA (Russian data), pandalids, squids, and Tanner crabs comprise 50% of the diet.

Whiteblotched skate (*Bathyraja maculata*) is most common in the Western AI, the center of this species' abundance. It is also found in the western GOA and on the EBS slope. In the GOA, the maximum observed size of the whiteblotched skate is 121 cm (Gaichas et al. 2003). Using an empirical regression method (Frisk et al. 2001), length at maturity would be about 86 cm based on that maximum size.

EBS biomass is the sum of 1991 shelf survey biomass and 2002 slope survey biomass, as full slope survey data were not available prior to 2002. GOA biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. AI biomass comes from bottom trawl survey estimates for 1991 and 1994. The estimates are a combined average of direct biomass estimates and the corresponding proportion of AK skates from the total biomass for "unidentified skates". Bycatch estimates were cut in half because the biomass of skates has doubled from 1991-94 to 97-00. Thus, we considered the bycatch extrapolated from 1997-2000 to be too high. The reduction by half reflects the fact that the biomass of skates was half at the time.

At present, there is no age and growth information for any skate species in Alaska. Frisk et al. (2001) estimated that on average, medium sized (100-199 cm) elasmobranchs have a potential rate of population increase around 0.21. We used this as a proxy for Z or P/B = 0.20 for a population at equilibrium, lacking other data. A growth efficiency intermediate between sharks and large teleost predators (arrowtooth and halibut) seemed a reasonable assumption for skates; we assumed a GE of 0.1, which led to a Q/B estimate of 2.0 for all skate species until better information becomes available.

EBS diets, due to lack of data, were considered to be the same as Aleutian skates sampled in the same region. GOA diet preference for whiteblotched skates was based on information from the Kuril Islands and Kamchatka collected in the early 1990s (Orlov 1998, Orlov 1999). AI diet composition based on 30 stomachs collected during the 1994 and 1997 AI bottom trawl surveys.

Biomass pedigree for all regions was considered 3: while surveys sampled the species, their deeper distribution had limited coverage by the surveys. PB and QB were considered 7 (general literature review from range of species). AI diets were considered 4 (direct sampling with low sample size) while EBS and GOA diets were considered 6 (measured from same species in different areas, or similar species in same area).

Approximately 90 % of whiteblotched skate mortality is unexplained in the EBS model. However, in the AI whiteblotched skates are the second most common skate and thus the low fisheries mortality might be because there was no bycatch incorporated as part of the halibut fishery. Halibut is caught in a much smaller magnitude than in the GOA, but still skate mortality might be significant. In the GOA 60% of the total mortality is explained by fishing and predation, with fishing causing 40% of it. Whiteblotched skates have relatively how abundance in the GOA, however, contributing to the uncertainty in this estimate. The GOA (Russian) diet composition is different from the

AI data, with only ~10% shrimp in the diet but 25% of each squid and benthic amphipods. Based on a sample 32 stomachs, shrimp, Atka mackerel and pollock make 75% of the diet in the AI.

Mud skates (*Bathyraja taranetzi*) are rare in the EBS and the GOA and thus are assumed to have a biomass of 0 in both of these models. In the AI, biomass comes from AI bottom trawl survey estimates for 1991 and 1994. The estimates are a combined average of direct biomass estimates and the corresponding proportion of Alaska skates from the total biomass for "unidentified skates". Bycatch estimates were cut in half because the biomass of skates has doubled from 1991-1994 to 1997-2000. Thus we considered the bycatch extrapolated from 1997-2000 to be too high. The reduction by half reflects the fact that the biomass of skates was half at the time.

At present, there is no age and growth information for any skate species in Alaska. Age, growth, and maturity studies of the Alaska skate were initiated in the EBS in 2003, and may provide information helpful to management of GOA species in the future. Frisk et al. (2001) estimated that on average, medium sized (100-199 cm) elasmobranchs have a potential rate of population increase around 0.21. We used this as a proxy for Z or P/B = 0.20 for a population at equilibrium, lacking other data. A growth efficiency intermediate between sharks and large teleost predators (arrowtooth and halibut) seemed a reasonable assumption for skates; we assumed a GE of 0.1, which led to a Q/B estimate of 2.0 for all skate species until better information becomes available. These P/B and Q/B values were assumed to be representative across Alaskan ecosystem models (AI, GOA, and EBS), of general small flatfish and for lack of better information were extended to skates. Diet composition was estimated from 5 stomachs collected 1994 as part of the AI bottom trawl surveys.

Biomass pedigree for all regions was considered 3: while surveys sampled the species, their deeper distribution had limited coverage by the surveys. PB and QB were considered 7 (general literature review from range of species). AI diets were considered 4 (direct sampling with low sample size).

Mud skates are found in very low numbers in all three systems (<1,000 t). Twenty percent is the most mortality explained in any of the systems; in the EBS it almost all is explained by the fisheries whereas in the GOA most is attributable to dogfish (which have equal diet preference for "skates") and Steller's sea lions. Diets are high in squids in the AI (83%), hermit crabs, non pandalid shrimps and pollock (jointly 65%) and squid, benthic amphipods and pandalids (jointly 70%) are preferred according to the GOA (Russian) data.

Longnose skate (*Raja rhina*) is one of the most abundant skates in the GOA, and second only to big skates (see below) in terms of biomass. Longnose skates were rare in the EBS and AI and thus considered to have a biomass of 0 in both of these models.

GOA biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. In terms of maximum adult size, the *Raja* species are larger than the *Bathyraja* species found in the area. Observed sizes for the longnose skate, *Raja rhina*, are second largest in the GOA at about 165-170 cm (Gaichas et al. 2003). Using an empirical regression method (Frisk et al. 2001), length at maturity would be about 119 cm based on that maximum size. At present, there is no age and growth information for any skate species in Alaska. The longnose skate, *Raja rhina*, achieves a smaller maximum length of about 1.4 m in California, and matures between ages 6 (males) and 9 (females). Maximum age reported for the longnose skate was 13 years, but again the maximum estimated size seemed small at 107 cm for females and 95 cm for males (Zeiner and Wolf, 1993). Information on fecundity in North Pacific skate species is extremely limited. There are one to seven embryos per egg case in locally occurring *Raja* species (Eschmeyer et al., 1983), but little is known about frequency of breeding or egg deposition for any of the local species.

Frisk et al. (2001) estimated that on average, medium-sized (100-199 cm) elasmobranchs have a potential rate of population increase around 0.21. We used this as a proxy for Z or P/B = 0.20 for a population at equilibrium, lacking other data. A growth efficiency intermediate between sharks and large teleost predators (arrowtooth and halibut) seemed a reasonable assumption for skates; we assumed a GE of 0.1, which led to a Q/B estimate of 2.0 for all skate species until better information becomes available.

Food habits information specific to GOA skates is currently lacking. Diet preference for longnose skates was based on information from the U.S. West Coast collected in the early 1980s (Wakefield 1984).

Biomass pedigree for all regions was considered 3: while surveys sampled the species, their deeper distribution had limited coverage by the surveys. PB and QB were considered 7 (general literature review from range of species). GOA diets were considered 6 (sampling of same species in different area).

Longnose skates are found only in the GOA. The explained mortality in the model is 80%. The predominant source of explained mortality for longnose skates are the fisheries (60% of total mortality) to which the halibut longline fishery contribute half the mortality. The bycatch estimate was based on data from the IPHC surveys. Dogfish and Steller sea lions explain most of the predation mortality. At present, there is no direct diet data from the GOA food habits collection, so we used information from the West Coast of the United States (Wakefield 1984) to construct the diets.

Big skate (*Raja binoculata*) is dominant skate in the GOA in terms of biomass. It is a rare visitor to the EBS and AI. The big skate is the largest skate in the Gulf of Alaska, with maximum sizes observed over 200 cm in the directed fishery, and 192 cm on the survey (Gaichas et al. 2003). Using an empirical regression method (Frisk et al. 2001), length at maturity would be about 137 cm based on that maximum size. At present, there is no age and growth information for any skate species in Alaska. However, vertebrae were collected from the Gulf of Alaska in 2003 from commercial fisheries and during ADF&G and NMFS trawl surveys. Until these collections are processed, the only age and growth information available is from a study completed off the U.S. West Coast which was limited to a size range of skates smaller than that observed off British Columbia (King and McFarlane 2002) or in Alaska. According to that study, Californian female big skates mature at 12 years (1.3-1.4 m), and males mature at 7-8 years (1-1.1 m), but the maximum sizes estimated were only 170 cm for females and 140 cm for males (Zeiner and Wolf, 1993). Maximum size from fisheries off California is reported to be 2.4 m, with 1.8 m and 90 kg common (Martin and Zorzi, 1993). Information on fecundity in North Pacific skate species is extremely limited. There are one to seven embryos per egg case in locally occurring *Raja* species (Eschmeyer et al., 1983), but little is known about frequency of breeding or egg deposition for any of the local species.

In the EBS, trawl survey biomass was used for the one year, 1996, in which big skates were identified in this survey. Big skates were considered absent from the AI. In the GOA, biomass for the whole population is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates.

Frisk et al. (2001) estimated that on average, medium sized (100-199 cm) elasmobranchs have a potential rate of population increase around 0.21. We used this as a proxy for Z or P/B = 0.20 for a population at equilibrium, lacking other data. A growth efficiency intermediate between sharks and large teleost predators (arrowtooth and halibut) seemed a reasonable assumption for skates; we assumed a GE of 0.1, which led to a Q/B estimate of 2.0 for all skate species until better information becomes available.

Food habits data from fewer than 3 skates was used to calculate the EBS feeding habits. Food habits information specific to GOA skates is currently lacking. Diet preference for big skates was based on information from the U.S. West Coast collected in the early 1980s (Wakefield 1984), with the modification that Dungeness crab in the West Coast diet was replaced with equal parts sand lance and eelpouts to reflect qualitative personal observations from the 2003 NMFS GOA trawl survey.

Biomass pedigree for all regions was considered 3: while surveys sampled the species, their distribution had limited coverage by the surveys. PB and QB were considered 7 (general literature review from range of species). Diet for EBS and AI were considered 5 (direct sampling but with extremely low sample size) while GOA diet were considered 6 (measured from same species, but in Russian waters).

Big skates are found only in the GOA. The explained mortality in the model is 50%. The predominant source of explained mortality for big skates are the fisheries (30% of total mortality) to which the halibut longline fishery contribute half the mortality. The bycatch estimate was based on data from the IPHC surveys. Dogfish and Steller sea lions explain most of the predation mortality. At present, there is no direct diet data from the GOA food habits collection, so we used information from the U.S. West Coast to construct the diets.

Black Skates were included for comparison purposes to the NCC model, but they are not really found in Alaskan waters. This group will probably be omitted in future model updates.

Sablefish (*Anoplopoma fimbria*), also known as black cod, range in the north Pacific from central Japan to central Baja California, Mexico. Adult sablefish inhabit near-bottom waters deeper than 200 m to depths of 2,740 m, (Love et al. 2005, Hanselman et al. 2006). Juveniles (<20 cm) are pelagic offshore, and arrive at inshore continental shelf habitats during the late summer of their first year, where they grow to ~40 cm in another year. They move offshore as they grow, arriving at adult continental slope habitat by 4-5 years of age (Hanselman et al. 2006). Sablefish grow to a maximum size of over a meter and a maximum age of 94 years, maturing at 57-65 cm or age 5-7 (Love et al. 2005, Sigler et al. 2004). Sablefish are an extremely valuable commercial species with a long history of exploitation in Alaska. Longline halibut fishing in the early 1900s led to incidental and then targeted fishing for sablefish throughout the coast by Americans and Canadians. The sablefish fishery remained small, removing an annual average of less than 5,000 t from the entire Northeast Pacific between 1915 and Alaskan statehood in 1959 (Low et al. 1976). Foreign fleets exploited many fish during the 1960s and 1970s in both the Bering Sea and Gulf of Alaska, including sablefish (Gusey 1978). Bering Sea sablefish were exploited by the Japanese starting in 1958, and Gulf of Alaska sablefish in 1963 (Low et al. 1976, Gusey 1978). Prior to the Japanese fishery, U.S. landings of sablefish in Alaska had peaked at 4,090 t during wartime in 1944, but had generally been 1,000 to 2,000 t annually. The Japanese fishery took similar tonnages until 1968 when landings increased to 17,000 t, and increased further to a peak for the North Pacific 38,713 in 1972; the majority of this catch was taken by hook and line, although 5,000-9,000 t were taken annually by trawl (Low et al. 1976). Catches declined fro 1972 to 1985, then increased to another peak in 1988 of 38,000 t. Since the mid-1990's, catches have stabilized in the range of 14,000 to 18,000 t annually throughout Alaska; most catch is taken in the Gulf of Alaska region (Hanselman et al. 2006).

Adult sablefish

Biomass for adult sablefish in the EBS is the 1991 NMFS bottom trawl survey estimate, as supplemented by the 2002 EBS slope survey for deeper strata. GOA adult biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. In the AI, biomass was originally the average of that estimated directly from the AI bottom trawl surveys (~6000 t). This abundance was not enough to satisfy consumption within the ecosystem and so it was corrected using catch data. Survey estimates were only available for the deep strata going from 200 to 500 m depth. However catches come both from deeper areas and shallower areas. The biomass for the deep strata was thus increased to account for catches deeper than 500 m and then shallow and middle biomass estimates were added to reflect the proportion of catches occurring between depths 0-100 and 100-200 m respectively. This was still not enough, but rather than increasing the abundance further, it was assumed that this imbalance was a reflection of the reduction in abundance seen in the stock during that period. To balance the model a negative biomass accumulation of 0.0329 was added; this rate was based on a linear regression of the biomass estimates of age 4+ between 1990 and 1996.

Sablefish are considered a single stock across all regions of Alaska (Sigler et al. 2004). The P/B ratio of 0.19 and Q/B ratio of 1.03 were estimated from the 1990-1993 age structure in the sablefish stock assessment, which applies to the EBS, AI, and GOA (Sigler et al. 2004) and weight at age data from all regions collected on NMFS bottom trawl surveys.

Diet composition was based on food habits collections made during the 1991 bottom trawl survey of the EBS, and the 1990 and 1993 bottom trawl surveys of the GOA. The following adjustments were made to ameliorate potentially inadequate sampling in several deeper strata: the percent of pollock and fishery offal in the diet were adjusted down and the percentages of squid, jellyfish, and pelagic gelatinous filter feeders in the diet were adjusted upward in compensation, because they are the components of sablefish diet in deeper areas where we have limited sampling, especially during the early 1990s surveys which did not cover strata deeper than 500 m. The assumption that adult sablefish in deeper offshore areas feed primarily on squid and gelatinous prey was verified during the 2003 GOA survey by personal observations. AI diet composition was based on stomachs from both the AI and the west GOA collected during 1990-1994.

The adult sablefish biomass data pedigree was 2 for the EBS model (direct regional estimate with poor subregional resolution), while the GOA and AI biomass data pedigree was 3 (proxy with known but consistent bias). P/B and Q/B parameters were rated 5 for all three models (general model specific to area). Diet composition data for adult sablefish rated 1 in the EBS model (data established and substantial, with resolution on multiple spatial scales), and 4 in the GOA and AI models (direct estimate with limited coverage).

Sablefish adults have substantially different mortality between systems. In the AI, predation and fishing mortality overall are very high (94% of total mortality); and there is a negative biomass accumulation of ~0.03,. The sablefish fishery accounts for the highest proportion of total mortality (33%, but all fisheries explain 44%), followed by arrowtooth and halibut predation (47% jointly). Survey biomass was corrected (scaled up) in the AI to account for deeper waters that were not surveyed, especially because a portion of the fishery catch comes from deeper waters (>500 m). In the GOA the sablefish fishery accounts for only 19% of the total mortality (all fisheries explain 25%), with salmon sharks as the highest single predator at 32%, and flow to detritus at 24%. In the EBS 70% of sablefish mortality is unexplained, with the highest explained mortality coming from the "turbot trawl" fishery (6% of total mortality) which during the early 1990s was allowed to retain sablefish; the fisheries jointly account for 24% of the total mortality. Sablefish diets are calculated from stomach samples in the EBS and GOA, and for the AI we used West GOA data. In the GOA and AI the diets had to be modified to reduce jellyfish and increase pelagic gelatinous filter feeders. In addition, for balance in the GOA the amount of pollock and fishery offal had to be reduced and the squids were increased to compensate. This was based on observations from the GOA survey in 2003 where larger offshore sablefish were not collected for food habits (this has happened on past surveys as well). Sablefish are important predators of rockfish (Other Sebastes) and jellyfish in the GOA, so it should be a high priority to improve the spatial coverage of the sampling in order to get a more comprehensive diet composition. At present, it is only clear that pollock dominates EBS sablefish diets , followed by other managed forage fish species (together 75% of diet), and that a variety of pelagic prey are taken in the AI and GOA. These are primarily pteropods, pelagic gelatinous filter feeders and euphasiids in the AI (80% of diet), and euphasiids, tunicates and copepods (75% of diet).

Juvenile sablefish

In all three models, juveniles were defined as fish less than 20 cm in length, which roughly corresponds to 0 through 1 year old sablefish which occupy pelagic habitats over the continental shelf. In the EBS, a biomass of 3300 t was assumed for the entire area based on an initial top-down balance using an EE of 0.80. The juvenile sablefish EE subsequently changed in the EBS due to other data updates, but since there was no new information on biomass this initial value was unchanged. In the GOA and AI, biomass for this juvenile group was estimated by assuming that EE was 0.8 for the group.

The juvenile sablefish P/B of 1.65 and Q/B of 3.32 were estimated by the same method and using the same information as for adults, and were applied across all three ecosystems.

Juvenile sablefish diet composition was estimated from food habits collections made during the 1990 and 1993 bottom trawl surveys of the GOA. Because no juvenile sablefish had been collected during EBS bottom trawl surveys, EBS diet compositions were based on this same data and rounded to exclude items estimated to be less than 1% of GOA diets. AI diet composition was based on stomachs from both the AI and the west GOA.

The juvenile sablefish biomass data pedigree was 8 for all three models (no estimate available, top down balance). P/B and Q/B parameters were rated 6 for all three models (general model specific to area with higher uncertainty due to low sample size of juveniles). Diet composition data for juvenile sablefish rated 6 in the EBS model (same species in neighboring region), 4 in the GOA model (direct estimate with limited coverage), and 6 in the AI model (limited coverage of correct area with some information from neighboring region).

Sablefish juveniles have 60%of their total mortality in the EBS explained by predation. Pacific cod account almost exclusively for the mortality in the AI as does arrowtooth flounder (65%) and Steller's sea lions (12%) in the GOA and fur seals in EBS. Diets in all systems are based on GOA data, and euphausiids make up at least 50% of the diet in all systems.

Eelpouts (family *Zoarcidae*) is a composite group which includes representatives of the genera *Lycodes*, *Lycodapes*, *Lycodopsis*, *Lycenchelys*, *Bothrocara*, and *Gymnelis*. Eelpouts are a diverse family in the modeled regions; the trawl surveys primarily catch the larger *Lycodes* species, particularly the marbled eelpout (*L. raridens*), the wattled eelpout (*L. palearis*) and the shortfin eelpout (*L. brevipes*). Data on smaller eelpout species is limited due to limited trawl catchability. Eelpouts are small, narrow, eel-like fishes which are extremely poorly sampled by bottom trawl survey gear designed for groundfish.

Initial attempts to include trawl survey biomass estimates for eelpouts indicated that the consumption of eelpouts is approximately four orders of magnitude higher than survey estimated biomass—this result is common to all Alaskan models, including a smaller scale model developed for the Pribilof Islands (Cianelli et al. 2004). Therefore, eelpout biomass was estimated by assuming that EE was 0.8 for the group in all models. Little is known about eelpout life history, but they are assumed to have similar productivity to other groundfish such as pollock, cod, and herring, so P/B was set to 0.40 (this was used as the default groundfish P/B if no other information was available).

Default growth efficiency was assumed to be 0.2, so default Q/B was set to 2.0 in the absence of other information (again, similar to groundfish such as Pacific cod).

Diet composition information was unavailable for GOA and AI eelpouts, so diet composition estimated from food habits collections made during the EBS bottom trawl surveys were substituted, with the modification that juvenile crabs in the EBS diet which have no equivalent in the other models were called miscellaneous crabs.

Eelpout biomass pedigree for all models was 8 (estimated by Ecopath) while PB and QB were 7 (average values across a wide range of groundfish) and diets were 6 (limited data for all species in the category in the EBS, and data from adjacent systems for the AI and GOA, but within and the correct time period).

Eelpout density, as estimated using EE = 0.80 in all systems, is greatest in the EBS, followed by the GOA and lowest in the AI. Major predators differ between systems: Atka mackerel and cod are the major predators in the AI accounting for 75% of the total mortality; cod, Alaska skates, and cannibalism are high mortality sources in the EBS accounting for 40% of the total mortality; and in the GOA eelpouts are eaten primarily by the ubiquitous arrowtooth flounder (43%). Diets for eelpouts are identical in all systems as the only available data was from the EBS; the main prey items are benthic amphipods, polychaetes and brittle stars which together are about 70% of the eelpout's diet.

Giant grenadier (*Albatrossia pectoralis*) are the most common grenadier in Alaska, and are the largest of all macrourid species (Nelson 1994) reaching a maximum size of 150 cm (not including the long, whiplike tail). Because grenadiers dominate the biomass in many deep-sea (> 400 m) habitats, they are suspected to play an important ecological role in energy transfer, either as pelagic predators, benthic predators, and/or as scavengers on detritus (McLellan 1977). According to research in Russian waters, giant grenadiers form sex-specific aggregations with females found shallower than males, and they migrate seasonally between shallower and deeper waters according to the timing of ovarian maturation and spawning (Novikov 1970, as referenced in Burton 1999). Concentrations of giant grenadiers peak during the summer months in Russian waters (Tuponogov 1997, as referenced in Burton 1999). Giant grenadier have a pelagic juvenile stage, with settlement to benthic habitats thought to coincide with the onset of maturity (Noikov 1970). This life history strategy may protect immature giant grenadiers from fishing pressure (Burton 1999). Giant grenadiers are very slow growing species which live at least 30 to 50 years, maturing at 10-15 years and 50-56 cm TL (Burton 1999). This life history indicates that grenadier populations may be more vulnerable to and slower to recover from heavy fishing pressure, similar to rockfish and elasmobranch populations. Although there is no target fishery for grenadiers in Alaska at present, bycatch of grenadiers in the sablefish fishery has ranged from 11,000 to 20,000 t between 1997 and 2005. Nearly all of this catch is discarded (Clausen 2006a).

EBS biomass was taken from 2002 slope surveys, as slope surveys prior to this time period were incomplete, and almost no biomass of grenadiers is found on the continental shelf. GOA biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. AI biomass was originally based on the averaged 1991 and 1994 AI bottom trawl survey estimates. However the biomass was not sufficient to satisfy consumption within the ecosystem: the maximum depth of the survey is considerably shallower than the main concentrations of grenadiers in other ecosystems. The survey estimate was increased by one order of magnitude based on the information from the 1996 SAFE Bering Sea Aleutian Islands Chapter 13 (Fritz 1996), in which the biomass of giant grenadiers for 1980, 1983, and 1986 were 322,409, 364,110, and 618,102 t, respectively (compared to 28,901 t, the average of 1991-1994 surveys). Therefore, an estimated 289,010 t of grenadiers were included in the AI model.

Because there is no direct information to estimate production or consumption rates for this group, we used values comparable to those for other relatively low productivity groups, a P/B of 0.15 and a Q/B of 2.0 for all models.

Diet composition was based on stomachs collected during bottom trawl surveys in all three regions for the same years that biomass was estimated.

Pedigree for biomass was considered 3 for GOA and EBS (survey coverage but limited over depths of main concentrations) while AI pedigree was 6 (limited information from surveys). P/B and Q/B pedigree was 7 for all ecosystems (average values across a wide range of groundfish). Diet pedigree was 2 in the EBS and GOA, and 3 in the AI, with direct sampling although with incomplete depth coverage.

Giant grenadiers have most of the mortality unexplained by the models for each system, with flow to detritus around 70% in the GOA, 70% in the EBS, and over 95% in the AI. The largest identified sources of mortality in each system are the GOA sablefish fishery (25%), and sleeper sharks in the EBS (22%). Sperm beaked whales are almost the only predator in the AI. Grenadier catch in the AI sablefish fishery appears to be very low; more so than in other areas. Giant grenadier diets are estimated from field data in all systems, but calculated by hand in the AI and EBS (so they were not weighted by habitat). They eat squid and non-pandalid shrimp in the EBS (50% each), myctophids and squids in the AI (47 and 44%, respectively), and non-pandalid shrimp, octopi and pandalid shrimp in the GOA (67, 16 and 11%, respectively).

Pacific grenadier (*Coryphaenoides pacificus*) are very slow growing macrourid species which reach a size of 84 cm TL and ages as high as 73 years, maturing at 20-40 years and 46-65 cm TL off the U.S. West Coast (Andrews et al. 1999). This life history indicates that grenadier populations may be more vulnerable to and slower to recover from heavy fishing pressure, similar to rockfish and elasmobranch populations. Target fisheries for Pacific grenadier have developed along the U.S. West Coast, although they are not yet fished in Alaska and appear low in biomass relative to the giant grenadier there (Clausen 2006a).

EBS biomass was taken from 2002 slope surveys, as slope surveys prior to this time period were incomplete, and almost no biomass of grenadiers is found on the continental shelf. GOA biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. Even our deepest surveys still do not sample deep enough to fully assess all three common grenadier species found in the GOA; for example, there are indications that the maximum density of Pacific grenadiers occurs around 1500 m depth (Andrews et al. 1999). AI biomass is not believed to be sampled adequately. There are indications that the maximum density of Pacific grenadiers occurs around 1500 m depth (Andrews et al. 1999), whereas the maximum depth during bottom trawl surveys is 500m. This problem is also exemplified with the giant grenadier, above. Therefore, AI Pacific grenadier biomass is based on a top down balance with EE = 0.80.

Because there is no direct information to estimate production or consumption rates for this group, we used values comparable to those for other relatively low productivity groups, a P/B of 0.15 and a Q/B of 2.0.

Pacific grenadier diet composition is unknown in all three ecosystems, so the ecosystem-specific giant grenadier diet composition was substituted in all three cases.

Pedigree for biomass was considered 3 for GOA and EBS (survey coverage but limited over depths of main concentrations) while AI pedigree was 6 (limited information from surveys). P/B and Q/B pedigree was 7 for all ecosystems (average values across a wide range of groundfish). Diet pedigree was 5 in all systems: it was taken from system-specific diet studies of the same family (giant grenadiers).

Pacific grenadiers and other macrourids have the same diets in all systems as giant grenadiers, because there was no information specific to these species. The only sources of explained mortality for Pacific grenadiers are fisheries in the GOA (for sablefish primarily) besides sperm beaked whales in a small proportion (part of their diet by preference) in all systems. The same is true for other macrourids, with the addition that cod and Pacific ocean perch (75% of total mortality) eat them in the AI (but note macrourids were top down balanced assuming an EE of 0.8 in this system).

Other macrourids (family *Macrouridae*) is a composite group which includes the remaining major grenadier species found in Alaska: mostly the popeye grenadier *Coryphaenoides cinereus*, and an additional 8 species which are known from the Pacific Ocean, and may be present in the North Pacific. There is little biological information on many species in this group in Alaskan waters.

EBS biomass was taken from 2002 slope surveys, as slope surveys prior to this time period were incomplete, and almost no biomass of grenadiers is found on the continental shelf. Other macrourid biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling group the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. The AI biomass estimate from the 1991 and 1994 AI trawl surveys was for popeye grenadier only, a mere 1.5 t. Thus the biomass was estimated by assuming an EE of 0.8 for balance purposes.

Because there is no direct information to estimate production or consumption rates for this group, we used values comparable to those for other relatively low productivity groups, a P/B of 0.15 and a Q/B of 2.0.

Other macrourid diet composition is unknown in the three ecosystems, so ecosystem-specific giant grenadier diet composition was substituted.

Pedigree for biomass was considered 3 for GOA and EBS (survey coverage but limited over depths of main concentrations) while AI pedigree was 8 (estimated by Ecopath). P/B and Q/B pedigree was 7 for all ecosystems (average values across a wide range of groundfish). Diet pedigree was 5 in all systems: it was taken from system-specific diet studies of the same family (giant grenadiers).

Miscellaneous fish, deep is a composite group containing a variety of less common deeper-dwelling fishes, including dragonfishes and viperfishes (*Stomiidae*), hatchetfishes (*Sternoptychinae*), tubesnouts (*Aulorhynchidae*), slickheads (*Alepocehpalidae*), pearleyes (*Scopelarchidae*), and bigscale fishes or ridgeheads (*Melamphaidae*).

No biomass estimate is available for any of these taxa, so biomass for this group was estimated by assuming EE was 0.8. Likewise, no information on production or consumption is available for these taxa. Because they are generally deep-sea dwellers, the standard P/B ratio was lowered to 0.2 to account for generally lower productivity in this habitat. The standard Q/B ratio of 4.0 was applied. The diet was assumed to be mainly squids and shrimp, a simplification of the grenadier's diet. These assumptions were the same in all models, AI, GOA and EBS.

Pedigree for this group is 8 for biomass (estimated by Ecopath) and 7 for P/B, Q/B, and Diet (general information from wide ranging species in similar habitats).

Miscellaneous fish, deep predation mortality is caused by adult pollock and POP in the AI (respectively 58% and 10% of the total mortality); fisheries account for 25% of the mortality and POP are also a main predator (48% of total mortality) in the GOA, and in the EBS 75% of the mortality is also explained by POP. Diet was the same for all systems, half squids and half non pandalid shrimps based on the diet for giant grenadiers in the EBS.

Pacific ocean perch (*Sebastes alutus*) are schooling rockfish in the family Scorpaenidae which range from southern Japan to central Baja California, Mexico, and are found from surface waters to 825 m depths (Love et al. 2005). Pacific ocean perch are relatively small but long-lived fish, reaching a maximum size of 55 cm and ages over 84 years in the GOA (Orr et al. 1998, Hanselman et al. 2003). The stock is managed as a unit within the BSAI, though catches are higher in the AI and historically, higher abundances have been estimated in the western and central Aleutians. Pacific ocean perch is still commercially important today in the Gulf of Alaska, but has not recovered to pre-1960's exploitation levels (OCSEAP 1986, Hanselman et al. 2003). With the peak of the Japanese and Soviet Pacific ocean perch trawl fishery in 1965, the largest recorded annual removal of any single species in the history of the Gulf of Alaska occurred—348,600 t (Ito 1982). (The 1984 peak catch of pollock was second largest in the GOA at 307,000 t.) In 1966, Soviet catches declined but Japanese catches increased to maintain the catch at over 100,000 t through 1968, after which total catches declined more steadily (Murai 1981, Ito 1982). There are some indications that these early Pacific ocean perch catches, totaling over 1.1 million t between 1963 and 1968, are underestimated (OCSEAP 1986). Gulf of Alaska Pacific ocean perch supported an average of 40% of all landings for the species throughout its range between 1960 and 2002; this early fishery represented 75% of total worldwide landings (FAO website fishery statistics 2005). From 1989-2005, catch of POP has averaged 9,785 t annually in the GOA (Hanselman et al. 2005). From 1990-2006, catch of POP has averaged 1,116 t in the EBS and 11,107 t in the AI (Spencer and Ianelli 2006).

Pacific ocean perch (POP) are divided into adult and juvenile groups only in the GOA model. The POP biomass for the entire EBS population is the 2002 NMFS slope survey estimate combined with 1991 EBS bottom trawl survey estimates from shelf strata. The AI biomass estimate for the whole POP population comes from the average of the 1991 and 1994 AI bottom trawl surveys. GOA adult biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. In the GOA, initial attempts at estimating juvenile (<20 cm) biomass using top-down methods were not successful because there are apparently few predators of juvenile POP in the GOA. Therefore, we estimated juvenile mortality to be 2.5, a rate comparable to those estimated by MSVPA model runs in the EBS (Jurado-Molina 2001). This estimated juvenile mortality rate was used to estimate juvenile biomass given the numbers and weight at age estimated for those years.

The P/B and Q/B ratios in the EBS were adapted from those calculated in the GOA for adult POP, 0.1 and 2, respectively. The GOA adult P/B ratio of 0.09 and Q/B ratio of 1.99 were estimated from the 1990-1993 age structure in the POP stock assessment (Hanselman et al. 2003) and weight at age data collected on NMFS bottom trawl surveys. The GOA juvenile POP P/B ratio of 1.1 for 1990-1993 was estimated based on stock assessment age structure and the assumed mortality rate of 2.5 (see above). The GOA juvenile POP Q/B of 3.48 was estimated by the same method and using the same information as for adults. The P/B and Q/B ratios in the AI were estimated by fitting a von Bertalanffy growth function to data from the 1991 age structure in the BSAI stock assessment, and weight at age data from the AI. The P/B and Q/B values are 0.21 and 1.8, respectively.

Diet composition in the EBS and AI was based on stomachs collected during the EBS and AI bottom trawl surveys in 1991 and 1994. Diet composition was estimated for both adult and juvenile POP from food habits collections made during the 1990 and 1993 bottom trawl surveys of the GOA.

The POP biomass data pedigree was 2 for adults in the GOA and all POP in the AI models (direct regional estimate with poor subregional resolution), while the EBS biomass data pedigree was 3 (proxy with known but consistent bias). GOA juvenile POP biomass data was rated 4 (proxy with limited confidence). P/B and Q/B parameters were rated 3 for adults in the GOA and all POP in the AI (proxy with known but consistent bias), and downgraded to 4 for juveniles in the GOA (proxy with limited confidence) and 6 for all POP in the EBS (same species in neighboring region). Diet composition data for POP rated 1 in all three models and all age groups (data established and substantial, with resolution on multiple spatial scales),

Juvenile Pacific ocean perch (POP) have few explained sources of mortality (EE <0.01) in the GOA, the only system where they were modeled. They prey on euphausiids (90%) and chaetognaths (9%). In the AI, adult POP had high unexplained mortality, with a flow of almost 69% to detritus, followed by mortality caused by rockfish trawl fisheries (11% of total mortality) and fulmars and Kamchatka flounders with 4% of total mortality each. Bird predation on rockfish in general is likely overestimated using the diets derived from Hunt et al. 2000, which considered cod, pollock and rockfish as “low density” fish and hence does not specifically distinguish between adult and juvenile rockfish. We modified Hunt’s estimates to reduce or eliminate rockfish in seabird diets in the GOA and EBS unless there was evidence from other sources that seabirds prey on rockfish in those systems. Improvements in seabird diet data should be prioritized in future modeling efforts. In the EBS, the rockfish trawl fishery is the dominant POP mortality source (40%) comprising the major portion of the fishing mortality (50% total mortality), followed by seals (20% total mortality). Only 15% of the total mortality is not explained by the model. In GOA the rockfish trawl fishery is the largest source of explained mortality (13% of total mortality), followed by marine mammals (15%) and halibut (5%). Adult POP have direct diet data in all three systems and show different dominant zooplankton prey items: euphausiids are 75% of diet in GOA while mysids dominate (60%) followed by euphausiids (24%) in the EBS, and copepods constitute 75% of POP diet in the AI.

Sharpchin rockfish (*Sebastes zacentrus*) are small roundfish in the family Scorpaenidae which range from Attu Island in the western Aleutians to southern California on the U.S. West Coast in depths from 25 to 660 m (Love et al. 2005). These rockfish grow to a maximum size of 39 cm, a similar size as Pacific ocean perch (POP) (Orr et al. 1998), and may live to 58 years (Clausen et al. 2003a). Sharpchin rockfish are not direct targets of commercial fisheries, although they may be retained as bycatch along with other rockfish.

This group was not split into adult and juvenile pools in any model due to lack of stock assessment information. In the all three ecosystems, sharpchin rockfish biomass estimated from trawl surveys was very low compared with apparent demand within the system, so biomass was estimated by assuming that EE was 0.8 for the group. Sharpchin rockfish are expected to occupy habitats which are poorly sampled with bottom trawl gear, hence fishery gear may encounter them at a higher rate than survey gear, although catches are low in both gears (e.g., 4 t fishery bycatch in the EBS compared with 2 t survey biomass).

Lacking specific information on sharpchin rockfish energetics, a P/B of 0.10 and a Q/B of 2.0 were applied to sharpchin rockfish in all three models based on the values calculated for adult POP in the GOA. Sharpchin rockfish diet composition was estimated from food habits collections made during bottom trawl surveys of the GOA. In the AI, no stomachs were available from either the AI or the western GOA, so the diet composition was assumed to be an average of all rockfish diets (except POP) based on stomachs collected in the AI during bottom trawl surveys. This method was also used in the EBS, where there were also no sharpchin rockfish diet collections.

The sharpchin rockfish biomass data pedigree was 8 in all three systems (top down balance). P/B and Q/B parameters were rated 6 in all ecosystems (general life history proxy). Diet composition data for sharpchin rockfish rated 2 in the GOA model (direct estimate with limited coverage), 5 in the EBS model (general model specific to area), and 5 in the AI model (general model specific to area), Sharpchin rockfish mortality is dominated by fishery bycatch mortality in all three systems, explaining about 60% of the total mortality. The high proportion in the fisheries contrasts with the lack of catch in the surveys, indicating that there may be a fishery catch data problem (perhaps involving species identification?). Alternatively, perhaps sharpchin rockfish are overfished in all three systems (or were during the early 1990s). Sharpchins eat primarily copepods, euphausiids and benthic amphipods in the GOA, which total 90% of the diet. It is difficult to compare diets because the only system with adequate data to estimate diet composition was the GOA. Diets were the average of several rockfish species in the EBS and AI.

Northern rockfish (*Sebastes polyspinis*) are small roundfish in the family Scorpaenidae which range from the Kuril Islands to northern British Columbia in depths from 10 to 740 m (Love et al. 2005). These rockfish grow to a maximum size of 40 cm, a similar size as Pacific ocean perch (POP) (Orr et al. 1998), and reach a maximum age of 67 years (Courtney et al. 2003). Northern rockfish are often caught with POP, which is reflected in their catch history, with peak GOA catch estimated at over 17,000 t in 1965 at the height of the POP fishery. Northern rockfish are an important commercial species with a directed fishery in the GOA since the 1990s, with catches ranging from 3,000 to 7,000 t annually (Courtney et al. 2006).

This group was not split into adult and juvenile pools in the any model, but could be in the future because an age structured assessment is now available in the GOA. Biomass was estimated using top down balance with an EE = 0.80 in the EBS, as no reliable trawl survey biomass estimate was available. GOA Northern rockfish biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. AI biomass was the average of the 1991 and 1994 bottom trawl survey estimates for the AI.

Lacking specific information on northern rockfish energetics, a P/B of 0.10 and a Q/B of 2.0 were applied based on the values calculated for adult POP in the GOA. These same values were used for the EBS and AI models.

Northern rockfish diet composition was estimated from food habits collections made during bottom trawl surveys of the EBS, GOA, and AI in the early 1990s.

The northern rockfish biomass data pedigree was 2 in the GOA and AI models (direct estimate with limited coverage), and 8 in the EBS (top down balance). P/B and Q/B parameters were rated 6 in all ecosystems (general life history proxy). Diet composition data for northern rockfish rated 2 in all three models (direct estimate with limited coverage),

Northern rockfish mortality is primarily from fisheries in the EBS (over 60% of total mortality is explained by the combined trawl fisheries), followed by marine mammals and seabirds. In the GOA the largest single source of mortality is the directed rockfish trawl fishery (41%), followed by marine mammals, birds, and bycatch in other fisheries (together fisheries account for 45% of the total mortality). In the AI, more than half of total northern rockfish mortality is unexplained, with the majority of explained mortality arising from bycatch in the Atka mackerel trawl fishery (18%), followed by seabirds, marine mammals, and bycatch in other fisheries (this last an additional 3 % of total mortality). Northern rockfish eat copepods and euphausiids, primarily the former in the EBS (79% of diet), the latter in the GOA (95%), and a mixture in the AI, but low sample sizes (~250 for the AI) for northern rockfish food habits collections in all areas might render this difference between systems preliminary.

Dusky rockfish complex (*Sebastes ciliatus* and *S. variabilis*) contains two species of relatively small roundfish in the family Scorpaenidae that were considered light and dark color morphs of a single species (*Sebastes ciliatus*) during the early 1990s. The lighter colored Dusky rockfish (*S. variabilis*) range from Japan to British Columbia in depths from 6 to 675 m. Dark rockfish (*S. ciliatus*) range from the western Aleutians to British Columbia in depths from 5 to 160 m (Love et al. 2005). Therefore, dusky rockfish are most common in the habitats sampled by the trawl survey, while dark rockfish are generally more common in shallower nearshore areas and may be less represented in trawl survey data (Orr and Blackburn 2004). Therefore, the data used to represent this complex likely represents the dusky rockfish better than the dark rockfish. Dusky rockfish grow to a maximum size of 53 cm, a similar size to POP (Orr et al. 1998), and a maximum age of 59 (Clausen et al. 2003b). Little is known at present about the life history of the newly described dark rockfish. Both species are managed within the pelagic shelf rockfish complex in the GOA, and in the Other rockfish complex in the BSAI. Dusky rockfish comprise most of the pelagic shelf rockfish complex in the GOA; estimated catches have ranged from 1600 to 4500 t annually between 1990 and 2005 (Lunsford et al. 2005).

This group was not split into adult and juvenile pools in any model, although a preliminary assessment for dusky rockfish is in development for the GOA. Dusky rockfish have similar survey biomass problems as other rockfish in the EBS ecosystem, but top-down balance was considered undesirable for this species which has more fishing mortality than natural mortality due to a relatively small amount of fishery bycatch. No stock assessment estimate of EBS dusky rockfish biomass is available, but this species is assessed in the GOA. Therefore, the EBS survey biomass estimate for dusky rockfish was scaled up by the ratio of stock assessment estimated biomass to survey biomass for GOA dusky rockfish (1.6), based on the assumption that an assessment in the EBS might compensate for bottom trawl survey biases similarly. GOA dusky rockfish biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. AI biomass was the average of the 1991 and 1994 bottom trawl survey estimates for the AI, increased in a minimal amount just to bring it into balance (EE was 1.005). This adjustment still falls well within the variance of the original estimate. Based on the bottom trawl surveys, the highest biomass is located in the central Aleutians.

Lacking specific information on dusky rockfish energetics, a P/B of 0.10 and a Q/B of 2.0 were applied in all three ecosystem models based on the values calculated for adult POP in the GOA.

Dusky rockfish diet composition was estimated from food habits collections made during bottom trawl surveys of the EBS, GOA, and AI during the early 1990s.

The dusky rockfish complex biomass data pedigree was 2 in the AI model (direct estimate with limited coverage), 3 in the GOA model (proxy with known but consistent bias: trawl survey differs from assessment estimate) and 7 in the EBS (selected from multiple incomplete sources). P/B and Q/B parameters were rated 6 in all ecosystems (general life history proxy). Diet composition data for dusky rockfish rated 2 in all three models (direct estimate with limited coverage),

Dusky rockfish biomass required some adjustment in each system, because bottom trawl estimates can vary significantly from year to year. In the GOA, another survey year (1996) was included in the average, while in the EBS, a conversion based on stock assessments was employed to augment survey data, in the AI survey biomass was increased slightly to accommodate a slightly high EE (EE<1.1). Fisheries account for the highest proportion of dusky rockfish mortality in both the AI and the GOA (70 and 60% of the total mortality, respectively), while the highest proportion of mortality is from unknown sources in the EBS, followed by fisheries (35% of total mortality) and 18% by seals. Diets are likely not meaningfully comparable across systems because they arise from limited sampling, especially in the AI where they are estimated to eat exclusively benthic amphipods (sample < 10 stomachs). Similarly, the preponderance of hermit crabs in the GOA may also be due to a limited sample size. In the EBS dusky rockfish eat mostly zooplankton.

Shortraker rockfish (*Sebastes borealis*) are large roundfish in the family Scorpaenidae which range from northern Japan to central California in depths ranging from 25 to 1,200 m (Love et al. 2005). Shortraker rockfish grow very large, to 108 cm (Orr et al. 1998). Ageing this species has been problematic, but despite uncertainty in methodology, it is clear that shortrakers are very long lived, with maximum age estimates ranging from 120-157 years (Clausen et al. 2003a). Within the AI they are found mostly within the deep strata (200-500 m) during bottom trawl surveys (where surveys only go as deep as 500m). Recent catches of shortraker rockfish in the GOA have ranged from 500-600 t (Clausen 2006b).

This group was not split into adult and juvenile pools in any model due to lack of stock assessment information. In the EBS model, shortraker biomass is the 1991 EBS NMFS bottom trawl survey estimate, including the 1991 slope survey estimate. GOA Shortraker rockfish biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling group the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. AI biomass was the average of the 1991 and 1994 bottom trawl survey estimates for the AI.

Lacking specific information on shortraker rockfish energetics, a P/B of 0.10 and a Q/B of 2.0 were applied in all three ecosystems (EBS, GOA and AI) based on the values calculated for adult POP in the GOA, but we recognize that shortrakers have different growth and these parameters should be updated when data become available.

Shortraker rockfish diet composition was estimated from food habits collections made during bottom trawl surveys of the EBS, GOA, and AI in the early 1990s.

The shortraker rockfish biomass data pedigree was 2 in the AI model (direct estimate with limited coverage), 3 in the GOA model (proxy with known but consistent bias: trawl survey differs from assessment estimate) and 7 in the

EBS (selected from multiple incomplete sources). P/B and Q/B parameters were rated 6 in all ecosystems (general life history proxy). Diet composition data for shortraker rockfish rated 2 in all three models (direct estimate with limited coverage),

Shortraker rockfish have half of the total mortality as flow to detritus in all systems (over half of total mortality in the AI and GOA, and 43% in the EBS). Directed fisheries (primarily rockfish trawl) represent the largest known source of mortality in the AI and GOA explaining about 20-23% of the total mortality, followed by marine mammals in the GOA; birds and marine mammals in the AI. In the EBS, shortraker mortality is divided approximately equally among pinnipeds and trawl fisheries, (20% of total mortality each) followed by birds (6%). Shortrakers eat primarily shrimp in all systems, with a predominance of pandalid shrimp in the EBS (82%) and GOA (93%), and non-pandalid shrimp in the AI (99%). Mysids constitute an additional 13% of the shortraker's diet in the EBS.

Rougheye rockfish (*Sebastes aleutianus*) are large roundfish in the family Scorpaenidae which range from northern Japan to southern California in depths ranging from 25 to 900 m (Love et al. 2005). There are two species of rougheye rockfish which have been distinguished genetically (Gharrett et al. 2005); since a species description is currently in progress we treat this as a single species group until further information is available. Like shortrakers, rougheye rockfish achieve large maximum size (97 cm) and very old age, but age is difficult to determine. Maximum age estimates range from 95 to 205 years for rougheye rockfish (Clausen et al. 2003a). Within the AI they are found mostly within the deep strata (200-500m) during bottom trawl surveys (where surveys only go as deep as 500m). Catches of rougheye in the GOA have ranged from 200 to 900 t annually since 1993 (Shotwell et al. 2005).

This group was not split into adult and juvenile pools in any model due to lack of stock assessment information. In the EBS model, rougheye biomass is the 1991 EBS NMFS bottom trawl survey estimate, including the 1991 slope survey estimate. GOA rougheye rockfish biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling group the 1999 survey biomass from deep strata were substituted to give a better estimate of total population biomass. AI biomass was the average of the 1991 and 1994 bottom trawl survey estimates for the AI, increased in a minimal amount just to bring it into balance (EE was 1.008).

Lacking specific information on rougheye rockfish energetics, a P/B of 0.10 and a Q/B of 2.0 were applied on all three systems (EBS, GOA and AI) based on the values calculated for adult POP in the GOA but we recognize that rougheye rockfish have different growth and these parameters should be updated when data become available.

Rougheye rockfish diet composition was estimated from food habits collections made during bottom trawl surveys of the EBS, GOA, and AI in the early 1990s.

The rougheye rockfish biomass data pedigree was 2 in the AI model (direct estimate with limited coverage), 3 in the GOA model (proxy with known but consistent bias: trawl survey differs from assessment estimate) and 7 in the EBS (selected from multiple incomplete sources). P/B and Q/B parameters were rated 6 in all ecosystems (general life history proxy). Diet composition data for rougheye rockfish rated 2 in all three models (direct estimate with limited coverage).

Half of rougheye rockfish total mortality is from unknown sources in the EBS and GOA. Seals cause 20% of the total mortality, followed by fisheries (14%) and birds (6%) in the EBS; in the GOA 23% of the total mortality is caused by fisheries, led by the directed rockfish and sablefish fisheries and followed by marine mammals (12%). In the AI, rougheye rockfish total mortality is explained predominantly by fisheries directed at rockfish, Atka mackerel and cod; all fisheries together account for 73% of the total mortality and birds and marine mammals explain 25%. Rougheye rockfish eat over 99% pandalid shrimp in the GOA and AI, but have a very different diet of squids (62%), euphausiids (19%), and non-pandalid shrimp (14%) in the EBS.

Shortspine thornyhead (*Sebastolobus alascanus*) are medium sized roundfish in the family Scorpaenidae which range from 17 to 1,524 m depth and along the Pacific rim from the Seas of Okhotsk and Japan in the western north Pacific, throughout the Aleutian Islands, Bering Sea slope and Gulf of Alaska, and south to Baja California in the eastern north Pacific (Love et al. 2005). Shortspine thornyheads grow to a size of 77 cm, maturing at a length of about 22 cm, but ages are very uncertain; maximum age estimates range from a low of 62 years to highs over 150-

200 years depending on methodology (Gaichas and Ianelli 2003). Within the AI they are found mostly within the deep strata (200-500 m) during bottom trawl surveys (where surveys only go as deep as 500 m). Shortspine thornyheads are abundant throughout the Gulf of Alaska and are commonly taken by bottom trawls and longline gear. In the past, this species was seldom the target of a directed fishery. Today thornyheads are one of the most valuable of the rockfish species, with most of the domestic harvest exported to Japan (Gaichas and Ianelli 2005).

In the EBS and AI models, shortspine thornyheads were not split into adult and juvenile groups due to a lack of stock assessment information. In the EBS, thornyhead biomass is the 1991 NMFS bottom trawl survey estimate (including the 1991 slope survey). In the AI, biomass was the average of the 1991 and 1994 bottom trawl survey estimates for the AI. Thornyheads were modeled as adult and juvenile pools in the GOA. GOA adult biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this relatively deep dwelling species, the 1999 survey biomass from deep strata was substituted to give a better estimate of total population biomass. GOA juveniles were defined as fish less than 20 cm in length, which roughly corresponds to 0 through 2 year old fish; biomass for this juvenile group was estimated by assuming that EE was 0.8 for the group.

Thornyhead P/B and Q/B ratios for all three models were based on data from the GOA stock assessment. The GOA adult thornyhead P/B ratio of 0.13 and Q/B ratio of 0.44 were estimated from the 1990-1993 age structure in the thornyhead assessment (Gaichas and Ianelli 2003) and weight at age data collected on NMFS bottom trawl surveys (in this case, only U.S. West Coast surveys had any shortspine thornyhead weight at age data). The GOA juvenile thornyhead P/B of 0.21 and Q/B of 0.57 were estimated by the same method and using the same information as for adults. The production and consumption values in the EBS and the AI were rounded off from those estimated for juveniles and adults in the GOA, The resulting values were a PB of 0.15 and a QB of 0.5.

Diet composition was based on food habits collections made during bottom trawl surveys of the EBS, the GOA and the AI from the early 1990s for each model.

The shortspine thornyhead biomass data pedigree was 2 in the AI model (direct estimate with limited coverage), 4 for adults in the GOA model (proxy with known but consistent bias: trawl survey differs from assessment estimate), 7 in the EBS (selected from multiple incomplete sources), and 8 for juveniles in the GOA model (no estimate available, top down balance). P/B and Q/B parameters for adults were rated 3 in the GOA (proxy with known but consistent bias), for juveniles in the GOA rated 4 (proxy with limited coverage), and for all ages rated 6 in the EBS and AI (general life history proxy). Diet composition data for shortspine thornyheads rated 2 in all three models (direct estimate with limited coverage),

Shortspine thornyheads are only modeled as split juvenile and adult pools in the GOA, where adult thornyheads cause the majority of juvenile thornyhead mortality, and juvenile diet is primarily pandalid shrimp, benthic amphipods, and zooplankton which together make up 80% of diet. The adult shortspine thornyheads have fishery dominated mortality in the GOA (52% of total mortality), but unknown sources cause some 65% of the total mortality in the EBS and AI (although we note that bycatch of thornyheads in halibut fisheries is unrecorded at present). The known mortality sources in the EBS include the fisheries (15%), marine mammals (15%) and seabirds (3%), and in the AI include sablefish and turbot longline fisheries (12% of total mortality), pinnipeds, and seabirds (16% jointly). Thornyheads eat shrimp in the GOA and AI (70 and 50% of diet respectively), but in the EBS they eat mysids and benthic amphipods.

Other *Sebastes* is a composite group containing the remaining rockfish (*Sebastes* and *Sebastolobus*, family Scorpaenidae) species found in the Alaska. The complex varies by area, but the most common other Sebastes in the modeled sections of the GOA are the redstripe (*S. proriger*), harlequin (*S. variegatus*), silvergrey (*S. brevispinis*), and redbanded (*S. babcocki*). In the AI the redstripe (*S. proriger*) and silvergrey (*S. brevispinis*) are the main species. This is an extremely low biomass group in the EBS which is dominated by rare slope species including broadfin and longspine thornyheads (*Sebastolobus macrochir* and *Sebastolobus altivelus*). Most of these are non-commercial species in all three ecosystems, although some may be retained as incidental catch in fisheries directed at more common rockfish species.

In the EBS model, there was insufficient biomass of other *Sebastes* and *Sebastolobus* to supply the consumption demand generated by Pacific cod. Therefore, EBS other *Sebastes* biomass was estimated by top-down balance. Similarly, in the GOA, other *Sebastes* aggregate biomass estimated from trawl surveys was low compared with apparent demand within the system, and rockfish are notoriously difficult to sample with bottom trawl surveys in their preferred rocky reef habitat, so biomass was estimated by assuming that EE was 0.8 for the group. AI biomass was also estimated assuming an EE of 0.8. This was because this is a composite group, yet the only biomass estimate available was for harlequin and redbanded rockfish (*Sebastes variegates* and *S. babcocki,* respectively) at 19 t, which was insufficient to satisfy consumption within the ecosystem.

Lacking specific information on energetics for the rockfishes in this group, a P/B of 0.10 and a Q/B of 2.0 were applied in all three systems based on the values calculated for adult Pacific ocean perch in the GOA.

Other *Sebastes* diet composition in the GOA was estimated from food habits collections made during bottom trawl surveys of the GOA. No stomachs from the AI are available for any of the *Sebastes* species included in this group, therefore diet composition was estimated from stomachs collected in the western GOA as part of the GOA bottom trawl surveys. In the EBS, no stomachs were available from either the AI or the western GOA, so the diet composition was assumed to be an average of all rockfish diets (except POP) based on stomachs collected in the EBS during bottom trawl surveys.

The other *Sebastes* biomass data pedigree was 8 in all three systems (top down balance). P/B and Q/B parameters were rated 6 in all ecosystems (general life history proxy). Diet composition data for other *Sebastes* rockfish rated 5 in the GOA (general model specific to area), and 6 in the EBS and AI (similar species in same region, and same species in neighboring region),

Atka mackerel (*Pleurogrammus monopterygius*) are not mackerel at all, but medium-sized schooling roundfish in the family Hexagrammidae. They range from the Sea of Japan to southern California (although they are rarely found south of Alaska) from intertidal waters to 720 m depths (Love et al. 2005). These fish are most abundant in the AI, with the population apparently expanding to occupy the GOA intermittently. Atka mackerel grow rather quickly to a maximum size of about 55 cm and an age of 13-15 years (the highest age being observed at the center of the population's abundance in the AI, Lowe and Lauth 2003). They mature at about 38 cm and 3-4 years of age in the GOA (McDermott and Lowe 1998). There is no age structured stock assessment for GOA Atka mackerel, because the population is so intermittent in the region that a fishery is not supported. However, an economically important commercial fishery takes place each year in the AI for Atka mackerel, where catches have ranged from 21,000 to over 100,000 t between 1990 and 2005 (Lowe et al. 2006). While managed as a BSAI stock, the Atka mackerel fishery and stock assessment are centered in the AI region of the BSAI; only a small biomass of Atka mackerel are found in the EBS region of the BSAI.

Adult Atka mackerel

Atka mackerel were divided into adult and juvenile biomass pools in all three models because juvenile Atka mackerel are important forage fish when present in each ecosystem. In the EBS, adult Atka mackerel biomass was also based on the stock assessment for the entire BSAI management area. The Atka mackerel assessment biomass for the BSAI was scaled down to reflect the percent of Atka mackerel occupying EBS model strata using the survey biomass in each stratum. In the GOA, the trawl survey biomass for this species is highly variable between GOA surveys because of the patchy distribution of the fish combined with occasional population expansion and contraction. Therefore, three surveys from the early 1990s were used to estimate biomass for GOA adult Atka mackerel, the 1990, 1993, and 1996 surveys. AI adult biomass was based on the average estimates from 1991 and 1994 bottom trawl surveys.

The best assessment information for Atka mackerel is based in the AI, and parameters for the GOA and EBS were derived from it. The P/B and Q/B ratios were estimated by fitting a von Bertalanffy growth function to data from the 1991 age structure in the BSAI stock assessment, and weight at age data from the AI. The resulting rates were a PB of 0.348 and QB of 5.647, respectively. In the GOA and the EBS the P/B of 0.35 and Q/B of 5.65 were rounded from the AI values.

Adult Atka mackerel diet composition was based on food habits collections made during bottom trawl surveys of the EBS, GOA, and AI during the early 1990s.

The adult Atka mackerel biomass pedigree was 1 in the AI (established and substantial direct estimated corroborated by survey and assessment data) and 4 in both the EBS and GOA (direct estimate with high variation). P/B and Q/B parameters were rated 3 in the AI (proxy with known bias) and 5 in the EBS and GOA (general model specific to area). Diet compositions rated 1 in the AI (data established and substantial, with resolution on multiple spatial scales), 2 in the EBS (direct estimate with limited coverage), and 5 in the GOA (correct species and area but wider time period to increase sample size).

Juvenile Atka mackerel

Juveniles were defined as fish less than 20 cm in length, which roughly corresponds to 0 through 1 year old fish. Biomass for this juvenile group in both GOA and AI was estimated by assuming that EE was 0.8 for the group. Top down balance proved numerically unstable in the EBS where some consumption of juvenile Atka mackerel is believed to come from predators outside the model in the basin. Therefore, we assumed that juvenile biomass would be 10% of adult biomass in the EBS. This assumption could be addressed in the future if further information on Atka mackerel in the EBS becomes available.

AI juvenile Atka mackerel P/B of 1.9 and Q/B of 8.9 were estimated by the same method and using the same information from the AI as for adults, and these values were used in the EBS and GOA models.

The AI juvenile Atka mackerel diet composition was based on analyzed stomachs collected during 1991 and 1994 as part of the bottom trawl surveys. Juvenile Atka mackerel diet composition information was unavailable for the GOA, so a similar diet composition of 90% euphausiids and 10% copepods was applied to this group as was assumed for all species of small pelagic forage fish. This assumption was common to the GOA and EBS models.

The juvenile Atka mackerel biomass pedigree was 8 in all three ecosystems (no estimate available, top down balance). P/B and Q/B parameters were rated 4 in the AI (proxy with lower confidence) and 6 in the EBS and GOA (general life history proxy). Diet compositions rated 2 in the AI (direct estimate with limited coverage), and 7 in the EBS and GOA (general literature review from a wide range of species).

Atka mackerel juveniles have poor data in all systems. They are primarily eaten by arrowtooth flounder in the GOA, pollock and arrowtooth flounder in the AI, and have basically no sources of mortality nothing in the EBS. In the AI Adult Atka mackerel are eaten primarily by Steller sea lions (30% of total mortality) followed by Pacific cod (25%) and the fisheries (20%). In the GOA they are eaten by arrowtooth flounder and halibut (together 50% of the total mortality, followed by the short-lived Atka mackerel directed fishery that took place in the GOA during the early 1990s and which accounted for 12% of the total mortality. Atka mackerel eat zooplankton in all systems, with copepods, euphausiids, and squids predominant in the AI (70 % of diet), and euphausiids constituting the main prey item (>90% diet) in the GOA and EBS.

Greenlings (family *Hexagrammidae*) is a composite group containing all remaining members of this family aside from Atka mackerel, including the kelp greenling (*Hexagrammos decagrammus*), the rock greenling (*H. lagocephalus*), the masked greenling (*H. octogrammus*), and the white spotted greenling (*H. stelleri*).

In the EBS model, biomass estimates were not reliable due to the patchy nature of these species, thus an EE of 0.8 was assumed. The GOA biomass for this composite group is the sum of survey biomass estimates for each species, averaged between the 1990 and 1993 GOA bottom trawl surveys. This group showed a slight decline over this period, so a BA term of -0.002 t/km^2 was calculated from the survey time series and included for balance. In the AI, biomass estimates were not available, thus an EE of 0.8 was assumed.

There is little to no life history information available for species in this group, so P/B was assumed to be 0.4 and Q/B was assumed to be 2.0. This set of assumptions implies that greenlings have similar production and consumption rates as adult Pacific cod (perhaps the quintessential default groundfish). This default assumption for groundfish production and consumption rates in the absence of life history information is common to the GOA, EBS, and AI models.

Diet composition in the EBS was based on food habits collections taken aboard NMFS bottom trawl surveys in the EBS during the early 1990s. Food habits data for GOA greenlings is not available, so diet composition for this group was estimated based on EBS food habits data for greenlings. The AI diet composition was based on stomachs collected during the AI bottom trawl surveys during 1991 and 1994.

The greenlings biomass pedigree was 8 in the EBS and AI ecosystems (no estimate available, top down balance), and 2 in the GOA (direct estimate with limited coverage). P/B and Q/B parameters were rated 7 in all three ecosystems (general literature review from a wide range of species). Diet compositions rated 2 in the EBS and AI (direct estimate with limited coverage), and 6 in the GOA (same species in neighboring area).

Greenlings are a relatively data poor category. From the limited data available, most mortality in the GOA is from Steller sea lions, while Pacific cod are eating them in the EBS and AI. Diet data is best for the EBS, where greenlings eat sculpins. Diet data is very limited in the AI and nonexistent in the GOA, where EBS information was substituted.

Large sculpins (suborder Cottoidei) is a composite group which includes several common species that achieve large sizes in Alaska, and are thought to be most likely encountered in the commercial fisheries (Reuter and TenBrink 2006): *Myoxocephalus* spp. (e.g., the great sculpin), *Hemilepidotus* spp. (Irish lords), and the bigmouth sculpin, *Hemitripterus bolini*. Despite their abundance and diversity, sculpin life histories are not well known in Alaska. Sculpins lay adhesive eggs in nests, and many exhibit parental care for eggs (Eschemeyer et al. 1983). Bigmouth sculpins, *Hemitripterus bolini*, lay eggs in vase sponges–however, it is unknown whether they are completely dependent on finding a particular type of sponge to reproduce. Some larger sculpin species such as the great sculpin, *Myoxocephalus polyacanthocephalus*, reach sizes of 70 cm and 8 kg in the western North Pacific. In the western Pacific, great sculpins are reported to have relatively late ages at maturity (5-8 years, Tokranov, 1985) despite being relatively short-lived (13-15 years), which suggests a limited reproductive portion of the lifespan relative to other groundfish species. Mean fecundities for great sculpin were 60,000 to 88,000 eggs per gram body weight (Tokranov, 1985).

In the EBS model, biomass for the large sculpins group was the sum of survey biomass estimates for each species in each model stratum from the 1991 NMFS EBS bottom trawl survey (as supplemented by the 2002 EBS slope survey). GOA biomass for this composite group is the sum of survey biomass estimates for each species, averaged between the 1990 and 1993 GOA bottom trawl surveys. In the AI no biomass estimate was available for any of the species in this complex and hence an EE of 0.8 was assumed to estimate biomass.

Because there is little to no life history information available for species in this group, P/B was assumed to be 0.4 and Q/B was assumed to be 2.0, a modification of those for Pacific cod, and the default value for sculpins, greenlings and miscellaneous shallow fish. This default assumption for groundfish production and consumption rates in the absence of life history information is common to the GOA, EBS, and AI models.

EBS large sculpin diet compositions were estimated from food habits collections taken aboard EBS trawl surveys during 1991. Food habits data for GOA large sculpins is not available, so diet composition for this group was estimated based on EBS food habits data for EBS large sculpins. The EBS diet composition was modified for the GOA as follows: Kamchatka flounder in the diet was added to arrowtooth flounder, yellowfin sole juveniles and adults in the diet were summed and entered as yellowfin sole, Northern rock sole juveniles and adults were summed and then divided evenly between Northern and Southern rock sole, and opilio and bairdi crabs were summed and entered as bairdi crabs. The feeding habits in the AI were based on stomachs collected as part of the AI bottom trawl surveys.

The large sculpin biomass pedigree was 2 in the EBS and GOA models (direct estimate with limited coverage), and 8 in the AI (no estimate available, top down balance). P/B and Q/B parameters were rated 7 in all three ecosystems (general literature review from a wide range of species). Diet compositions rated 2 in the EBS and AI (direct estimate with limited coverage), and 6 in the GOA (same species in neighboring area).

Large sculpins have the highest biomass and the lowest explained mortality in the EBS relative to the other two areas, with 4% of mortality explained by fisheries and 2% explained by groundfish predation. GOA large sculpin mortality is 32% unexplained, followed by greenling, sablefish, sea lion and halibut predation, followed by fishery bycatch. Most mortality in the AI is from the Atka mackerel trawl fishery but there was no reliable biomass estimate for this group in that region. Diets were available only for the EBS and AI, where a variety of invertebrates are consumed, as well as Atka mackerel in the AI.

Other sculpins (suborder Cottoidei) is a composite group which includes all other sculpin species in Alaska not found in the large sculpin group (see above). These species are thought to be less likely to comprise much commercial fishery bycatch, due to small size, inaccessible habitat, or both (Gaichas 2003). This category includes sculpins in the genera *Icelus*, *Triglops*, *Artediellus*, *Enophrys*, *Gymnocanthus*, *Icelinus*, *Leptocottus*, *Malacocottus*, *Blepsias*, *Dasycottus*, and *Rhamphocottus*, among others. Limited life history information on related species from other areas suggests that other sculpins have broadly similar life history to the better studied large sculpins, with maximum ages on the order of 10 years or less and ages at maturity ranging from 4-6 (Gaichas et al. 2004).

Although these species are encountered on NMFS trawl surveys, they are either too small for effective catch by the gear or inhabit untrawlable areas, so biomass for this group was estimated by assuming EE was 0.8 for the group in all three ecosystems.

Because there is little to no life history information available for species in this group, P/B was assumed to be 0.4 and Q/B was assumed to be 4.0. This default assumption for groundfish production and consumption rates in the absence of life history information is common to the GOA, EBS, and AI models.

EBS other sculpin diet compositions were estimated from food habits collections taken aboard EBS trawl surveys during 1991. Food habits data for GOA other sculpins is not available, so diet composition for this group was estimated based on EBS food habits data for EBS other sculpins. The EBS diet composition was modified for the GOA by assigning yellowfin sole juveniles in EBS other sculpin diets to flathead sole juveniles in GOA other sculpin diets. The AI diet was based on the stomach contents of samples collected in the AI as part of the bottom trawl surveys. AI other sculpin diet was modified to avoid within-group "cannibalism" which tended to artificially inflate the biomass of this top-down balanced group: the fraction corresponding to "other sculpins" moved to the category "size unknown".

The other sculpin biomass pedigree was 8 in all three models (no estimate available, top down balance). P/B and Q/B parameters were rated 7 in all three ecosystems (general literature review from a wide range of species). Diet compositions rated 2 in the EBS and AI (direct estimate with limited coverage), and 6 in the GOA (same species in neighboring area).

Other sculpins are mostly eaten by Pacific cod the AI and GOA, while a variety of predators consume them in the EBS, including eelpouts, seals, skates, and pollock. Diets were available only in the EBS and AI. In the EBS small sculpins eat primarily non-pandalid shrimp and benthic amphipods. In the AI the primary diet items are polychaetes, benthic amphipods, and mysids.

Miscellaneous shallow fish is a composite group containing a variety of demersal fishes, including poachers (Agonidae), lumpsuckers (Cyclopteridae), snailfishes (Liparidae), Arctic and saffron cod (Gadidae), ronquils (Bathymasteridae), wolffishes (Anarhichadidae), prowfish (Zaproridae), lampreys (Petromyzodontidae), hagfish (Myxinidae), and others.

Although these species are encountered on NMFS trawl surveys, they are either too rarely encountered to estimate biomass, small for effective catch by the gear, or inhabit untrawlable areas, so biomass for this complex was estimated by assuming EE was 0.8 for the group in all three models.

Because there is little to no life history information available for species in this group, P/B was assumed to be 0.4 and Q/B was assumed to be 4.0. This default assumption for groundfish production and consumption rates in the absence of life history information is common to the GOA, EBS, and AI models.

EBS miscellaneous shallow fish diet compositions were estimated from food habits collections taken aboard EBS trawl surveys during 1991, but modified to reproportion the prey items and make jellyfish a minor component of the diet (as opposed to the dominant one). This modification was though to better represent the diet of the species other than snailfish and prowfish, the species most represented in survey catches in the EBS. Food habits data for GOA miscellaneous shallow fish is not available, so diet composition for this group was estimated based on EBS food habits data for this group. The EBS diet composition was modified for the GOA by removing within group cannibalism (to prevent artificial blow up of a top-down balanced group), and re-allocating jellyfish in diets to pelagic gelatinous filter feeders based on information from food habits experts that these groups may be confused in preserved samples combined with field observations. The AI diet was originally based on prowfish stomachs collected in the AI as part of the bottom trawl surveys. It was later modified in the manner described above for the EBS diet data, for the same reasons.

The miscellaneous shallow fish biomass pedigree was 8 in all three models (no estimate available, top down balance). P/B and Q/B parameters were rated 7 in all three ecosystems (general literature review from a wide range of species). Diet compositions rated 5 in all three models (estimate based primarily on some species but modified to include others in the category).

Octopi (Order Octopoda) are cephalopod molluscs which are related to squids. They range in size from tiny to huge, with the one of the largest species in the world inhabiting Alaskan waters. The North Pacific giant octopus, *Enteroctopus dofleini*, is the largest of all octopods. While this species may dominate our image of the octopus species complex in the Alaska, there are many more octopus species found in the area, many of which are currently being described (E. Jorgenson, AFSC, pers. comm., 2004). In general, short lifespans of 1 to 5 years with a single reproductive period are reported for octopod species (Boyle, 1983). In Japan, where giant Pacific octopus support directed fisheries, seasonal inshore-offshore migrations are reported, with mating occurring during autumn inshore in less than 100 m depth. Male octopus migrate back offshore and die, while females remain inshore, spawning 18,000 to 74,000 eggs in shallow water nests (< 50 m) on rocky or sandy bottom between May and July. Eggs are brooded for 6-7 months; female octopi do not feed during this period, and die soon after the eggs hatch. Hatchlings are about 10 mm long, and are planktonic until growing to 20 - 50 mm, settling out to benthos in about March of the year following hatching (Roper et al., 1984). Life history in the eastern North Pacific is not as well known, but spawning may be more common in winter months (Hartwick, 1983). It is thought that giant octopus require 3 years to grow to an adult (mature female) size of 10 kg, and that they live 3-5 years. Because at least some octopus species migrate seasonally inshore and offshore, the sexes are often found in separate habitats.

Trawl surveys do not produce reliable biomass estimates for most octopus species (Gaichas et al. 2004), so biomass for this group was estimated by assuming EE was 0.8 for the group in all three models.

Until better information is available, P/B is assumed to be 0.8, and Q/B is assumed to be 3.65 for this relatively productive group. This default assumption for productive forage species is common to the GOA, EBS, and AI models.

Octopus diets have not been quantitatively evaluated in Alaska. EBS octopus diet composition was based on assumptions about the Giant Pacific octopus, which is considered primarily a mollusc feeder with consumption of some crabs. Diet information is not available for GOA or AI octopi, so EBS diet compositions were substituted with the modification that juvenile crabs in the EBS diet which have no GOA equivalent were called miscellaneous crabs.

The octopus biomass pedigree was 8 in all three models (no estimate available, top down balance). P/B and Q/B parameters were rated 7 in all three ecosystems, as were diet compositions (general literature review from a wide range of species).

Octopus are primarily eaten by giant grenadiers and Pacific cod in the GOA, by pinnipeds and Pacific cod in the EBS, and by miscellaneous shallow fish, halibut and cod in the AI. Diet compositions were assumed similar in all systems, with snails, bivalves, hermit crabs, and other crabs comprising the general octopus diet.

Squids (Order Teuthoidea) are cephalopod molluscs which are related to octopus. They are active predators which swim by jet propulsion, reaching swimming speeds of up to 40 km/hr, the fastest of any aquatic invertebrate. The 18 squid species found in the mesopelagic regions of the Bering Sea represent 7 families and 10 genera (Sinclair et al. 1999). Less is known about which squid species inhabit the GOA, but the species there are likely to represent both EBS species and more temperate species in the genus *Loligo*, which are regularly found on the U.S. West Coast and in British Columbia, Canada, especially in warmer years (Gaichas 2003). Squid are distributed throughout the North Pacific, but are common in large schools in pelagic waters surrounding the outer continental shelf and slope (Sinclair et al. 1999). The most common squid species in the Eastern Bering Sea are all in the family Gonatidae. Near the continental shelf, the more common species are *Berryteuthis anonychus* and *Berryteuthis magister*. Further offshore, the likely common species are *Gonatopsis borealis*, *Gonatus middendorfi* and several other *Gonatus* species, according to survey information collected in the late 1980s (Sinclair et al. 1999). The predominant species of squid in commercial catches in the EBS is believed to be the red squid, *Berryteuthis magister*, while the boreal clubhook squid , *Onychoteuthis borealijaponicus*, is likely the principal species encountered in the Aleutian Islands region (Gaichas, 2003). In addition, marine mammal food habits data and recent pilot studies indicate that *Ommastrephes bartrami* may also be common, in addition to *Berryteuthis magister* and *Gonatopsis borealis* (B. Sinclair, AFSC, pers. comm., 2001). The best studied squid in the north Pacific is *Berryteuthis magister*. This species is distributed from southern Japan throughout the Bering Sea, Aleutian Islands, and Gulf of Alaska to the U.S. West Coast as far south as Oregon (Roper et al. 1984). The maximum size reported for *B. magister* is 28 cm mantle length (Arkhipkin et al., 1996). *B. magister* from the western Bering Sea are described as slow growing (for squid) and relatively long lived (up to 2 years). Males grew more slowly to earlier maturation than females (Arkhipkin et al., 1996).

The NMFS bottom trawl surveys are directed at groundfish species, and therefore do not employ the appropriate gear or sample in the appropriate places to provide reliable biomass estimates for the generally pelagic squids (Gaichas et al. 2004). Biomass for this group was estimated by assuming EE was 0.8 in all three models.

Squids are highly productive and voracious predators, so a P/B of 3.2 and a Q/B of 10.62 were adapted from Radchenko (1992) for the EBS, GOA, and AI models.

EBS diet composition was based on information for *Berryteuthis magister* (Radchenko 1992), but were modified to eliminate cannibalism (originally 12%) and reduce consumption of forage fish (from 5% to 2.5%), because this uncertain but high squid consumption may over-amplify the biomass estimates in these top down balanced groups. Consumption of euphausiids and copepods were increased by 12% and 10% respectively to compensate; this was intended to reflect the diet of smaller pelagic squid species not studied by Radchenko (1992). Diet information is not available for GOA or AI squids, so EBS diet compositions were substituted.

The squids' biomass pedigree was 8 in all three models (no estimate available, top down balance). P/B and Q/B parameters were rated 7 in all three ecosystems, as were diet compositions (general literature review from a wide range of species).

Squids are consumed mostly by salmon returning to the GOA, giant grenadier in the EBS, and Atka mackerel and grenadier in the AI. Identical diet assumptions were made between systems.

Pacific salmon (Genus *Oncorhynchus*) is a composite group which includes the ocean going adults and juveniles of pink (*O. gorbuscha*), chum (*O. keta*), coho (*O. kisutch*), sockeye (*O. nerka*), and Chinook (*O. tshawytscha*). Salmon are anadromous fish, spawning in freshwater streams so that fry and small juveniles may rear in protected waters. Juveniles leave freshwater to grow and mature in the open ocean basins for 1 to 5 years depending on the species, when they return to natal streams to spawn. Therefore, they are only transient species in ecosystem models for the continental shelves of the EBS, AI, and GOA. All five species are found in all three areas during in- or out-migrations from other habitats, although within the Aleutian Islands salmon are mainly pink and chum. The five species of Pacific salmon support Alaska's most important and long-running commercial fishery. The first Pacific salmon industrial fishery began on the Columbia River when the Hudson Bay company packed and exported salted Chinook salmon in the 1820s (Browning 1980). By 1880, the target species expanded beyond Chinook to sockeye and coho, canneries operated throughout the Pacific Northwest, and two canneries had opened in Southeast Alaska. Cannery expansion continued to Kodiak in 1882, and by 1888 there were 17 canneries operating in Alaska (Mohr 1979, Browning 1980). The salmon fishery expanded quickly; by 1898 there were 55 canneries from Southeast Alaska to the Aleutian Islands, and up to Norton Sound in the Bering Sea. Almost a million cases were packed that year. The years 1914-1918 saw 53 new canneries open. By 1917 there were 118 canneries operating, and the industry packed 6 million cases worth $46 million. In 1919 the salmon industry reached its cannery peak with 159 canneries and 9 million cases packed (Mohr 1979). By 1929, 156 canneries packed 5 million cases, and profits had fallen (Browning 1980). Landings peaked at nearly 90,000 t in the Gulf of Alaska in the late 1930s and early 1940s, then declined and remained relatively low throughout the 1950s, 1960s, and early 1970s (M. Plotnick, ADF&G, pers. comm., 2005). While there was not foreign fishing for salmon on the continental shelf during this period, there was a Japanese mothership fishery exploiting salmon in the North Pacific ocean which had its greatest fishing effort measured between 1968 and 1972 in the area north of 56^{o}N and east of 175^{o}E (Fredin 1985). It is unknown whether this fishery affected salmon landings in the Gulf of Alaska, but it is known that salmon landings increased again beginning in 1976, and have steadily increased thereafter to average over 100,000 t between 1976 and 2002 (ADFG data). While some have attributed the increase in salmon landings to effective Alaskan management, others have suggested that a favorable climate regime boosted salmon production (Rigby et al. 1995, Mantua et al. 1997).

Pacific salmon were divided into functional groups representing the large mature salmon returning through continental shelf environments on the way back to freshwater spawning grounds (**Salmon Returning**), and the small outmigrating smolts entering the oceanic habitat (**Salmon Outgoing**). Because these groups represent multiple species with different life histories and abundances, these two groups are treated separately and will not be parameterized to interact as adult and juvenile groups comparable to groundfish in future dynamic models.

EBS returning salmon biomass is the 1991 catch + escapement estimated for Western Alaska (Rogers 2001) as proportioned to model strata by the estimated EBS trawl survey biomass for 1991. Outgoing juvenile salmon biomass in the EBS was estimated by top down balance assuming an EE = 0.80. The total biomass of returning mature salmon in the GOA, including ocean going salmon from stocks originating outside the GOA, has been estimated (Rogers 1987), and was proportioned to GOA strata using the proportions of salmon found on the NMFS bottom trawl surveys from the early 1990s. The biomass of outgoing salmon smolts is expected to be about 1/30 of mature GOA biomass (Rogers 1987), but because the salmon returning biomass included stocks from outside the GOA, a conservative biomass for GOA outgoing salmon smolts was estimated as 1/50 of that of returning mature salmon. In the AI Salmon returning biomass was estimated assuming a density of 0.14 throughout all strata. This gave a biomass estimate of 7,982 t. It was assumed that outgoing salmon were found in a density 10% that of returning salmon. The resulting biomass in the AI is 798 t.

Production and consumption rates for each of the five Pacific salmon species were estimated in the field (Aydin 2000) and were weighted by the relative biomass of each species in each area. EBS relative biomass was from Rogers (1997?). In the EBS, this process resulted in returning (mature) salmon P/B and Q/B ratios of 1.65 and 11.6, respectively. The EBS outgoing (juvenile) salmon P/B and Q/B were estimated to be 1.28 and 13.56, respectively. In the GOA relative biomass from Rogers (1987) and ADFG (2003) weighted species specific rates from Aydin (2000) to arrive at the composite P/B of 1.815 and Q/B of 11.826 for salmon returning (mature), and P/B of 1.642 and Q/B of 14.386 for salmon outgoing (smolts). To estimate the salmon returning production rate in the AI, salmon were considered to be mainly pink and chum (from tag data Myers et al. 1996). The resulting PB of 1.8 is the average of the PB of returning chum age 2 & 3 and pink age 1 (age/species specific rates from Aydin, 2000). The same holds for the calculation of QB, which resulted in a value of 12.12. To estimate the salmon outgoing AI production rate, salmon were considered to be mainly pink and chum (from tag data Myers et al. 1996). The resulting PB of 1.77 is the average of the PB of juvenile outgoing chum and pink (age/species specific rates from Aydin, 2000). The same holds for the calculation of QB, which resulted in a value of 16.

Salmon diet information is sparse for Alaska. EBS salmon returning diet was assumed for a generalized salmon foraging on the continental shelf, realizing that the diet composition could vary greatly according to species composition within this composite group. This generalized diet was evenly distributed across squids, chaetognaths, euphausiids, pteropods and copepods (Aydin, AFSC, personal observation). EBS salmon outgoing diet was based on Higgs et al. (1995) again modified to represent generalized smolts of all five species. Salmon diet information was not available for the GOA or AI, so diet composition for EBS salmon returning and EBS salmon outgoing were substituted.

The salmon returning (adult) biomass pedigree was 6 in all three models (historical information). P/B and Q/B parameters were rated 5 in all three ecosystems, as were diet compositions (general model specific to area).

The salmon outgoing (smolt) biomass pedigree was 7 in all three models (multiple incomplete sources). P/B and Q/B parameters were rated 6 in all three ecosystems, as were diet compositions (general life history proxies and generalized diet across species).

Salmon returning to natal streams as spawning adults have half to two thirds unexplained mortality in the GOA and AI, respectively. However, Alaska skates are the largest (40%) source of mortality in the EBS for salmon returning even though salmon is only 2% of Alaska skate diet. Fur seals are the next largest source of salmon mortality in the EBS, followed by sleeper sharks and cod. In the GOA the salmon fleet accounts for 21% of mortality, followed by arrowtooth flounder, salmon sharks, and sea lion predation. In AI, sea lions account for 30% of mortality, followed by salmon sharks and whales. Salmon returning diet assumptions were common to all three models. Salmon outgoing to the ocean as smolts have mostly unexplained mortality in the GOA, but are eaten by fur seals in the EBS and sea lions in the AI.

Bathylagidae is a composite taxonomic group containing all members of this family of deep-sea smelts found in Alaska. Maximum lengths for common North Pacific Bathylagids range from 12-25 cm (Nelson 2003). No biomass estimate exists for this group of small mesopelagic schooling fishes (Nelson 2003), so biomass for this group was estimated by assuming EE was 0.8 in all three models. Similarly, energetics information is not available for this group. Until better information is available, P/B is assumed to be 0.8, and Q/B is assumed to be 3.65 for this relatively productive group. This default assumption for productive forage species is common to the GOA, EBS, and AI models. Bathylagid diet composition information was unavailable for the GOA, so a similar diet composition of 90% euphausiids and 10% copepods was applied to this group as was assumed for all species of small pelagic forage fish. This assumption was also common to the GOA, EBS, and AI models.
The data pedigree for species Biomass was 8 (estimated by Ecopath), while PB, QB, and Diets were 7 (general literature review for a wide range of species).

All forage fish groups (Bathylagids, Myctophids, Capelin, Sand lance, Eulachon, Managed forage, and Other pelagic smelt) are top down balanced in all systems and share an identical zooplankton diet in all systems. However their predators differ significantly across systems. Bathylagids are eaten primarily by pollock in the EBS, by a combination of pollock and grenadiers in the AI, and by grenadiers in the GOA.

Myctophidae is a composite taxonomic group containing all members of this family of lanternfishes found in Alaska. Myctophids are a key prey item for both fish and marine mammals in the Aleutian Islands, particularly towards the west. In a global context, they are among the most abundant group of mesopelagic fishes. The group includes all members of the family, but within Alaska the dominant species are the California headlightfish (*Diaphus theta*), lampfish (*Lampanyctus* sp., *Stenobrachius* sp., *Protomyctophum* sp.), broken line myctophid (*L. jordani*), lanternfish (*L. tenuiformes*), northern lampfish (*S. leucopsarus*), garnet myctophid (*S. nannochiri*), bigfin lanternfish (*Symbolophorus californiense*), and blue lanternfish (*Tarletonbeania crenularis*). All members of the family have photophores on the head and body (hence the name lanternfish/ lampfish). Most myctophids are less than 10 cm long, but some reach about 30 cm. They are oviparous, with planktonic eggs and larvae (Moser and Ahlstrom, 1996). Diurnal migration is exhibited by many: most species have peak abundance between 300 and 1200 m by day and between 10 and 100 m at night (Nelson 1994).

No biomass estimate exists for this group of small mesopelagic schooling fishes (Nelson 2003), so biomass for this group was estimated by assuming EE was 0.8. Similarly, energetics information is not available for this group.

Until better information is available, P/B is assumed to be 0.8, and Q/B is assumed to be 3.65 for this relatively productive group. This default assumption for productive forage species is common to the GOA, EBS, and AI models.

Myctophid diet composition information was unavailable for the GOA, so a similar diet composition of 90% euphausiids and 10% copepods was applied to this group as was assumed for all species of small pelagic forage fish. This assumption was common to the GOA and EBS models, but limited food habits information was available for the AI and was used in that model.

The data pedigree for species Biomass was 8 (estimated by Ecopath), while PB, QB, and Diets were 7 (general literature review for a wide range of species).

All forage fish groups (Bathylagids, Myctophids, Capelin, Sand lance, Eulachon, Managed forage, and Other pelagic smelt) are top down balanced in all systems and share an identical zooplankton diet in all systems. However their predators differ significantly across systems. Myctophids are being eaten by squids in all systems, but by more diverse predators in the AI which has the best myctophid data in general. Pollock and grenadiers also eat myctophids in the AI.

Capelin (*Mallotus villosus*) are small, densely schooling smelts found throughout the shallow nearshore waters of Alaska. They reach a maximum size of 25 cm and an age of 4 years, with maturity arriving at 3-4 years. Spawning takes place in intertidal sand and gravel, and most capelin die after spawning once (Nelson 2003). No biomass estimate exists for this group of small pelagic schooling fishes, so biomass for this group was estimated by assuming EE was 0.8. Similarly, energetics information is not available for this group. Until better information is available, P/B is assumed to be 0.8, and Q/B is assumed to be 3.65 for this relatively productive group. This default assumption for productive forage species is common to the GOA, EBS, and AI models. Capelin diet composition information was unavailable for the GOA, so a similar diet composition of 90% euphausiids and 10% copepods was applied to this group as was assumed for all species of small pelagic forage fish. This assumption was common to the GOA, EBS, and AI models.

The data pedigree for species Biomass was 8 (estimated by Ecopath), while PB, QB, and Diets were 7 (general literature review for a wide range of species).

All forage fish groups (Bathylagids, Myctophids, Capelin, Sand lance, Eulachon, Managed forage, and Other pelagic smelt) are top down balanced in all systems and share an identical zooplankton diet in all systems. However their predators differ significantly across systems. Capelin are eaten by arrowtooth flounder, pollock, and squids in the GOA, and primarily by squids in the EBS and AI.

Sand lance (*Ammodytes hexapterus*) are small, eel-like benthic fish which reach a maximum size of 17 cm and an age of 6 years (Robards et al. 1999), maturing at 2-3 years and 10-15 cm (Nelson 2003). No biomass estimate exists for this group of small benthic schooling fishes, so biomass for this group was estimated by assuming EE was 0.8. Similarly, energetics information is not available for this group. Until better information is available, P/B is assumed to be 0.8, and Q/B is assumed to be 3.65 for this relatively productive group. This default assumption for productive forage species is common to the GOA, EBS, and AI models. Sand lance diet composition information was unavailable for the GOA, so a similar diet composition of 90% euphausiids and 10% copepods was applied to this group as was assumed for all species of small pelagic forage fish. This assumption was common to the GOA, EBS, and AI models.

The data pedigree for species Biomass was 8 (estimated by Ecopath), while PB, QB, and Diets were 7 (general literature review for a wide range of species).

All forage fish groups (Bathylagids, Myctophids, Capelin, Sand lance, Eulachon, Managed forage, and Other pelagic smelt) are top down balanced in all systems and share an identical zooplankton diet in all systems. However their predators differ significantly across systems. Sand lance are also eaten by squids, but mortality is more evenly divided between squids, pollock, rock sole and cod in the EBS, and by squids, arrowtooth flounder, and pollock in the GOA.

Eulachon (*Thaleichthys pacificus*) are anadromous smelts which achieve a maximum size of 25 cm and age of 5, but like capelin, they most often do not survive past one spawning, which may happen as early as age 3 (Nelson 2003). No biomass estimate exists for this group of small pelagic schooling fishes, so biomass for this group was estimated by assuming EE was 0.8. Similarly, energetics information is not available for this group. Until better information is available, P/B is assumed to be 0.8, and Q/B is assumed to be 3.65 for this relatively productive group. This default assumption for productive forage species is common to the GOA, EBS, and AI models. Eulachon diet composition information was unavailable for the GOA, so a similar diet composition of 90% euphausiids and 10% copepods was applied to this group as was assumed for all species of small pelagic forage fish. This assumption was common to the GOA, EBS, and AI models.

The data pedigree for species Biomass was 8 (estimated by Ecopath), while PB, QB, and Diets were 7 (general literature review for a wide range of species).

All forage fish groups (Bathylagids, Myctophids, Capelin, Sand lance, Eulachon, Managed forage, and Other pelagic smelt) are top down balanced in all systems and share an identical zooplankton diet in all systems. However their predators differ significantly across systems. Eulachon are primarily eaten by squid in the EBS and AI, and squid combined with arrowtooth flounder in the GOA.

Other Managed forage is a composite group which includes other members of a North Pacific management category known as “forage fish” aside from the separately grouped and more common capelin, eulachon, sand lance, bathylagids, and myctophids (see above). Managed forage includes the Pacific sandfish (*Trichodon trichodon*), gunnels (Pholidae), bristlemouths and anglemouths (Gonatostomatidae), and pricklebacks, warbonnets, eelblennys, cockscombs, and shannys (Sticheidae). No biomass estimate exists for this group of generally small but numerous fishes, so biomass for this group was estimated by assuming EE was 0.8. Similarly, energetics information is not available for this group. Until better information is available, P/B is assumed to be 0.8, and Q/B is assumed to be 3.65 for this relatively productive group. This default assumption for productive forage species is common to the GOA, EBS, and AI models. Managed forage diet composition information was unavailable for the GOA, so a similar diet composition of 90% euphausiids and 10% copepods was applied to this group as was assumed for all species of small pelagic forage fish. This assumption was common to the GOA, EBS, and AI models.

The data pedigree for species Biomass was 8 (estimated by Ecopath), while PB, QB, and Diets were 7 (general literature review for a wide range of species).

All forage fish groups (Bathylagids, Myctophids, Capelin, Sand lance, Eulachon, Managed forage, and Other pelagic smelt) are top down balanced in all systems and share an identical zooplankton diet in all systems. However their predators differ significantly across systems. Managed forage are primarily eaten by squid in the EBS and AI, and squid combined with arrowtooth flounder in the GOA, but we know little about them in any system.

Other pelagic smelts is a composite group which includes herring smelts or argentines (Argentinidae), surf smelts (*Hypomesus pretiosus*), whitebait smelts (*Allosmerus elongatus*), and rainbow smelts (*Osmerus mordax*). No biomass estimate exists for this group of small pelagic schooling fishes, so biomass for this group was estimated by assuming EE was 0.8. Similarly, energetics information is not available for this group. Until better information is available, P/B is assumed to be 0.8, and Q/B is assumed to be 3.65 for this relatively productive group. This default assumption for productive forage species is common to the GOA, EBS, and AI models. Other pelagic smelt diet composition information was unavailable for the GOA, so a similar diet composition of 90% euphausiids and 10% copepods was applied to this group as was assumed for all species of small pelagic forage fish. This assumption was common to the GOA, EBS, and AI models.

The data pedigree for species Biomass was 8 (estimated by Ecopath), while PB, QB, and Diets were 7 (general literature review for a wide range of species).

All forage fish groups (Bathylagids, Myctophids, Capelin, Sand lance, Eulachon, Managed forage, and Other pelagic smelt) are top down balanced in all systems and share an identical zooplankton diet in all systems. However their predators differ significantly across systems. Other pelagic smelts are primarily eaten by squid in the EBS and AI, and squid combined with arrowtooth flounder in the GOA, but we know little about them in any system.

6.5 Benthic Invertebrates

Tanner crab (*Chionoecetes bairdi*) is a large brachyuran (true) crab in the family Majidae that ranges from the Kuril Islands and the southeast Bering Sea to Oregon in relatively warmer and deeper waters than its congener, the snow crab (*C. opilio*) (Slizkin 1989, Orensanz et al. 1988). While it is difficult to determine the age of crabs, Tanner crabs are thought to live to 14 years of age, with males of commercial size ranging from 7 to 11 years and 1-2 kg (ADF&G 1994). Tanner crabs comprised approximately two thirds of the measured benthic invertebrate biomass in the Central and Western GOA during the late 1970s (Feder and Jewett 1986). However, by the mid 1990s biomass was substantially reduced for this commercially important species, to the extent that directed Tanner crab fisheries around Kodiak were closed from 1994-2000. The Kodiak fishery reopened in 2001-2006 (Sagalkin 2004, 2006). Tanner crab fisheries off the Alaska Peninsula were closed from 1989-1999, and reopened in the 2000-1, 2004-5, and 2005-6 seasons (Mattes 2006). Bering Sea Tanner crab fisheries have been closed since 1997 (Woodby et al 2005).

Tanner crabs were modeled as a single biomass pool in the AI and GOA models, and as adults and juveniles (<5cm carapace width) in the EBS model. Adult Tanner crabs are found only in the middle and outer southeast model strata in the EBS; the biomass estimate for 1991 is from NMFS (Stevens et al. 2002). Juvenile EBS Tanner crab biomass was estimated using a top down balance with an EE=0.80. Although there were some estimates of biomass for GOA Tanner crabs from NMFS and ADF&G trawl surveys during the early 1990s, none were sufficient to meet the apparent groundfish predation demand estimated from food habits sampling. Trawl surveys are not designed to estimate crab biomass in the GOA, and the crab surveys conducted by ADF&G are too limited in spatial extent to apply Gulfwide, so biomass for this group was estimated by assuming EE was 0.80. This procedure resulted in biomass estimates two orders of magnitude higher than those estimated by the NMFS GOA trawl survey, and 71% higher than the highest estimate produced by any ADF&G survey from 1989-2002. Note that this Tanner crab biomass estimated by the early 1990s GOA model is an order of magnitude lower than that reported for the late 1970's (Feder and Jewett 1986), and so seems plausible. AI Tanner crab biomass was also estimated using a top down balance with an EE of 0.80.

P/B and Q/B parameters for Tanner crabs were derived from Trites et al. (1999) and from stock assessment information available for the EBS (OSCEAP 1986). EBS adult Tanner crab P/B and Q/B were estimated to be 1 and 2.75, respectively, while juvenile Tanner crab values were 1.35 and 3.84 in the EBS. These values were adapted for the whole population biomass pools in the GOA and the AI so that the P/B and Q/B were 1 and 3, respectively in both models.

Diet information for adult and juvenile Tanner crabs was available only for the EBS from a Russian survey of the area in 1972 (Tarverdieva 1976). This information was specific to adult and juvenile crabs, but was averaged to account for the entire populations of the GOA and AI, since no other information was available.

The Tanner crab biomass pedigree was 2 for EBS adults (direct regional estimate with poor subregional resolution) and 8 for EBS juveniles and the entire populations in the GOA and AI (no estimate available, top down balance). P/B parameters were rated 6 for all ages in all three ecosystems (general life history proxy), while Q/B parameters were rated 5 for all ages in all three ecosystems (same species in historical time period). Diet compositions rated 5 in the EBS for both age groups (same species in historical time period) and 7 in the AI and GOA (general literature review).

Tanner crab juveniles (EBS) are eaten by cod, small sculpins, and sea stars. The juveniles eat very small clams, based on data from the 1970s from Russia. Adult bairdi have a biomass estimate in the EBS, but are top down balanced in the AI and GOA. In those systems octopus causes the most mortality, followed by eelpouts in the AI and cod in the GOA. About 10% of mortality is unexplained in the EBS, with 72% of mortality caused by cod predation and 12% from the crab pot fishery. There are no current fisheries in AI or GOA. Bairdi adults in the EBS and all bairdi in all areas use diets from the EBS, where adults eat mostly polychaetes and clams.

King Crab (Lithodidae) is a composite group of Anomuran crabs which contains red king crab (*Paralithodes camtschaticus*), blue king crab (*Paralithodes platypus*), and golden or brown king crab (*Lithodes aquispina*) in Alaska (Orensanz et al. 1998). In terms of habitat preference, summer distributional patterns for red king *P. camtschaticus* and Tanner crab *Chionoecetes bairdi* were examined by manned submersible in the southeast Alaska fjord. Videos showed highest crab densities for both species were in the sand-mud habitat, while no crabs were observed in the rock wall and algae habitats. Peak depths are distinct, 75 m for king crab and 145 m for Tanner crab (Zhou & Shirley, 1998). Such distribution changes seasonally, at least for ovigerous female red king crab, which has been monitored with ultrasonic biotelemetry. Crabs occupied deep water between summer-fall (June and mid-November) then moved to relatively shallow water during late-fall winter (mid-November and early March), then returned to deeper water before molting and mating in spring. Females were nonrandomly distributed both in deep and shallower waters, their behavior and degree of aggregation changing seasonally. Crabs were more aggregated in winter; females of mixed age-classes formed dense aggregations in shallow water. They were less so in summer and fall. Adult males were associated with aggregations during late winter and early spring (Stone et al. 1993). In golden crabs the number of days between the first and last egg hatching is about 34; about 192 days after the last egg hatched, females molted, the eggs being extruded 2 days after the molt. The egg clutches are incubated for some 362 days, successive egg clutches happening about 590 days apart. (Paul and Paul, 2001a). Laboratory studies showed that even when some test males had exclusive access to three ripe females, not all induced the third female to ovulate but the first two mates produced viable clutches with 81-100% of eggs exhibiting development. For the third mate these proportions decreased to 56 to 100%. (Paul and Paul, 2001b). These commercially important crabs are currently fished only in the EBS (red in Bristol Bay and blue near St. Matthews Island) and AI. The king crab fisheries in the Aleutians are reported off Adak for red king crab *Paralithodes camtschaticus* and golden (brown) king crab *Lithodes aequispinus.* Both fisheries were open during 1991 and 1994, the first one was closed in 1996. King crab biomass has changed dramatically in the GOA over the past century. Red king crabs were commercially fished as early as 1935 in the GOA (Feder and Jewett 1986), with the peak commercial landings occurring in the 1966 at 45,000 t, and steady landings in the 10,000 t range throughout the 1970's. The landings, and presumably the biomass, of GOA king crabs dropped off abruptly in 1982, and the fishery was closed in 1983-1984 (Feder and Jewett 1986). GOA king crabs have not recovered as of 2006.

King crabs were modeled as a single biomass pool in the AI and GOA models, and as adults and juveniles (<10cm carapace length) in the EBS model. Biomass estimates for adult EBS king crabs are 1991 NMFS EBS bottom trawl survey estimates, as supplemented by 2002 EBS slope survey estimates. Juvenile EBS king crab biomass was estimated using a top down balance with an EE=0.80. No crab specific surveys take place in the AI, so biomass was roughly estimated based on catches and a logistic model: king crab catches were summed over a 3 year window from 1991 to 1994 and then averaged. Therefore, 1991 + 1992 + 1993 catch is biomass in 1991 assuming there at least had to be the biomass of the three next years in the stock. Likewise for 1992 + 1993 + 1994, and so on. Then the 3 year windows for the years 1991-1994 were averaged to give a minimum biomass estimate of King crab in Adak. No comprehensive surveys of king crab biomass in the GOA have been conducted. We assumed that king crab biomass remains at a historical low in the GOA. Limited surveys in areas of historical king crab abundance were used to estimate king crab density: ADFG surveys around Kodiak (1989) indicated a density of 0.18 t/km^2, which was rounded down to 0.1 to account for unsurveyed areas with lower abundance in the central GOA shelf and gully model strata, and ADF&G surveys near the Alaska peninsula (2002) indicated a king crab density of 0.004 t/km^2, which was increased to 0.005 for balance in the western GOA shelf and gully model strata. King crabs were assumed to be absent from eastern GOA model strata, and all slope strata, although limited NMFS trawl survey data suggests that density on the central slope may be as high as 0.002 t/km^2.

P/B and Q/B parameters for king crabs were derived from Trites (1999) and from stock assessment information available for the EBS (OSCEAP 1986). EBS adult king crab P/B and Q/B were estimated to be 0.6 and 2.7, respectively, while juvenile king crab values were 1.5 and 3.7 in the EBS. These values were adapted for the whole population biomass pools in the GOA and the AI so that the P/B and Q/B were 0.6 and 3, respectively in both models.

Diet information for adult and juvenile king crabs was available only for the EBS from a Russian survey of the area in 1972 (Tarverdieva 1976). This information was specific to adult and juvenile crabs, but was averaged to account for the entire populations of the GOA and AI, since no other information was available.

The king crab biomass pedigree was 2 for EBS adults (direct regional estimate with poor subregional resolution), 5 for GOA king crabs (direct estimate but with highly uncertain scaling factors), 7 for AI king crabs (multiple incomplete sources), and 8 for EBS juveniles (no estimate available, top down balance). P/B parameters were rated 6 for all ages in all three ecosystems (general life history proxy), while Q/B parameters were rated 5 for all ages in all three ecosystems (same species in historical time period). Diet compositions rated 5 in the EBS for both age groups (same species in historical time period) and 7 in the AI and GOA (general literature review).

King crab juveniles (EBS) are eaten by large sculpins. King crab adults have very different sources of mortality between systems. Biomass is so low in the GOA that a few large sculpins eating them is a huge source of mortality (85%), while EBS adult mortality is dominated by Pacific cod (20%) and the crab fishery (14%). The crab fishery dominates AI mortality at 62%, followed by thornyhead, halibut, and whiteblotched skate predation. All diet data for king crabs is derived from the EBS, where they eat a variety of benthos, including snails, polychaetes, clams, and urchins (almost entirely sand dollars).

Snow Crab (*Chionoecetes opilio*) is a large brachyuran (true) crab in the family Majidae that ranges throughout the Arctic into southeast Bering Sea in relatively colder and shallower waters than its congener, the Tanner crab (*C. bairdi*) (Slizkin 1989, Orensantz et al. 1998). While it is difficult to determine the age of crabs, snow crabs are thought to be similar to Tanner crabs in that they live to 14 years of age, with males of commercial size ranging from 7 to 11 years and 0.5-1 kg (ADFG Wildlife Notebook Series). Snow crabs are the target of an economically important fishery in the EBS. However, they are extremely rare in the GOA and AI; a trace biomass of less than a ton Gulfwide was estimated from NMFS trawl surveys. In results and discussion from the GOA and AI model, snow crabs are not included.

Snow crabs were modeled as adults and juveniles (<5cm carapace width) in the EBS. Adult snow crabs are found in all model strata in the EBS; the biomass estimate for 1991 is from NMFS (Stevens et al. 2002). Juvenile EBS snow crab biomass was estimated using a top down balance with an EE = 0.80.

P/B and Q/B parameters for snow crabs were derived from Trites (1999) and from stock assessment information available for the EBS (OSCEAP 1986). EBS adult snow crab P/B and Q/B were estimated to be 1 and 2.75, respectively, while juvenile snow crab values were 1.35 and 3.84 in the EBS.

Diet information for adult and juvenile snow crabs was available only for the EBS from a Russian survey of the area in 1972 (Tarverdieva 1976).

The snow crab biomass pedigree was 2 for EBS adults (direct regional estimate with poor subregional resolution) and 8 for EBS juveniles (no estimate available, top down balance). P/B parameters were rated 6 for all ages (general life history proxy), while Q/B parameters were rated 5 for all ages (same species in historical time period). Diet compositions rated 5 in the EBS for both age groups (same species in historical time period).

Snow crabs are only modeled in the EBS, where juveniles are eaten by eelpouts and cod, sea stars, then octopus. Juveniles eat benthic detritus, polychaetes and clams. Opilio adults have much (66%) unexplained mortality, followed by fishery mortality (16%) and cod predation (8%). Opilio eat polychaetes, bivalves, detritus, and other benthic prey.

Pandalid shrimp is a composite group which contains commercial shrimp species in the family Pandalidae, including the pink shrimp (*Pandalus borealis*), the humpy shrimp (*Pandalus goniurus*), the sidestripe shrimp (*Pandalopsis dispar*), the coonstripe shrimp (*Pandalus hypsinotis*), and the spot shrimp or spot prawn (*Pandalus platyceros*). Pandalid shrimps are opportunistic feeders and have a boreo-artic distribution in both the Pacific and Atlantic Oceans, inhabiting varying depths and habitat types. Spots and coonstripes are generally associated with rock piles, coral, and debris-covered bottoms, whereas pinks, sidestripes, and humpies typically occur over muddy bottom. Pink or northern shrimp can occur anywhere between 30-1,460 m; humpies and coonstripes usually inhabit shallower waters, 10-370 m; spot shrimp (or spot prawn) range from 5 to 450 m, and sidestripes can be found somewhat deeper, 45 to 640 m though most concentrations occur at depth greater than 70 m. Most pandalids have seasonal migrations, from deep to shallow waters and up the water column. For example, pink shrimp, may move off the bottom towards the evening, occupy the whole water column through the night, and return to the bottom in early morning. Pandalids are protandric hermaphrodites, which means they mature as males and then become females. The females carry anywhere between a few hundred to up to 4,000 eggs until they hatch; clutch size is generally proportional to the size of the female. Pandalids tend to spawn in fall and hatch in spring, but this may vary among species and range. Pandalid shrimps have been used as ecosystem indicators in the Gulf of Alaska, their abundance declined quickly following water column warming caused by an abrupt climate change after 1977 (Anderson, 2000). Like Tanner crabs and king crabs, Pandalid shrimp appear to have declined dramatically in the GOA since fishery catches peaked during the 1960's (Orensanz et al. 1998). No comprehensive measurement of Gulfwide Pandalid biomass has ever taken place, but the evidence for decline comes from both fishery landings time series and nearshore small mesh trawl surveys conducted by ADF&G (Anderson and Piatt 1999).

Due to the low catchability of shrimps in bottom trawl surveys, Pandalids in the EBS and AI were estimated by assuming an EE of 0.8. Although there were some estimates of biomass for GOA Pandalids from NMFS and ADF&G trawl surveys during the early 1990's, none were sufficient to meet the apparent groundfish predation demand estimated from food habits sampling. NMFS groundfish trawl surveys are not designed to estimate shrimp biomass in the GOA, and the small mesh surveys conducted by ADF&G are too limited in spatial extent to apply Gulfwide, so biomass for this group was estimated by assuming EE was 0.8. This procedure resulted in a biomass estimate three orders of magnitude higher than that estimated by the NMFS GOA trawl survey.

The P/B of 0.57 and Q/B of 2.4 was based on growth and longevity studies of spot shrimp in Prince William Sound, Alaska (Kimker et al. 1996). These values were used in all three models. Shrimp diets were assumed identical in all three models and were estimated from information found in Feder (1978) and Rice (1981).

Biomass pedigree for all models was 8 (no estimate available, top down balance), while P/B and Q/B were 5 (Alaskan area reference for appropriate species, but covering limited species in this functional group). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Pandalid shrimp are important prey items, but little information is available on their diets or their biomass, so common assumptions (including top down balance) were made in all models. Pandalids in the GOA are eaten by pollock (35%), arrowtooth (13%), and flathead sole (10%). Pandalids in the EBS are also consumed by pollock (57% of mortality). In the AI, most mortality of pandalid shrimp is from miscellaneous shallow fish and sculpin predation (41% combined). Pandalid shrimp eat benthic detritus, benthic amphipods and euphausiids and clams.

Non-Pandalid shrimp is a composite group which contains all other (generally non-commercial) shrimp species outside the family Pandalidae. At least seven families comprise this group, including Penaeidae, Sergestidae, Caridea, Oplophoridae, Pasiphaeidae, Hippolytidae, and Crangonidae. The most representative genera are *Spirontocaris* sp. (6 species), *Eualus* sp. (11 species), *Crangon* sp. (8 species), *Argis* sp. (6 species), and *Metacrangon* sp. (4 species) but multiple other genera are also included (*Metapenaeopsis* sp, *Sergestes* sp, *Bentheogennema* sp., *Hymenodora* sp., *Pasiphaea* sp. (glass shrimp), *Parapasiphae* sp. (grooved-back shrimp),. *Lebbeus* sp., *Heptacarpus* sp., *Sclerocrangon* sp., and *Rhynocrang* sp.). Non-pandalid shrimps have a wide depth range, though most of them are generally found in the mesopelagic zone, located roughly around at 200 m depth. None of them support a commercial fishery in Alaskan waters, though they do in some other areas of the North Pacific. Hyppolytids (cleaner shrimps) are known to associate with anemones; within Alaska (around Kodiak Island), the pink sea anemone *Cribrinopsis fernaldi* was observed surrounded by several species of Caridean shrimp. These were aggregated in a radial pattern beneath or just beyond the anemone's tentacle canopy. The caridean species observed included *Eualus suckleyi*, *Spirontocaris* sp., *Lebbeus grandimanus*, *L. groenlandicus* and *Pandalus tridens*, but not *Pandalus borealis*, although it was probably also present. The number of shrimps per anemone increased with depth from 61 to 115m; more shrimp were observed on silty-sand than on sandy-gravel substrates. (Stevens and Anderson, 2000).

Non-pandalid shrimp biomass for all models was estimated by assuming EE was 0.8. For the GOA, this procedure resulted in a biomass estimate five orders of magnitude higher than that estimated by the NMFS GOA trawl survey.

The P/B of 0.57 and Q/B of 2.4 were based on growth and longevity studies of spot shrimp in Prince William Sound, Alaska (Kimker et al. 1996), and were applied to non-pandalid shrimp in all three models. Diets were likewise assumed identical to those of pandalid shrimp, as no data were available specific to non-pandalids.

Biomass pedigree for all models was 8 (no estimate available, top down balance), while P/B and Q/B were 6 (ranking of 5 were appropriate for Pandalidae, this was downgraded for non-pandalid shrimp due to species differences). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Non-pandalid shrimp are important prey items, but little information is available on their diets or their biomass, so common assumptions (including top down balance) were made in all models. GOA non-pandalids are eaten primarily by pollock and grenadiers. Most mortality on EBS non-pandalid shrimp is from sculpins (15%), grenadiers (14%), and pollock (13%) to a lesser extent. In the AI, non-pandalid mortality is mostly from deep dwelling miscellaneous fish (prowfish) and juvenile pollock (40% combined). Non-pandalid shrimp eat benthic detritus, benthic amphipods and euphausiids and clams.

Sea Stars is a composite group which contains all members of the class Asteriodea, particularly the Family Asteriidae. One of the most common species in Alaska, and especially the GOA, is *Ctenodiscus crispatus*, the mud sea star, but the family is well represented and varied. Other common species include: blackspined sea star *Lethasterias nanimensis*, cookie star *Ceramaster patagonicus*, crested sea star *Lophaster furcilliger*, cushion sea star *Pteraster tesselatus*, fish-eating star *Stylasterias forreri*, northern sea star *Dipsacaster borealis*, redbanded sea star *Leptasterias coei*, rose sea star *Crossaster papposus*, scarlet sea star *Pseudarchaster parelii*, spiny red star *Hippasteria spinosa* and sunflower sea star *Pycnopodia helianthoides*. Sea stars do not have a sharp demarcation between the arms and central body; they move along the sea floor using their tube feet. Most sea stars are predators, feeding on either sessile or slow-moving prey such as mollusks and barnacles; sea stars turn a portion of their stomachs out through the mouth, which enables them to digest exogenously.

For EBS biomass, the estimate from the 1991 summer trawl survey was used without adjustment. Biomass estimates for GOA sea stars were drawn from multiple sources; a density estimate for western GOA model strata was taken from 1993ADFG groundfish surveys off the Alaska Peninsula and Kodiak Island. Central and eastern GOA model strata sea star densities were taken from Feder and Jewett 1986, which reported the results of Northern GOA surveys conducted in the 1970s which were designed to estimate biomass of benthic epifauna and infauna. Using older estimates from an invertebrate specific survey increased the biomass estimate for sea stars by more than 100% relative to the NMFS GOA trawl survey estimates, where sea stars are incidental catch. Biomass in the AI was estimated by assuming an EE of 0.8.

The P/B of 1.21 for sea stars was calculated for intertidal species by Zaika (1983) and Asmus (1987). Little information exists for consumption rates of invertebrate benthic predators in the model regions. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). Diet compositions were obtained from the Alaska-wide OCSEAP invertebrate studies summarized by Feder and Jewett (1981): identical diets were assumed for all three models.

Biomass pedigree for EBS was 3 (direct sampling, but poor catchability) and 4 for the GOA (direct sampling methods had to be supplemented by literature values due to balancing issues). For AI, biomass pedigree was 8 (no estimate available, top down balance). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Sea stars have different biomass estimates between systems, which may account for some difference in estimated mortality. In the EBS and GOA, trawl survey biomass estimates of sea stars exist, but may be of different quality due to differences in habitat and sampling nets. In AI sea star biomass is a top down balance so it’s a minimal estimate. The highest EBS sea star mortality is from the flatfish trawl fishery, but is <1%, as are all other known mortality sources. Sculpins and king crab cause the AI mortality of 73% for this minimal biomass estimate. Pollock cause most GOA mortality (39%). Sea stars eat more than 90% clams in all systems (diet was a common assumption between models).

Brittle Stars is a composite group which contains all members of the class Ophiura, which includes both brittle and basket stars. The basket star *Gorgonocephalus eucenemis* has been reported in Alaska. Three families of brittle stars are found in Alaska, Ophiuridae, Ophiocomidae and Amphiuridae. Species include *Ophiurida chilophiurina*, *Amphiophiura megapoma*, *Opniura leptocteni*, *O. maculata*, *O. sarsi*, *Ophiocantha normani*, *Ophiopholis aculenta*, *Amphiodia euryaspis*, *Amphiopholis pugetana* and *A squamata*. Ophiurids or brittle stars (snake stars) have a well marked central disc and usually five arms. The arms are long and flexible, which allows them to move rapidly (by wriggling them) as they have no tube feet like the sea stars. The basket stars (Order Euryalida) have a similar structure to that of snake stars, but are usually larger. The arms are very distinct, highly forked and branched, and even more flexible than those of brittle stars. Snake and basket stars can be found in shallow water, and a few species can adapt to brackish water (unusual in echinoderms) but they are also found in deeper waters; brittle stars in particular can be dominant in many parts of the deep sea. Most ophiuroids are either scavengers or detritus feeders, however they also prey on small live animals like small crustaceans and worms. Basket stars on the other hand, filter-feed on plankton with their arms, for the most part.

The EBS biomass estimated from the 1991 summer trawl survey was too low to balance the model (EE>5), so the top-down balance method was used with EE=0.8. It is not surprising that the trawls undersample these benthic invertebrates. Central and eastern GOA model strata brittle star densities were taken from Feder and Jewett 1986, which reported the results of Northern GOA surveys conducted in the 1970s which were designed to estimate biomass of benthic epifauna and infauna. This density was also used for western GOA model strata in the absence of other information. Using older estimates from an invertebrate specific survey increased the biomass estimate for brittle stars by more than three orders of magnitude relative to the NMFS GOA trawl survey estimates, where brittle stars are unlikely to be retained and basket stars are often fragmented. Biomass in the AI was estimated by assuming an EE of 0.8.

The P/B of 1.21 for brittlestars was calculated for intertidal species by Asmus (1987). Little information exists for consumption rates of invertebrate benthic predators in the model regions. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999).

Diet compositions were obtained from the Alaska-wide OCSEAP invertebrate studies summarized by Feder and Jewett (1981): identical diets were assumed for all three models.

EBS and AI biomass pedigrees were 8 (no estimate available, top down balance) while GOA biomass was considered a 4 (direct sampling methods had to be supplemented by literature values due to balancing issues). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Brittle stars are top down balanced in EBS and AI, but had a biomass estimate from the GOA. Eelpouts and flathead sole account for most mortality in the EBS and GOA, as do other sculpins and eelpouts in the AI. (We note that the eelpout diet is all from the EBS, so this represents an indirect common model assumption applied to brittle stars). Diets were assumed identical between systems, with some benthic amphipods and the rest of the diet from benthic detritus.

Urchins, dollars, and cucumbers is an assemblage of the echinoderms within the Echinoidea (sea urchins and dollars) and the Holothuroidea (sea cucumbers). Species found in Alaska include *Echinacea* sp., *Strongylocentrotus* sp (sea urchin); Family Clypeasteridae (sand dollars); Family Cucumariidae, and *Pentamera* sp. (sea cucumber).

The EBS biomass estimated from the 1991 summer trawl survey was too low to balance the model (EE>20), so the top-down balance method was used with EE=0.8. It is not surprising that the trawls undersample these benthic invertebrates. Central and eastern GOA model strata urchin dollar cucumber densities were taken from Feder and Jewett 1986, which reported the results of Northern GOA surveys conducted in the 1970s which were designed to estimate biomass of benthic epifauna and infauna. This density was also used for western GOA model strata in the absence of other information. Using older estimates from an invertebrate specific survey increased the biomass estimate for urchins dollars and cucumbers by two orders of magnitude relative to the NMFS GOA trawl survey estimates, where small echinoderms are unlikely to be retained. Biomass in the AI was estimated by assuming an EE of 0.8.

Rough estimates of P/B for western Bering Sea urchins averaged 0.61 as calculated by Banse and Mosher (1980) and this value was used for this functional group in all models. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999).

Diet compositions were obtained from the Alaska-wide OCSEAP invertebrate studies summarized by Feder and Jewett (1981): identical diets were assumed for all three models. However, since macroalgae grazing was not quantified in these results, 25% of diet was assumed to be macroalgae.

EBS and AI biomass pedigrees were 8 (no estimate available, top down balance) while GOA biomass was considered a 4 (direct sampling methods had to be supplemented by literature values due to balancing issues). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Urchins, dollars, and sea cucumbers have similar biomass estimates despite the sources being top down balanced in the EBS and AI and a biomass estimate from surveys in GOA. However, the EE was very low in the GOA (0.27) compared with a top down balance using EE = 0.80. Echinoderms are by southern rock sole in the GOA, followed by Dover sole and northern rock sole. More predation pressure is observed for this group in the EBS from yellowfin sole, northern rock sole, and commercial crabs. It seems possible that the existence of the large small flats community in EBS places more demands on this group relative to the other systems. Echinoderms are eaten by sea otters in the AI, and also to a lesser extent in the GOA. They are assumed to eat benthic detritus and algae in all systems.

Snail (Class Gastropoda) includes all gastropods except for pteropods. Their life histories and ecology are very diverse, which allows them to fill in a number of niches. Within Alaska, the group encompasses both shallow (intertidal to 200 m) and deep species (200-300 m) such as *Bathybembix* sp. They may also be pelagic, such as the heteropods, which have a finlike foot and reduced shells. Whelks, false tritons (Family Buccinidae) and moonshells (Family Naticidae) are also found in Alaskan waters. While most gastropods are herbivores, many feed on organic debris and others are carnivores. Predatory snails commonly drill holes into the shells of their prey which include other snails as well as skate egg cases, worms, sea urchins and fish.

The EBS biomass estimated from the 1991 summer trawl survey was too low to balance the model (EE > 1), so the top-down balance method was used with EE = 0.8. It is not surprising that the trawls undersample these benthic invertebrates. GOA biomass for this group was estimated by assuming EE was 0.8. This procedure resulted in a biomass estimate two orders of magnitude higher than that estimated by the NMFS GOA trawl survey. AI biomass was also estimated by assuming an EE of 0.8.

A P/B value of 1.81 for intertidal snails was calculated by Asmus (1987). Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999).

Feder and Jewett (1981) report that *Neptunea* and *Solariella* snails feed on polychaetes, other infauna, and detritus in the eastern Bering Sea: for lack of information, diets of snails were equally proportioned between representatives of these groups and macroalgae.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Snails are top down balanced in all systems. Even though we have different ranges of predators between systems we get similar biomass density estimates by this method. In the GOA and EBS snail mortality is dominated by octopus predation, followed by bairdi and opilio in the EBS. In the AI Atka mackerel are a major source of snail mortality, followed by northern rock sole. Diet composition was assumed identical between systems.

Hermit crabs (Family Paguridae) are Anomuran crabs which encase their abdomens within empty gastropod shells (Barnes 1980**).** Approximately 28 species of hermit crabs have been identified in Alaskan waters. Both polychaetes (annelids) and/or amphipods (crustaceans) have been found to be comensals with pagurids from the Alaska shelf, namely *Pagurus aleuticus, P. capillatus, P. confragosus, P ochotensis , P. rathbuni, P. setosus, P. trigonocheirus, Elassochirus cavimanus* , and *Labidochirus splendescens.*

The EBS biomass estimated from the 1991 summer trawl survey was too low to balance the model (EE > 1), so the top-down balance method was used with EE = 0.8. It is not surprising that the trawls undersample these benthic invertebrates. GOA biomass for this group was estimated by assuming EE was 0.8. This procedure resulted in a biomass estimate three orders of magnitude higher than that estimated by the NMFS GOA trawl survey. AI biomass was also estimated by assuming an EE of 0.8.

A P/B of 0.82 is reported for hermit crabs by Volvenko (1995) and Dulepov (1995) and this value was used for all models. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999).

Hermit crabs were assumed to consume infauna and detritus; for lack of better data, diet proportions were assumed to be equally split between clams, polychaetes, miscellaneous worms, and detritus in all ecosystems.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Hermit crabs are eaten by juvenile pollock, octopus, cod, adult pollock and halibut in the GOA. In the EBS hermit crab mortality is primarily from cod and opilio, while octopi account for 60% of mortality in the AI. Hermits are top down balanced in all systems, and share a diet composition.

Miscellaneous crabs group includes all non commercial species of crabs, except for hermit crabs, which are a separate group (see above). Within Alaskan waters the group is an assemblage of some 50 species, including about 14 stone crabs (Family Lithodidae), 14 spider crabs (Family Majidae) and 6 pea crabs (Family Pinnotheridae). Though not crabs per se, mud shrimps are also included in this group (Family Axiidae).

The EBS biomass estimated from the 1991 summer trawl survey was too low to balance the model (EE > 6), so the top-down balance method was used with EE = 0.8. It is not surprising that the trawls undersample these benthic invertebrates. GOA biomass for this group was estimated by assuming EE was 0.8. This procedure resulted in a biomass estimate three orders of magnitude higher than that estimated by the NMFS GOA trawl survey (which was also inadequate to balance consumption within the ecosystem). Biomass in the AI was estimated by assuming an EE of 0.8.

The P/B estimate for misc. crabs in all models was assumed to be the same as for hermit crabs, 0.82, above. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999).

Miscellaneous crabs were assumed to consume infauna and detritus; for lack of better data, diet proportions were assumed to be equally split between clams, polychaetes, miscellaneous worms, and detritus in all ecosystems.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Miscellaneous Crustaceans is a group that consolidates most of the arthropods not found in any of the other groups. It is an assemblage of barnacles, ostracods, cladocerans, isopods, cumaceans and sea spiders. Cumaceans can be found either in the intertidal zone or in deep seas. They are generally smaller than 8 mm in size, but can reach up to 25 mm. As a rule they burrow in the surface sediments and become active swimmers in open waters at night. Sea spiders (or picnogonids) feed on soft-bodied invertebrates, particularly cnidarians, nudibranchs, and other small gastropods; larval pycnogonids often live as parasites within cnidarian tissues. Most are very small but some of the largest ones can be up to 20 inches across. Sea spiders have been found at depths of up to 2,850 m off Newport, Oregon.

No biomass estimates for this group were available for any of the modeled ecosystems, so biomass was estimated using the top-down balance method with EE = 0.8.

Dulepov (1995) calculated a P/B ratio specific to benthic amphipods of 7.4 (compared to pelagic amphipod P/B of 1.5) and this higher value was assumed to apply to miscellaneous crustaceans. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999).

Miscellaneous crustaceans were assumed to consume detritus; however, detritus consumption was assumed to be split evenly between detritus and benthic bacteria, to make trophic levels comparable between benthic and pelagic secondary consumers (e.g. copepods).

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Benthic Amphipods groups at least 10 families of benthic crustaceans within the order Amphipoda: Caprellidae, Gammaridae, Ampeliscidae, Corophiidae, Eusiridae, Haustoriidae, Isaeidae, Ischyroceridae, Lysianassidae, and Pardaliscidae. Benthic amphipods may be facultative predators when they compete for space with other organisms such as the northern sand dollar *Echinarachnius parma*. This in part, may explain alternative benthic communities in the eastern Bering Sea. In general though, benthic amphipods are scavengers and are important in recycling organic material (Schmitt, 1968). Studies on northern Bering Sea benthic amphipod show that high latitude species grow slowly, take 2 to 4 years to mature, reach a large size, and have long lifespans. Amphipod growth rates and molting rates appear to be decoupled, resulting in small adults at warm temperatures and large adults at lower temperatures. It is believed that at warm temperatures molting occurs rapidly irrespective of tissue growth, and that sexual maturity is reached after a fixed number of molts. Alternatively, gonad development is also temperature-dependent and may drive maturation, regardless of the number of molts experienced. Amphipods have linear or exponential growth rates, as opposed to the familiar asymptotic curve (they do not reach a maximum size). Consequently, secondary production is highly dependent upon the proportion of large individuals in the population as opposed to the proportion of young, which is the pattern prevailing in populations of species with maximum size. Production is correlated with standing stock but not the P:B ratios. This may be the case for other organisms with non asymptotic growth, and thus seems to be comparable only as an index of generation time (Highsmith and Coyle, 1991). Benthic amphipods are common in the diet of juvenile skates (Orlov, 1998).

No biomass estimates for this group were available for any of the modeled ecosystems, so biomass was estimated using the top-down balance method with EE = 0.8.

Dulepov (1995) calculated a P/B ratio specific to benthic amphipods of 7.4 (compared to pelagic amphipod P/B of 1.5) and this higher value was used in all three models. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999).

Benthic Amphipods were assumed to consume detritus; however, detritus consumption was assumed to be split evenly between detritus and benthic bacteria, to make trophic levels comparable between benthic and pelagic secondary consumers (e.g. copepods).

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Benthic amphipods are a specific diet item in many fish food habits, so we expected the mortalities are different for this group between systems. However, large, top-down balanced, low trophic level groups dominate benthic amphipod mortality before the effects of groundfish predation can be observed this far down in the food web. Bivalves dominate mortality in the EBS and GOA followed by non-pandalid shrimp. Non-pandalid shrimp cause the most mortality in the AI, followed by bivalves and pandalids. Groundfish data accounts for small proportions of total benthic amphipod mortality in the GOA, with adult pollock at less than 3%, in the EBS with eelpouts at 2%, and in the AI with myctophids at the high of 6.7%.

Anemones (Class Anthozoa, Order Actiniaria) is an assemblage of sea anemones, which are large, solitary cnidiarian polyps characterized by stinging tentacles surrounding an oral opening at the top of a tube-like body, which is attached to hard benthic substrate (including hermit crab/snail shells) at its base by a pedal disc (Barnes 1980). Anemones are found anywhere from the intertidal zones down to trenches (to 6,000 m). Within Alaska, they are relatively more abundant in the Eastern Bering Sea, though are commonly found throughout both the Gulf of Alaska and the Aleutian Islands. Species occurrence is not very well documented, as many sea anemones are only identified as actiniarians on trawl surveys (some 80%). Some of the most frequently observed species include *Liponema brevicornis, Meridium* sp., and *Uricina* sp.

For EBS biomass, the estimate from the 1991 summer trawl survey was used without adjustment. GOA Anemone biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this wide ranging group of invertebrates, the 1999 survey biomass from deep strata was substituted to give a better estimate of total population biomass. Biomass in the AI was estimated using data from the Gulf of Alaska as surrogate, keeping density depth specific, so shallow and middle have a higher density than deep areas. The density estimates were taken from the 1993 ADFG surveys around Kodiak for the deep areas, and around the Alaska Peninsula for the shallow and middle areas.

There was no data on anemone growth rates so they were assumed to have a seasonal generation time, with a P/B of 1/year. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group's proportion of unassimilated food was assumed to be 0.4, rather than 0.2, the default for all other model groups.

These species were initially assumed to be 100% detritivores; however, detritus consumption was split between detritus (60%), benthic bacteria (15%) and benthic crustaceans/amphipods (25%) to make trophic levels comparable with pelagic tertiary consumers (e.g. euphausiids).

EBS and GOA biomass pedigree was considered 3 for anemones, as catch occurs in trawl surveys although they may be undersampled. AI used GOA estimates as a surrogate so the AI pedigree was downgraded to 5 (estimate requiring highly uncertain scaling factors/extrapolation). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Anemones have field-estimated biomass all three systems: from trawl surveys in the GOA and EBS, and from ADF&G survey from GOA transferred to the AI. They are not consumed by predators in the models, and consume only detritus. Even trawl surveys are likely to produce severe underestimates of density for these groups as they are designed to catch fish, not benthic structure forming invertebrates. We strongly caution that biomass estimates for these groups produced in these models should not be considered representative for analyses outside this narrow trophic context.

Corals is a group composed of Anthozoan cnidarians that includes soft corals, cup corals, sea fans, hydrocorals and black corals. In Alaska, corals form gardens, as opposed to reefs like those in the tropics; these gardens can be quite extensive, as those found around the Aleutian Islands, and in very localized areas of the GOA. Main species in the AI include the bubble gum coral *Paragorgia* sp, *Fanellia* sp, *Primnoa* sp (gorgonians), *Thouarella superba* (white gorgonian), *Stylantheca petrograpta* (pink hydrocoral) and *Stylaster* sp (hydrocoral). *Paragorgia* is a long lived cold water gorgonian (gorgonians include the sea fans, bamboo and tree corals) (Wing and Barnard 2003). Within the Aleutians Islands, gorgonians prevail, followed by cup corals, hydrocorals and soft corals. They create a habitat that can be occupied by a diversity of life and provides shelter for numerous organisms, as in Adak Canyon; dead coral maybe covered with gooseneck barnacles, sponge, pink octocoral and bryozoan colonies. In the Eastern Bering Sea soft corals are largely dominant, particularly *Gersemia* sp. and *Eunephthya* sp., there is little of either cup or gorgonian corals. A similar pattern to that of the AI is observed in Gulf of Alaska, where gorgonians also prevail followed by cup corals, but hydrocorals here are the most infrequent instead of soft corals. The most common species are *Callogorgia* sp. and *Primnoa* sp. (found at 161-365 m depth), among the gorgorians and the cup coral *Scleractinia* sp. In terms of frequency, all corals are more numerous in the AI, except for the soft corals in the EBS. Within the AI, the highest abundance of gorgonian corals, was found in the vicinity of Attu and Kiska Islands. In the Gulf of Alaska the highest abundance areas were located off the end of the Kenai Peninsula and in Dixon entrance (the latter is outside the bounds of the current GOA model) (Heifetz 2000).

Specific associations were observed between groups of fish and types of coral. Rockfish, sablefish, Atka mackerel, and arrowtooth flounder were rarely found with soft coral (compared to the other types), whereas gadids, Greenland turbot, greenlings, and other flatfish were found more frequently around them. The branches of *Primnoa* are used for suspension feeding by crinoids, basket stars, anemones, and sponges, mostly at depths greater than 300m. *Primnoa* provides shelter for six rockfish species, as well as crabs and shrimp, and is therefore a key component of the deepwater ecosystem (Krieger & Wing, 2002).

For EBS biomass, the estimate from the 1991 summer trawl survey was used without adjustment. However, the total trawl biomass of 6,500 t for the Bering Sea is probably an underestimate due to difficulty of sampling rocky areas. GOA coral biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. Biomass in the AI was estimated based on the average of the 1990-1993 NMFS survey highest density estimates for the Gulf of Alaska; highest density of coral occurred in the central gulf shelf (0.011); since this would not satisfy the demand in the ecosystem it was multiplied by 8, which is how much more bycatch of coral there is in the AI compared to GOA (7.8333, rounded to 8).

Longevity of 100 years is reported for Aleutian Islands Gorgonians by Andrews et al. 2002. Assuming that this is the length of time for 99% of mortality to occur gives a P/B equal to the mortality rate of 0.046/year. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group's proportion of unassimilated food was assumed to be 0.4, rather than 0.2, the default for all other model groups.

These species were initially assumed to be 100% detritivores; however, detritus consumption was split between detritus (60%), benthic bacteria (15%) and benthic crustaceans/amphipods (25%) to make trophic levels comparable with pelagic tertiary consumers (e.g. euphausiids).

Biomass pedigree was 2 for GOA and 3 for EBS, with the difference between the greater presence of structured corals in GOA habitats sampled by the trawls. AI used GOA estimates as a surrogate so the AI pedigree was downgraded to 5 (estimate requiring highly uncertain scaling factors/extrapolation). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Corals also have field-derived biomass estimates in the GOA and EBS. AI density is eight times the highest area density for the GOA which was 0.011. We caution that these models are ineffective in estimating or validating coral biomass density estimates because there are almost no predators of coral, and even the survey estimates are based on trawl surveys where we don't (can't) trawl in areas of high coral density. They are not consumed by predators in the models, and consume only detritus. We strongly caution that biomass estimates for these groups produced in these models should not be considered representative for analyses outside this narrow trophic context.

Benthic Hydroid (Class Hydrozoa) includes some 200 species which have been identified in Alaskan waters (O'Clair and O'Clair 1998). Hydroids are mostly colonial, either erect, tree-like, or prostrate encrustations on mollusk shells (live or dead), rock, or other hard surfaces. Tree like species are usually not taller than 15 cm. Some hydroids have alternating benthic and pelagic generations. The pelagic medusae are like tiny jellyfish. Reproduction in the group is varied and complex, with many species having a free-swimming planula larva that spends hours/ days in the water column before settling to the bottom (Barnes 1980). The family Sertulariidae, identified as a food item in Alaskan groundfish diets, has been identified as part of the epifaunal community of deep-sea corals (Henry 2001).

On the west Kamchatka Shelf, a rich assemblage dominated by hydroids, bryozoans, and sponges was the favored habitat of young-of-the-year red king crab (*Paralithodes camtschaticus*), and hydroids were considered to be their main food. In the EBS hydroids are also part of the sessile invertebrate communities where young-of-the-year red king crab are found (McMurray et al. 1984, Stevens and MacIntosh 1991). In the SE Bering Sea, the hermit crab *Labidochirus splendescens* (splendid hermit) is typically found in a moon snail shell encrusted with the velvet textured hydroid *Hydractinia* sp. (Kessler, 1985).

No biomass estimates for this group were available for any of the modeled ecosystems, so biomass was estimated using the top-down balance method with EE = 0.8.

There was no data on benthic hydroid growth rates so they were assumed to have a seasonal generation time, with a P/B of 1/year. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group's proportion of unassimilated food was assumed to be 0.4 (rather than 0.2 which was used as the default for all other model groups).

These species were initially assumed to be 100% detritivores; however, detritus consumption was split between detritus (60%), benthic bacteria (15%) and benthic crustaceans/amphipods (25%) to make trophic levels comparable with pelagic tertiary consumers (e.g. euphausiids).

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Benthic hydroids are top down balanced in all systems and are trace in everyone's diet, so the biomass estimates are likely extremely minimal. Mortality of benthic hydroids is primarily from other sculpins in the GOA and EBS, and from king crabs in the AI. They are not consumed by predators in the models, and consume only detritus. Even trawl surveys are likely to produce severe underestimates of density for these groups as they are designed to catch fish, not benthic structure forming invertebrates. We again strongly caution that biomass estimates for these groups produced in these models should not be considered representative for analyses outside this narrow trophic context.

Benthic Urochordata (Phylum Urochordata) or tunicates, includes ascidians also known as sea squirts, sea potatoes, sea onions and sea peaches. The body of an adult tunicate is quite simple, being essentially a sack with two siphons through which water enters and exits. Water is filtered inside the sack-shaped body. Sessile as adults, the larvae of many tunicates are free-swimming, and include a structural precursor to the vertebrate backbone, which disappears in the adult stage. Ascidians are most frequent in the EBS, though they are also found in GOA and AI. Common genera include *Aplidium* sp. *Boltenia* sp, *Styela* sp, *Halocynthia* sp. (Malecha et al. 2005).

For EBS biomass, the estimate from the 1991 summer trawl survey was used without adjustment. Central GOA shelf model strata benthic urochordate density was taken from Feder and Jewett 1986, which reported the results of Northern GOA surveys conducted in the 1970s which were designed to estimate biomass of benthic epifauna and infauna. This density was also used for all other GOA model strata in the absence of other information. Using older estimates from an invertebrate specific survey increased the biomass estimate for benthic urochordates by two orders of magnitude relative to the NMFS GOA trawl survey estimates, where small tunicates are unlikely to be retained. Biomass density in the AI was also estimated using the above data from the Gulf of Alaska as surrogate.

A P/B value of 3.58 for intertidal Ascidians was calculated by Asmus (1987). Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group's proportion of unassimilated food was assumed to be 0.4, rather than 0.2, the default for all other model groups.

These species were initially assumed to be 100% detritivores; however, detritus consumption was split between detritus (60%), benthic bacteria (15%) and benthic crustaceans/amphipods (25%) to make trophic levels comparable with pelagic tertiary consumers (e.g. euphausiids).

EBS biomass pedigree was considered 3, as reasonable catch levels occur in trawl surveys although they may be undersampled. For the GOA and AI, using literature results from non-modeled time periods, values of 6 were assigned to biomass pedigree (historical study not overlapping in time). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Benthic urochordata have biomass information from field surveys in the EBS, GOA, and AI. Over 90% of mortality is unexplained in each system. They are not consumed by predators in the models, and consume only detritus. Benthic urochordata represent potentially important ecosystem components where biomass is not well estimated. Even trawl surveys are likely to produce severe underestimates of density for these groups as they are designed to catch fish, not benthic structure forming invertebrates. We again strongly caution that biomass estimates for these groups produced in these models should not be considered representative for analyses outside this narrow trophic context.

Sea Pens (Octocorallia: Pennatulacea) groups the benthic cnidarians commonly known as sea pens and sea whips. Age and growth estimates for the sea pen *H. willemoesi* have been based on the ring couplets in the axial rod which were considered as annuli. The ring couplet counts indicate growth in total rod length is slow at first, fastest at medium size, and slows toward maximum size, with an estimated longevity approaching 50 yr. They can form large colonies of over 150 cm. (Wilson, et al. 2002). Sea pens are most frequently found in the Gulf of Alaska, but they also occur in the EBS and the AI. Species identified belong to the genera *Halipteris* sp, *Stylatula* sp, *Virgularia* sp, and *Ptilosarcus* sp. Cod and pollock are most commonly caught with sea anemones, sea pens and sea whips (Malecha et al. 2005).

For EBS biomass, the estimate from the 1991 summer trawl survey was used without adjustment. However, the total trawl biomass of 6,600 t for the Bering Sea is probably an underestimate due to difficulty of sampling rocky areas. GOA sea pen biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates. Biomass density in the AI was estimated using the data from the Gulf of Alaska trawl surveys as surrogate.

A 50 year longevity is reported for sea pens in Alaska by Wilson et al. (2002). Assuming that this is the length of time for 99% of mortality to occur gives a P/B equal to the mortality rate of 0.092/year. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group's proportion of unassimilated food was assumed to be 0.4, rather than 0.2, the default for all other model groups.

These species were initially assumed to be 100% detritivores; however, detritus consumption was split between detritus (60%), benthic bacteria (15%) and benthic crustaceans/amphipods (25%) to make trophic levels comparable with pelagic tertiary consumers (e.g. euphausiids).

Biomass pedigree was 2 for GOA and 3 for EBS, with the difference between the greater catch rates of sea pens in GOA habitats sampled by the trawls. AI used GOA estimates as a surrogate so the AI pedigree was downgraded to 5 (estimate requiring highly uncertain scaling factors/extrapolation). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Sea Pens had biomass estimates in all systems but have high unexplained mortality in all systems. They are not consumed by predators in the models, and consume only detritus. Sea pens represent potentially important ecosystem components where biomass is not well estimated. Even trawl surveys are likely to produce severe underestimates of density for these groups as they are designed to catch fish, not benthic structure forming invertebrates. We again strongly caution that biomass estimates for these groups produced in these models should not be considered representative for analyses outside this narrow trophic context.

Sponge (Phylum Porifera) is a varied group, well represented throughout Alaskan waters. In the Eastern Bering Sea however, they are poorly identified, as most are cataloged as “Porifera”. Information on species diversity is better for both the Gulf of Alaska and the Aleutian Islands. GOA dominant species include *Aphrocallistes vastus, Micale loveni, Myxilla incrustans, Halichondria panacea* while in the Aleutians the most frequent species are *Halichondria* cf *sitiens, Polymastia* sp, *Tethya* sp, and *Micale loveni*. Several sponges are classified by their common names only, these include club sponges, cat-o-nine tail sponges, and the hairy lemon sponge (Malecha et al. 2005). Sponges are important live substrates; the stalks of glass sponges (hexactinellids) provide hard substrate and act as habitat islands for deep-sea fauna (Beaulieu, 2001). They also seem to play some role in halibut habitat. When given the choice between bare sand or sand with 16% sponge coverage, halibut demonstrated strong preference for sponge. Sponges also tend to provide shelter from predation; their emergent structure, in otherwise low-relief benthic habitats, may play an important role in the ecology of some juvenile flatfishes. Removal of emergent structure by towed fishing gear and other anthropogenic and/or natural disturbance may influence patterns of distribution for juvenile halibut, as fish redistribute to less preferred habitat, and may decrease survival rates through increased losses to predation (Ryer et al. 2004).

For EBS biomass, the estimate from the 1991 summer trawl survey was used without adjustment. GOA biomass is the average of 1990 and 1993 GOA NMFS bottom trawl survey estimates, except for deep survey strata which were only fully surveyed in 1999. For this wide ranging group of invertebrates, the 1999 survey biomass from deep strata was substituted to give a better estimate of total population biomass. Biomass in the AI was estimated using sponge data from the Gulf of Alaska. Data for the shallow and middle areas in the AI comes from the 1990 and 1993 NMFS GOA survey estimates for the west GOA shelf (660.4 t). Data for the deep areas in the AI comes from the 1999 NMFS GOA slope survey estimates for the west GOA (20011.43).

There were no data on sponge growth rates so they were assumed to have a seasonal generation time, with a P/B of 1/year. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group’s proportion of unassimilated food was assumed to be 0.4, rather than 0.2, the default for all other model groups.

These species were initially assumed to be 100% detritivores; however, detritus consumption was split between detritus (60%), benthic bacteria (15%) and benthic crustaceans/amphipods (25%) to make trophic levels comparable with pelagic tertiary consumers (e.g. euphausiids).

EBS and GOA biomass pedigree was considered 3 (proxy with unknown but consistent bias) for sponges, as catch occurs in trawl surveys although they may be undersampled. AI used GOA estimates as a surrogate, and additionally deepwater areas were not sampled, so the AI pedigree was downgraded to 6 (estimate not overlapping in area). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Sponges are top down balanced in the AI, but we used trawl survey biomass estimates in the EBS and GOA. Sponge mortality is high in the EBS due to opilio predation, while the GOA biomass from trawl surveys results in a very low EE because there are apparently no predators of sponge other than opilio. They are not consumed by predators in the models, and consume only detritus. Sponges represent potentially important ecosystem components where biomass is not well estimated by top down balance using EE=0.80 because they are not major prey of groundfish. Even trawl surveys are likely to produce severe underestimates of density for these groups as they are designed to catch fish, not benthic structure forming invertebrates. We again strongly caution that biomass estimates for these groups produced in these models should not be considered representative for analyses outside this narrow trophic context.

Bivalve (Class Bivalvia) is a group that comprises an assemblage of all mollusks with two bilaterally symmetrical hinged shells, the second largest class of mollusks following gastropods. This group includes clams, mussels, scallops, cockles and scaphopods. Within Alaskan waters there are at least eight families of bivalves that are important as prey: Nuculidae, Nuculanidae, Mytilidae, Pectinidae, Lucinidae, Cardiidae, Tellinidae, Myidae.

EBS bivalve biomass was averaged from benthic grab samples collected across the EBS survey area and reported by (McDonald et al. 1981). The estimate of 60 t/km^2 from these samples was extremely high, and to a certain extent was driven by a few stations that were reported in this study. However, removing these outliers resulted in biomass levels below the total consumption demand of the ecosystem (EE > 1), so the high estimate was accepted: bivalves are an important prey item for many species, and the muddy substrate of the Bering Sea shelf may support extremely high population levels.

GOA biomass for this group was estimated by assuming EE was 0.8. This procedure resulted in a biomass estimate four orders of magnitude higher than that estimated by the NMFS GOA trawl survey, which is not designed to sample benthic infauna. Similarly, biomass in the AI was estimated by assuming an EE of 0.8.

An estimate of P/B = 1.3/year for clams was obtained from Evans (1984), which is comparable to the value 1.47 cited from various sources in the western Bering Sea (Aydin et al. 2002). Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group’s proportion of unassimilated food was assumed to be 0.4, rather than 0.2, the default for all other model groups.

These species were initially assumed to be 100% detritivores; however, detritus consumption was split between detritus (60%), benthic bacteria (15%) and benthic crustaceans/amphipods (25%) to make trophic levels comparable with pelagic tertiary consumers (e.g. euphausiids).

Bivalves for the AI and GOA had a biomass pedigree of 8 (no estimate available, top down balance). Due to the high variance of the EBS estimate, and the fact that it was measured in the 1970s, the EBS pedigree was considered 7 (selection between multiple incomplete estimates with wide range). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Bivalves are represented by a biomass estimate in the EBS, and top down balances in the GOA and AI. All of these biomass estimates are uncertain due to both survey uncertainty and diet uncertainty within higher trophic levels feeding directly on bivalves. The bivalve EE estimate is 0.34 in the EBS, as opposed to the default assumption of 0.80 used for top down balance. Identical diets were assumed between systems. Polychaetes are also top down balanced in the AI and GOA, while the EBS again has a survey biomass estimate. The polychaete EE is 0.22 in the EBS, as opposed to the 0.80 assumed by default. While top down balance is a good way to estimate minimal biomass, we might consider different default EE for lower trophic level groups if enough information on consumption could be gathered. Alternatively, we could improve biomass estimates for these important, diverse, and ubiquitous benthic groups to improve our understanding of ecosystem structure and function.

Polychaetes (Class Polychaeta) includes most marine segmented worms. Polychaetes are well represented within Alaskan fish diets, and numerous families have been identified: Alciopidae, Aphroditidae, Chaetopteridae, Eunicidae, Flabelligeridae, Glyceridae, Lumbrineridae, Maldanidae, Nephtyidae, Nereidae, Onuphidae, Opheliidae, Phyllodocidae, Polynoidae, Sabellidae, Terebellidae, Tomopteridae, Trichobranchidae, Sigalionidae, Euphrosinidae, Syllidae, Sphaerodoridae, Goniadidae, Arabellidae, Orbiniidae, Paraonidae, Spionidae, Cirratulidae, Scalibregmidae, Sternaspidae, Capitellidae, Oweniidae, Sabellaridae, Pectinariidae, Ampharetidae, Serpulidae, Spirorbidae. However, groundfish prey items are often unidentifiable beyond class Polychaeta. For the AI, out of the 37 families listed above, only the first 18 have been identified among stomach contents. The bristles, or setae, of polychaetes project from side flaps called parapods. Polychaete feeding habits vary from detritus feeding to suspension feeding (filtering plankton and detritus from the water using feathery feeding tentacles) to active predation. On hard substrates such as rocks or corals, polychaetes may build temporary or permanent tubes, where they lead stationary lives by filtering the water for suspended food. A few polychaete species, such as scale worms, have taken up a symbiotic lifestyle, living in association with sea stars and limpets or other marine animals. Reproduction is generally through dispersal of gametes directly into the sea. Once fertilized, eggs develop into ciliated larvae called trochophores. These larvae live in the plankton, feeding on suspended algae, until they develop into juvenile worms that settle to the benthos to become adults.

EBS polychaete biomass was averaged from benthic grab samples collected across the EBS survey area and reported by (Feder et al. 1981). GOA biomass for this group was estimated by assuming EE was 0.8; this procedure resulted in a biomass estimate three orders of magnitude higher than that estimated by the NMFS GOA trawl survey, which were insufficient to balance the model. Biomass in the AI was estimated by assuming an EE of 0.8.

An average P/B of 2.97 for polychaetes in multiple ecosystems was calculated from sources cited in Aydin et al. (2002); this is neither species nor system specific. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group's proportion of unassimilated food was assumed to be 0.4, rather than 0.2, the default for all other model groups.

Polychaetes for the AI and GOA had a biomass pedigree of 8 (no estimate available, top down balance). Due to the high variance of the EBS estimate, and the fact that it was measured in the 1970s, the EBS pedigree was considered 7 (selection between multiple incomplete estimates with wide range). Polychaetes were assumed to consume detritus; however, detritus consumption was assumed to be split evenly between detritus and benthic bacteria, to make trophic levels comparable between benthic and pelagic secondary consumers (e.g. copepods). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Miscellaneous Worm Etc. is a composite assemblage containing annelid worms (including oligochaetes, leeches, flatworms), sipunculids (peanut worms), bryozoans (moss animals), and brachiopods (lampshells). For the AI, most of the prey items in this group were either bryozoans (Ectoprocta) or marine worms (Echiuridae).

No biomass estimates for this group were available for any of the modeled ecosystems, so biomass was estimated using the top-down balance method with EE=0.8.

An average P/B of 2.23 for miscellaneous worms was based on the same information as for polychaetes; the P/B for all ecosystems was calculated from sources cited in Aydin et al. (2002); this is neither species nor system specific. Q/B for most benthos was calculated from P/B by assuming a growth efficiency of 0.2 (a rounded average for benthic groups documented in Trites et al. 1999). This detritus feeding group's proportion of unassimilated food was assumed to be 0.4, rather than 0.2, the default for all other model groups.

Miscellaneous Worms were assumed to consume detritus; however, detritus consumption was assumed to be split evenly between detritus and benthic bacteria, to make trophic levels comparable between benthic and pelagic secondary consumers (e.g. copepods).

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B pedigree was considered 6 (estimate from related species in other ecosystems) and Q/B pedigree considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

6.6 Plankton and Detritus

Scyphozoid Jellies, or Jellyfish (Phylum Cnidaria, Class Scyphozoa) are relatively large gelatinous planktonic predators which capture zooplankton prey with stinging cells on tentacles extending from the hemispherical or bell shaped body (Barnes 1980). While identification to species can be problematic (Purcell 2003), common jellyfish in the EBS, AI, and GOA include *Aurelia labiata*, *Cyanea capillata*, *Aequorea aequorea*, and *Chrysaora melanaster*. These jellyfish can form dense aggregations in localized areas, and when they appear in high densities they have been hypothesized to compete with fish for zooplankton prey (Purcell and Sturdevant 2001, Brodeur et al. 2002). However, competition with groundfish could not be confirmed in extensive jellyfish diet studies conducted in Prince William Sound, AK (Purcell, 2003). Because biomass of jellyfish is highly variable and difficult to measure, we used relatively high density estimates from literature, even if they may represent overestimates for the entire regions covered by the models, to explore the maximum potential effects of jellyfish predation within these models.

EBS jellyfish density was the highest density reported for the early 1990s (1994) from surveys of the EBS shelf (Brodeur et al. 2002). In the GOA, a jellyfish density estimate reported in Purcell (2001) was used. This was reportedly the highest density observed in trawl surveys of the GOA which occurred in 1980, which we used as the maximal estimate possible. Other jellyfish biomass estimates from Prince William Sound have been two orders of magnitude lower than the estimate we used, but were also observed vary by an order of magnitude on an annual basis (Purcell 2003). No information specific to the AI existed, so GOA densities were substituted there.

The jellyfish P/B of 0.857 for jellyfish for all three systems was calculated from sources cited in Trites (1999) where P/B was assumed equal to the inverse of the generation time from Arai (1997); this is neither species nor system specific. The jellyfish Q/B of 3 for all three ecosystems was estimated from the summer ration reported in Brodeur et al. (2002).

Jellyfish diets were transformed to % wet weight from the % frequency of occurrence reported for 1997 and 1999 (then averaged) in Brodeur et al. (2002). This diet was used in all three ecosystems.

Biomass pedigree for all models was 4 for the EBS (direct estimate with limited confidence), 5 for the GOA (highly uncertain scaling factors from PWS to whole GOA), and 7 for the AI (multiple incomplete sources with wide range). The P/B and Q/B pedigrees were considered 6 (estimate from related species in other ecosystems). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Biomass densities of jellyfish were estimated by independent references in each system. Sablefish are the largest source of jellyfish mortality in the GOA, as are miscellaneous shallow fish in the EBS and Atka mackerel in the AI. Jellyfish diets were assumed identical in each system.

Fish Larvae is a group intended to represent all planktonic life stages of fish, but this group is not quantitatively connected to modeled groundfish groups. Therefore, it serves primarily as a prey pool within the plankton for planktivorous animals.

Biomass for this group in all models was estimated using top down balance assuming EE = 0.80.

P/B and Q/B for this large zooplankton group was assumed equal to that estimated for euphausiids, because no data specific to this group exists.

Diet for this large zooplankton group was based on that estimated for euphausiids (based on Mauchline 1980): 25% copepods, 15% microzooplankton, 50% large phytoplankton and 10% small phytoplankton.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Fish larvae are top down balanced in all systems. Their primary sources of mortality are schypho jellies in the GOA (80%), and also in the EBS (80%), but Atka adults in the AI (80%). Note that the fish larvae are not connected to actual fish populations so jellyfish really don’t affect recruitment in the models at present.

Chaetognaths (Phylum Chaetognatha) includes arrow worms and the acorn worms (Hemichordata: Enteropneusta). Arrow worms range in size from 3mm to 12cm, are transparent or translucent, and are covered by a cuticle. All species are hermaphroditic, carrying both eggs and sperm. A few species are known to use neurotoxins to subdue prey. *Sagitta* sp has been identified in Alaskan waters. For the Aleutian Islands, they comprise common food items for walleye pollock, Atka mackerels, Pacific ocean perch, northern rockfish, arrowtooth, spectacled sculpin and northern lampfish.

Biomass for this group in all models was estimated using top down balance assuming EE = 0.80.

P/B and Q/B for this large zooplankton group was assumed equal to that estimated for euphausiids, because no data specific to this group exists.

Diet for this large zooplankton group was based on that estimated for euphausiids (based on Mauchline 1980) but with half the consumption of large phytoplankton shifted to other zooplankton group due to chaetognaths large size: 25% copepods, 15% microzooplankton, 25% large phytoplankton, 10% small phytoplankton, and 5% each euphausiids, mysids, pelagic amphipods, pelagic gelatinous filter feeders, and pteropods.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Chaetognath density in each system is driven top down from salmon consumption (where salmon diets were from the EBS) in the GOA, by pollock consumption in the EBS, and by myctophids in the AI. They have the same diets in all areas, which are adapted from a generic large predatory zooplankton from multiple NPZ model sources. Chaetognaths have the potential for multiple interactions with larval fish (eating fish larvae or competing with them for prey, see Brodeur and Terazaki 1999 for Shelikof Strait) but dynamics at this scale are not well captured by these models.

Euphausiids (Family Euphasiidae) is a dominant group within the zooplankton in high latitude seas worldwide. Twenty three species have been identified in the NE Pacific, from northern California to northern Alaska (Kathman, et al. 1986); at least fourteen of these have been identified in Alaskan diets. Common Alaskan genera include *Euphausia* sp., *Nematoscelis* sp., *Stylocheiron* sp., *Tessarabrachia* sp., *Thysanoessa* sp. In the Aleutian Islands the most common species are *Thysanoessa spinifera, T.inermis, T. longipes, Euphausia pacifica,* and *Tessarabrachia oculatum.*

Biomass for this group in all models was estimated using top down balance assuming EE = 0.80.

The P/B of 5.475 was estimated for euphausiids in all three models using information from Smith (1991), who reported a range of 2% to 6% per day for spring-late summer *T. inermis* and *T. raschi*, during 1980-81 (warm and cold years), higher estimates include egg production females only. We used 3%/day for half the year. The Q/B for euphausiids was estimated by assuming a growth efficiency of 0.35.

Diet for this large zooplankton group was based on Mauchline (1980), but modified to include microzooplankton: 25% copepods, 15% microzooplankton, 50% large phytoplankton and 10% small phytoplankton.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 5 (general model specific to area). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Euphausiids are top down balanced in all systems, a situation which should be corrected with field data for this important forage species when/if it becomes available. In the AI, euphausiid biomass is driven by myctophid and squid consumption, while in the GOA capelin dominate euphausiid mortality followed by pollock, and in the EBS pollock are responsible for most euphausiid mortality. No source accounts for more than 25% of mortality.

Mysids is a group comprised mostly by the Order Mysidacea, however unidentified malacostraca (which includes decapods, amphipods, and isopods among others) are also within this group. Represented in Alaskan diets are at least 24 of the 48 mysid species reported for the northeast Pacific (Kathman et al. 1986). The most representative families are Mysidae and Eucopiidae, with well represented genera such as *Acanthomysis,* sp., and *Neomysis* sp. In the AI however, these are not main prey items, rather the most commonly consumed species are *Gnathophausia gigas,* and *Meterythrops* sp. Mysids are shrimp-like crustaceans, sometimes referred to as opossum shrimps because the females carry their developing young in a bulging pouch or marsupium formed by at the base of their legs. Females can carry broods of up 30 fry in their pouches, although 6 or 7 is the normal brood size. Young mysids are only released once they are well-developed juveniles. Mysids, cumaceans, amphipod and shrimps and can be found in swarms and these swarms are important in describing the geographic patterns of gray whales feeding from the Chukchi Sea to Baja California (Kim & Oliver 1989, Kathman et al. 1986).

Biomass for this group in all models was estimated using top down balance assuming EE = 0.80.

P/B and Q/B for this large zooplankton group was assumed equal to that estimated for euphausiids, because no data specific to this group exists.

Diet for this large zooplankton group was based on that estimated for euphausiids: 25% copepods, 15% microzooplankton, 50% large phytoplankton and 10% small phytoplankton.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Mysids are eaten by adult pollock and chaetognaths in the GOA, juvenile and adult pollock in the EBS, and by myctophids, pollock and other sculpins in the AI.

Pelagic Amphipods groups a minimum of 9 families which have been identified in Alaskan waters **:** Melphidippidae, Oedicerotidae, Phoxocephalidae, Pleustidae, Podoceridae, Stenothoidae, Synopiidae, Hyperiidae, Phronimidae. Within the Aleutians, the most common family is Hyperiidae followed by Stenothoidae, and only 3 genera have been identified: *Themisto* sp, *Phromina* sp, and *Primno* sp. Hyperiids are primarily nektonic amphipods are mostly commensals and parasitoids of gelatinous zooplankton like medusas, salps, and coelenterates; gammarid and hyperiid amphipods, along with mysids, and euphausiids can prey on eggs and yolk-sac larvae of walleye pollock (Bailey et al. 1993).

Biomass for this group in all models was estimated using top down balance assuming EE = 0.80.

P/B for all three models was estimated from western Bering Sea information (Aydin et al. 2002). Q/B for this large zooplankton group was assumed equal to that estimated for euphausiids, because no data specific to this group exists.

Diet for this large zooplankton group was based on that estimated for euphausiids: 25% copepods, 15% microzooplankton, 50% large phytoplankton and 10% small phytoplankton.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 6 (general life history proxy). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Pelagic amphipods are also driven by chaetognaths in the GOA, by pollock in the EBS and by chaetognaths in the AI followed by Atka mackerel. In the GOA Pollock are third with 13% of mortality.

Pelagic Gelatinous Filter Feeders is a composite group which includes the salps and larvaceans (the only free-swimming pelagic urochordates), and ctenophores. Ctenphores are also known as gooseberries, sea walnuts or Venus's girdles. Both *Salpa* sp. and *Thaliacea* sp. are salps found in diets within the AI, but it is the larvaceans of the Order Copelata that are found most frequently as prey items. There are about 70 species of larvaceans; they can filter particles as small as 1 micron, which enables them to feed on coccolithophorid phytoplankton. Larvaceans reproduce sexually and are mostly hermaphrodites; they are small, typically not longer than 5mm across, but can reach up to 100 mm. They secrete a temporary gelatinous house (they lack a tunic) which they replace several times a day, as it becomes clogged with particles. Salps have the inlet siphon at one end and the outlet at the other end (as opposed to ascidians which have both on the same side). Rather than having cilia to move the water, they contract rhythmically to pump water through the body. They have no larval stage as they develop directly into adult organisms. They commonly form swimming colonies and are bioluminescent. Ctenophores are mainly composed of inert mesoglea, which causes them to have a low rate of metabolism. Many species are bioluminescent. Ctenophores are also known as comb jellies because of the eight "comb rows" of fused cilia. The ctenophores are hermaphroditic, and some species can reproduce asexually. Unlike cnidarians, with which they share several superficial similarities, they lack stinging cells. Instead, in order to capture prey, ctenophores possess sticky cells called colloblasts.

Biomass for this group in all models was estimated using top down balance assuming EE = 0.80.

P/B and Q/B for this large zooplankton group was assumed equal to that estimated for euphausiids, because no data specific to this group exists.

Diet for this large zooplankton group was based on that estimated for euphausiids: 25% copepods, 15% microzooplankton, 50% large phytoplankton and 10% small phytoplankton.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Pteropods (Order Pteropoda) are pelagic mollusks also known as sea butterflies, as their anterior portion of the foot has expanded to form swimming fins. Genera include *Thecosomata* sp, *Lumacina* sp and *Clione* sp. Within Alaskan waters, both *Thecosomata* and *Gymnosomata* are found as part of fish diets. Due to their specific environmental requirements, most single-species populations, as well as species assemblages, characterize various water masses and circulation patterns. Ecological biogeographers have mapped the limits of ranges of numerous taxa and have drawn broad ecological inferences. Being planktonic, both foraminifera and pteropods float passively, or nearly so, with currents (Herman & Andersen, 1989).

Biomass for this group in all models was estimated using top down balance assuming EE = 0.80.

P/B and Q/B for this large zooplankton group was assumed equal to that estimated for euphausiids, because no data specific to this group exists.

Diet for this large zooplankton group was based on that estimated for euphausiids: 25% copepods, 15% microzooplankton, 50% large phytoplankton and 10% small phytoplankton.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 7 (growth efficiency averaged over wide range of species). Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Pteropods are driven by salmon returning in the GOA and then chaetognaths (which were also driven by salmon in the GOA), by chaetognaths in the EBS (driven by pollock) followed by salmon in the EBS, and by chaetognaths and Atka mackerel in the AI, followed by salmon returning. We may be underestimating other components of pteropod mortality because we missing pteropods in diets other than salmon due to sampling time and feeding mode of predators. We sample groundfish in the summer when pteropods are rare, and we lack diet information for forage fish which may consume pteropods.

Copepods (Order Copepoda) are a major zooplankton group worldwide. Most Alaskan species belong to the superfamily Calanoida, which is not surprising as calanoids are the most successful copepods in colonizing pelagic environments. Several families are well represented: within the Family Calanoidae, common genera include *Calanus, Neocalanus,* and *Mesocalanus.* Within the Family Eucalanidae are the genera *Ecucalanus, Rhincalanus,* and *Paracalnus.* Within Family Pseudocalanidae are the genera *Clausocalanus, Ctenocalanus,* and *Pseudocalanus.* Family Aetideidae contains the genera *Aetideopsis, Aetideus, Chiridius, Euchirella,* and *Gaetanus,* and Family Euchatetidae contains genus *Euchaeta*. Family Metridiidae contains genera *Metridia, Pleuromamma, Centropages, Pachyptilus, Candacia, Epilabidocera,* and *Acartia.* Superfamily Harpacticoida contains genera *Oncaea, Corycaeus, Oithona,* and *Copepoda monstrilloida,* and Superfamily Caligoida is also found in Alaska. Though the list of species is extensive, within the Aleutians, only a few of these species have been found as prey, namely: *Candacia columbiae, Candacia* sp, *Neocalanus cristatus.* Though the list of species is extensive, within the Aleutians, only a few of these species have been found as prey, namely: *Candacia columbiae, Candacia* sp, *Neocalanus cristatus.*

Biomass for this group in all models was estimated using top down balance assuming EE=0.80.

P/B of 6 for all three models was derived from the upper range reported in Trites et al. (1999). The Q/B of 27.74 for all three models was estimated from Cooney (1981), which is within the range of 33 reported by Dagg et al. (1982), 26.2 for Trites et al. (1999).

Generalized copepod diets in all three systems were estimated from multiple sources (summarized in a NEMURO NPZ model, Kishi et al. 2007): 50% microzooplankton, 25% large phytoplankton and 25% small phytoplankton.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B pedigree was considered 7 (growth efficiency averaged over wide range of species) in all three models. The Q/B pedigree was 5 (general model specific to area) for the EBS model, and 6 (same group from neighboring system) for the GOA and AI models. Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Copepods are top down balanced in all systems. Their mortality is primarily from euphausiids in the GOA, from euphausiids and pollock in the EBS, and also from euphausiids in the AI. The euphausiids and copepods are estimated to be double the density in the AI as in the GOA and EBS. Surprisingly, the GOA is estimated to have a slightly higher copepod density than the EBS, which may be realistic if we consider the reported importance of large oceanic copepods into the GOA coastal ecosystem (e.g., Cooney, 1986).

Microzooplankton is a composite group of protozoan zooplankton which is intended to represent processes within the pelagic microbial loop.

In the EBS, the density of microzooplankton was estimated as 45 from Olson et al. (2002) for 1999 in and out of a bloom. In the GOA and AI, no data were available to estimate biomass, so microzooplankton were top down balanced assuming an EE = 0.80.

The P/B for microzooplankton was derived from Sorokin (1995) which gives a range of 0.2 to 0.6 per day; we used the low estimate of 0.2 which translates to 36.5 over a half year assumed growing season. The Q/B was then estimated using a growth efficiency of 0.35 (the same default value applied to all pelagic zooplankton).

Microzooplankton were assumed to eat 70% small phytoplankton and 30% pelagic detritus in all models.

Biomass pedigree for the EBS was 7 (multiple incomplete sources with wide ranges) and for the GOA and AI models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 7 (growth efficiency averaged over wide range of species) in all three models. Diet estimates were considered poor (7) due to extrapolation of primarily qualitative data.

Microzooplankton are top down balanced in the AI and GOA, but a biomass estimate was available for the EBS. The EBS estimated microzooplankton EE is 0.225. In the AI and GOA an EE of 0.80 was used to estimate density, and we observe a lower density in the GOA than in the EBS. However, microzooplankton are estimated to have roughly the same density in the AI as in the EBS because of all the copepods in the AI consuming microzooplankton. In top down balanced systems copepods account for 68% of mortality (as engineered) but in the EBS they account for only 20%.

Benthic Bacteria is a composite group of protozoan benthos which is intended to represent processes within the benthic microbial loop.

No data were available to estimate biomass, so benthic bacteria were top down balanced assuming an EE = 0.80 in all models.

The P/B for benthic bacteria was assumed to be the same as that for microzooplankton, which was derived from Sorokin (1995) which gives a range of 0.2 to 0.6 per day; we used the low estimate of 0.2 which translates to 36.5 over a half year assumed growing season. The Q/B was then estimated using a growth efficiency of 0.35 (the same default value applied to all microzooplankton).

Benthic bacteria were assumed to eat 100% benthic detritus in all models.

Biomass pedigree for all models was 8 (no estimate available, top down balance). The P/B and Q/B pedigrees were considered 7 (growth efficiency averaged over wide range of species) in all three models. Diet estimates were considered good (1) because this group was designed to feed entirely on detritus.

Benthic bacteria differences are entirely the result of different proportions of consumers resulting from different top down balances. Algae eaters are snails then urchins in all systems. All are top down balanced and have traces in groundfish diets.

6.7 Primary Producers

Algae includes all macroscopic, non-planktonic primary producers. Biomass for this group was estimated by assuming EE was 0.80 in all models. This likely results in a very low biomass estimate for algae in all systems, given that few groundfish graze on algae and that it is difficult to identify in stomach contents. However, nearshore areas where algae contribute greatly to primary production are proportionally small within the EBS, GOA, and AI models. P/B for algae was from general literature (Luning 1990), and was the same as that used in a model of an Alaskan nearshore ecosystem, Prince William Sound (Okey and Pauly 1999). The pedigree for algae biomass is 8 (no estimate available, top down balance), and the pedigree for P/B is 7 (estimate from multiple incomplete sources).

Large phytoplankton includes all planktonic primary producers above a system-specific size threshold; this category generally includes all diatoms and large dinoflagellates. In the EBS, large phytoplankton were defined as cells >10 micrometers, based on Olson et al. (2002). The distinction between “Large” and “Small” Phytoplankton in the GOA model comes from Strom et al. (2001). Large Phytoplankton are defined in the GOA model as cells larger than 8 micrometers, which likely includes diatom species. The AI model shares the GOA definition. Plankton communities on the GOA continental shelf have a mixture of coastal and oceanic species, with different groups dominating seasonally and spatially. In the pre-1977 time period, over 50 common phytoplankton species and species groups (>1000 cells/liter between April and August 1976, Larrance et al. 1977 as summarized in Sambrotto and Lorenzen 1987) were listed in shelf and coastal environments. Phytoplankton communities experiencing blooms were dominated by diatom species, as expected, but there was a succession in time and space of the species of diatoms that dominated during summer high biomass conditions (Sambrotto and Lorenzen 1987). Of the 50 groups listed, only 7 were present during the entire April-August sampling of Lower Cook Inlet (an area with localized upwelling that maintains relatively high phytoplankton standing stocks throughout the summer). One of these, *Melosira sulcata,* is a neritic species which dominated upper Cook Inlet throughout the period. In contrast, the other dominant diatom groups *Thalassiosira* and *Chaetoceros w*ere both abundant in Cook Inlet in April and May (the period of highest productivity), only *Chaetoceros* dominated in July, and by August the dominant group in Lower Cook inlet was "microflagellates" (which also were reported to dominate in oceanic regions of the GOA—see small phytoplankton below). These phytoplankters were reported to achieve over 10,000 cells/liter on some portions of the shelf, and were thought to be up to an order of magnitude higher in density than in oceanic regions (Larrance *et al.* 1977 as summarized in Sambrotto and Lorenzen 1987). Changes in community composition alter primary production, as well as the production of zooplankton grazers which are more efficient at grazing certain size classes of cells. This is just a backwards way of saying that blooms happen both because stratification and nutrients become available for phytoplankton, and because zooplankton grazers cannot keep up with phytoplankton growth rates for one reason or another when growth conditions are favorable—hence the dominance of large diatoms during blooms demonstrated at several coastal and shelf sites in Sambrotto and Lorenzen (1987). These bursts of diatom productivity, even a single species of diatom in a coastal bay, accounted for up to 25% of total annual productivity of the bay. In the open GOA shelf where nutrient limitation in the surface layer is not found, bloom species might account for a larger portion of annual productivity, although larger grazers are seasonally abundant on the shelf to counteract this tendency.

There is some information from the post 1990 period on GOA plankton community composition and its variability in space and time. Strom et al. (2001) describe GOA shelf phytoplankton community composition as highly variable along the transect they sampled; for example in May 1999, a station further out on the shelf was diatom dominated, while more inshore stations were dominated by small flagellates (these were all described as bloom conditions). A station adjacent to the diatom dominated station (~75 km away) and with a similar overall concentration chl a, sampled one day earlier, was dominated by small dinoflagellates. This is not necessarily in conflict with the idea that plankton species found on the shelf are distributed Gulfwide over longer timescales, as argued in the references from the pre-1977 period. While this post 1990 data is too limited to say much about community composition in general, it does indicate the potential for small scale and short term variability in community composition on the GOA shelf, and defies generalizations about inshore versus offshore dominance by diatoms during the high productivity season.

In the EBS and AI, no system-wide estimates of phytoplankton standing stock were available to estimate biomass, so biomass was estimated using top down balance with an EE of 0.80. Primary production estimates were available for the GOA prior to 1977. These estimates of annual primary production for the GOA continental shelf indicate that it is more productive than any of the surrounding ecological zones (nearshore/estuarine, fjord, and open ocean). Sambrotto and Lorenzen (1987) summarize estimates of annual primary productivity from three locations on the continental shelf, which range from 300-330 g C/m^{2}y. (This compares with 150-200 g C/m^{2}y reported for nearshore and fjord areas, and 50-80 g C/m^{2}y for the oceanic region.) Assuming that C weight is about 45% of dry weight and dry weight is about 15% of wet weight (Valiela 1995), this converts to a wet weight production estimate of 4444 t/km^2 per year. These estimates are based on studies which were conducted prior to 1977. Strom *et al.* (2001) demonstrate the spatial and (possibly) interannual variability in the seasonal cycle of primary production when they describe conditions on a single cross shelf transect in the central GOA. During April of 1998, phytoplankton standing stock measured as chl a varied from bloom (>6 micrograms per liter) in Prince William Sound to "oceanic" (<0.5 micrograms per liter and most cells smaller than 8 micrometers) at most stations on the middle and outer shelf. At the same locations in May of 1999, conditions were reversed with a bloom (2-4 micrograms per liter chl a) observed over the shelf and very low chlorophyll inside Prince William Sound ("oceanic"). The P/B estimated for GOA large phytoplankton (below) was used to estimate the biomass density of 7.8 t/km^2 .

P/B estimates for EBS and GOA phytoplankton were derived from growth rates reported for each cell size class in each region. In the EBS, growth rates for large phytoplankton were averaged over areas with and without bloom conditions during 1999 (Olson et al. 2002) to estimate at P/B of 101.8. We averaged Strom et al's (2001) growth rates for large phytoplankton in April and May over four sampling areas and two years (1998 and 1999) to estimate a P/B of 166.5. The GOA value was used in the AI.

Pedigree for large phytoplankton biomass was 6 in the GOA (historical and single study not overlapping in time) and 8 in the EBS and AI (no estimate available, top down balance). The P/B was rated 5 in the EBS and GOA (same group in historical time period) and 6 in the AI (same group in neighboring region).

Small phytoplankton includes all planktonic primary producers below a system-specific size threshold. In the EBS, small phytoplankton were defined as cells <10 micrometers, based on Olson et al. (2002). Small Phytoplankton are defined in the GOA model based on Strom et al. (2001) as cells smaller than 8 micrometers, which includes flagellates. The AI model shares the GOA definition. Please see the discussion of Large phytoplankton for a complete description of the species composition and variability of phytoplankton on the GOA continental shelf.

In the EBS and AI, no system-wide estimates of phytoplankton standing stock were available to estimate biomass, so biomass was estimated using top down balance with an EE of 0.80. Primary production estimates were available for the GOA prior to 1977. These estimates of annual primary production for the GOA continental shelf indicate that it is more productive than any of the surrounding ecological zones (nearshore/estuarine, fjord, and open ocean). Sambrotto and Lorenzen (1987) summarize estimates of annual primary productivity from three locations on the continental shelf, which range from 300-330 g C/m^{2}y. (This compares with 150-200 g C/m^{2}y reported for nearshore and fjord areas, and 50-80 g C/m^{2}y for the oceanic region.) Assuming that C weight is about 45% of dry weight and dry weight is about 15% of wet weight (Valiela 1995), this converts to a wet weight production estimate of 4444 t/km^2 per year. These estimates are based on studies which were conducted prior to 1977. Strom *et al*. (2001) demonstrate the spatial and (possibly) interannual variability in the seasonal cycle of primary production when they describe conditions on a single cross shelf transect in the central GOA. During April of 1998, phytoplankton standing stock measured as chl a varied from bloom (>6 micrograms per liter) in Prince William Sound to “oceanic” (<0.5 micrograms per liter and most cells smaller than 8 micrometers) at most stations on the middle and outer shelf. At the same locations in May of 1999, conditions were reversed with a bloom (2-4 micrograms per liter chl a) observed over the shelf and very low chlorophyll inside Prince William Sound (“oceanic”). The P/B estimated for GOA small phytoplankton (below) was used to estimate the biomass density of 27.7 t/km^2 .

P/B estimates for EBS and GOA phytoplankton were derived from growth rates reported for each cell size class in each region. In the EBS, growth rates for large phytoplankton were averaged over areas with and without bloom conditions during 1999 (Olson et al. 2002) to estimate at P/B of 110.9. We averaged Strom et al’s (2001) growth rates for large phytoplankton in April and May over four sampling areas and two years (1998 and 1999) to estimate a P/B of 113.4. The GOA value was used in the AI.

Pedigree for large phytoplankton biomass was 6 in the GOA (historical and single study not overlapping in time) and 8 in the EBS and AI (no estimate available, top down balance). The P/B was rated 5 in the EBS and GOA (same group in historical time period) and 6 in the AI (same group in neighboring region).

Large phytoplankton show remarkable similarities in mortality, but there was a standing stock estimate for the GOA and wasn’t in the other systems, so the EE for GOA is 0.28 while the default of 0.80 was used for top down balance in other systems. Small phytoplankton display similar consumption patterns to large phytoplankton, but again there was a biomass estimate for the GOA and not for the other systems. The estimated EE is 0.38 in the GOA but top down balance is with 0.80 which results in pretty high standing stocks already in the EBS. In the EBS the field-based estimate for microzooplankton is higher than that estimated by top down balance in the GOA and AI thus increasing demand for small phytoplankton in the EBS. In the GOA, there were not “excess” microzooplankton as a result of the top down balance, so there is less demand for the (allegedly known) biomass of GOA small phytoplankton.

7. Appendix B: Detailed Estimation Methods

This section details estimation methods used for particular groups. First we detail detritus assumptions by species. Then, the appendix is organized by group, with marine mammal and bird methods first, followed by methods applied to fish groups. The designation of fisheries within the model is described in the final section of this appendix.

7.1 Benthic-PelagicFlows

Overall, benthic:pelagic flows were assumed similar between systems unless data indicated otherwise. The benthic:pelagic ratio in the EBS always favors flow to the benthic detritus whereas in the GOA and the AI the flow may be equally distributed or even favor the pelagic route for the non-benthic groups. See Table 4 in the main text for the order of groups referred to below. Flow partition among detrital pools was as follows:

Table B1. Flow to detrital pools by model group, read as percent to benthic:percent to pelagic.

Benthic:pelagic ratios	EBS	GOA	AI
Model groups from Transient killer whales to dogfish	60:40	50:50	50:50
Model groups from Juvenile pollock to other pelagic smelt ratio for EBS offal:benthic:pelagic	2:58.8:39.2	50:50	50:50
Model groups from Tanner crabs to miscellaneous worms	90:10	90:10	90:10
Model groups from Scypho jellyfish to microzooplankton	60:40	30:70	50:50
Model groups Benthic bacteria (and Algae for the EBS)	90:10	90:10	90:10
Model groups Algae, large and small phytoplankton	50:50	50:50	50:50

7.2 Cetacean Biomass

Biomass for cetaceans was derived from stock assessment information for the entire North Pacific and partitioned to each model area using the best available data. This process is detailed below in tabular form, with one table for each of the EBS, GOA, and AI models. Pinniped and sea otter biomass estimation methods are detailed in the sections for each group in Appendix A.

Table B2. Biomass for cetaceans

EBS	Number of animals	Number reference	Conversions			Conversion reference	Number in model	Body Weight (kg)	Biomass (t/km^2)
			Area	Time	Misc.				
Transient Killer Whales	391	Waite et al. 2002	75%	100%	10%	Abundance split between EBS and ALU; 10% sighting rate of transient vs. resident (Dahlheim pers. comm..)	29	2280	1.35E-04
Sperm/beaked whales	930,000	Rice 1989	0.11%	50%	50%	Percentage of NP deep area which is EBS deep area; summer occupancy; adult males	265	33000	1.77E-02
Resident Killers	391	Waite et al. 2002	75%	100%	100%	Abundance split between EBS and ALU	293	2280	1.35E-03
Dall's Porpoises	24,119	Moore et al. 2002	100%	100%	20%	Turnock & Quinn 1991; vessel attraction	4,824	62	6.04E-04
Harbor Porpoises	48,161	Waite & Hobbs in review	100%	100%	100%	---	48,161	31	3.01E-03
PWS Dolphins	0	Too few sightings to be significant biomass	---	---	---	---	0	79	0
Porpoise/Dolphin	72,280	Sum of Dall's porpoise, harbor porpoise, and Pacific white-sided dolphins					52,985		3.62E-03
Beluga whales	20,025	Angliss & Lodge 2002; mean of estimates from 1999 & 2000 for Bristol Bay stock + Eastern Bering Sea stock in 2000	100%	100%	100%	Angliss & Lodge 2002; 50% of time spent in coastal estuaries, bays, and rivers	20,025	303	1.23E-02
Gray Whales	22,284	Rugh et al. 2005; Rounded average of estimates from 1992 to 2002	100%	5%	100%	Adjusted for animals migrating through and for seasonal residents.	1,000	16177	3.27E-02
Humpback whales	394	Calambokidis et al. 1997	100%	50%	100%	---	197	30408	1.21E-02
Fin Whales	4,051	Moore et al. 2002	100%	100%	100%	---	4,051	55590	4.55E-01
Sei whales	10,000	Tillman 1977; range 7,260 to 12,620	1.87%	100%	100%	Percentage of NP which is in EBS	187	16811	6.33E-03
Right whales	100	Angliss & Lodge 2002; Wada 1973; 100 in modeled area as a maximum	59%	100%	100%	Percentage of modeled area which is in EBS	59	30000	3.55E-03
Minke whales	1,813	Moore et al. 2002	100%	100%	100%	---	1,813	6566	2.40E-02
Bowhead Whales	8,200	IWC 1996; Zeh et al. 1995	10%	42%	33%	Moore & Reeves 1993; Lowry 1993; 10% of EBS in northern Bering; 5 month winter residents; 2/3rds of feeding outside EBS	113	31506	7.17E-03

Table B2. Continued.

ALU	Number of animals	Number reference	Conversions			Conversion reference	Number in model	Body Weight (kg)	Biomass (t/km^2)
			Area	Time	Misc.				
Transient Killer Whales	391	Waite et al. 2002	25%	100%	10%	Abundance split between EBS and ALU; 10% sighting rate of transient vs. resident (Dahlheim pers. comm..)	10	2280	3.91E-04
Sperm/beaked whales	930,000	Rice 1989	0.11%	50%	50%	Percentage of NP deep area which is ALU deep area; summer occupancy; adult males	253	33000	1.46E-01
Resident Killers	391	Waite et al. 2002	25%	100%	100%	Abundance split between EBS and ALU	98	2280	3.91E-03
Dall's Porpoises	302,000	Hobbs & Lerczak 1993	100%	100%	20%	Turnock & Quinn 1991; vessel attraction	60,400	62	6.58E-02
Harbor Porpoises	0	Too few sightings to be significant biomass	---	---	---	---	0	31	0
PWS Dolphins	0	No sightings in area	---	---	---	---	0	79	0
Porpoise/Dolphin	302,000	Sum of Dall's porpoise, harbor porpoise, and Pacific white-sided dolphins					60,400		6.58E-02
Beluga whales	0	Outside area	---	---	---	---	0	303	0
Gray Whales	0	Gray whale population migrates from North Pacific to Bering Sea through Unimak and False Pass	---	---	---	---	0	16177	0
Humpback whales	268	Zerbini et al. 2006; blocks 11 to 17	100%	100%	100%	---	268	30408	1.43E-01
Fin Whales	45	Zerbini et al. 2006; blocks 11 to 17	100%	100%	100%	---	45	55590	4.39E-02
Sei whales	10,000	Tillman 1977; range 7,260 to 12,620	0.21%	100%	100%	Percentage of NP which is in ALU	21	16811	6.33E-03
Right whales	100	Angliss & Lodge 2002; Wada 1973; 100 in modeled area as a maximum	6.75%	100%	100%	Percentage of modeled area which is in ALU	7	30000	3.55E-03
Minke whales	846	Zerbini et al. 2006; blocks 11 to 17	100%	100%	100%	---	846	6566	9.76E-02
Bowhead Whales	0	Outside distribution	---	---	---	---	0	31506	0

Table B2. Continued.

GOA	Number of animals	Number reference	Conversions			Conversion reference	Number in model	Body Weight (kg)	Biomass (t/km^2)
			Area	Time	Misc.				
Transient Killer Whales	174	Dahlheim 1997	100%	100%	10%	10% sighting rate of transient vs. resident (Dahlheim pers. comm..)	17	2280	1.36E-04
Sperm/beaked whales	930,000	Rice 1989	0.17%	50%	50%	Percentage of NP deep area which is GOA deep area; summer occupancy; adult males	399	33000	4.51E-02
Resident Killers	174	Dahlheim 1997	100%	100%	100%	---	174	2280	1.36E-03
Dall's Porpoises	106,000	Hobbs & Lerczak 1993	100%	100%	20%	Turnock & Quinn 1991; vessel attraction	21,200	62	4.50E-03
Harbor Porpoises	31,012	Waite & Hobbs in review	100%	100%	100%	---	31,012	31	3.29E-03
PWS Dolphins	26,880	Buckland, et al.1993	100%	100%	100%	---	26,880	79	7.28E-03
Porpoise/Dolphin	163,892	Sum of Dall's porpoise, harbor porpoise, and Pacific white-sided dolphins					79,092		1.51E-02
Beluga whales	0	Too few sightings to be significant biomass; tagging studies indicate that Cook Inlet stock stays in Cook Inlet	---	---	---	---	0	303	0
Gray Whales	22,284	Rugh et al. 2005; Rounded average of estimates from 1992 to 2002	100%	5%	100%	Adjusted for animals migrating through and for seasonal residents.	1,000	16177	5.54E-02
Humpback whales	1,712	Zerbini et al. 2006; blocks 1 to 10	100%	100%	100%	---	1,712	30408	1.78E-01
Fin Whales	1,397	Zerbini et al. 2006; blocks 1 to 10	100%	100%	100%	---	1,397	55590	2.66E-01
Sei whales	10,000	Tillman 1977; range 7,260 to 12,620	1.10%	100%	100%	Percentage of NP which is in GOA	110	16811	6.33E-03
Right whales	100	Angliss & Lodge 2002; Wada 1973; 100 in modeled area as a maximum	35%	100%	100%	Percentage of modeled area which is in GOA	35	30000	3.55E-03
Minke whales	105	Zerbini et al. 2006; blocks 1 to 10	100%	100%	100%	---	105	6566	2.36E-03
Bowhead Whales	0	Outside distribution	---	---	---	---	0	31506	0

7.3 Marine Mammal Production Rates

A variant of applying a constant mortality rate as an estimate of PB, Siler's competing risk model (Siler, 1979) as modified by Barlow and Boveng (1991) is used to construct a general model of survivorship for marine mammals. The model uses a minimum of information, a surrogate life table scaled by an estimate of longevity. Given these, a survivorship curve is estimated, from which averages of specific life stages (juvenile or adult) may be drawn. The equations as modified by Barlow and Boveng (1991) are as follows:

$$l(x)=lj(x)*lc(x)*ls(x)$$

$$lj(x)=exp[(-a1/b1)*\{1-exp(-b1*x/W)\}]$$

$$lc(x)=exp[-a2*x/W]$$

$$ls(x)=exp[(a3/b3)*\{1-exp(b3*x/W)\}]$$

where: lc is the constant mortality risk experienced by all age classes; lj and ls are the mortality risk due to juvenile and senescent factors respectively. The parameters $a1$, $a2$, $a3$, $b1$ and $b3$ allow flexibility in the shape of the functions.

The values for the surrogate life tables provided by Barlow and Boveng (1991) are shown below. The authors advise taking these as starting values and then fitting to data if possible. When data are not available, it is recommended that those two life histories which encompass that of the species of interest are used to set a range of plausible values. Since the present case required an absolute value, rather than a range, the more conservative survivorship schedule was chosen and PB values estimated from there.

Table B3. Parameters of surrogate life tables:

		a1	*a2*	*a3*	*b1*	*b3*
1	**fur seal**	14.343	0.171	0.0121	10.259	6.6878
2	**Monkey**	30.43	0	0.7276	206.72	2.3188
3	**Human**	40.409	0.4772	0.0047	310.36	8.029

Table B4. Longevity, surrogate life table and ages used to estimate survivorship curves.

Functional group	Life stages	Surrogate life table	Longevity	PB
Sperm whale	adult 15-60	3	60	0.046921
Belugas	adult 7-30	2	30	0.112092
Gray whale	adults 1-60	2	60	0.063365
Fin whale	adult 25-105	3	105	0.026676
Sei	adult 17-70	3	70	0.040015
Right whale	adult 20-85	3	85	0.032778
Minke	adult 12-40	2	50	0.051141
Sea otter	adult 3-20	1	20	0.116863
Walrus	mortality 5%			0.051293
Fur seal	juv 3-7	1	25	0.115826
	adult 8-25	1	25	0.091245
Steller sea lion	adult 8-30	1	30	0.074004
	juv 3-7	1	30	0.122436
harbor seals	adults 3-30	1	30	0.082653
ringed seals	juv+adults 3-46	1	40	0.064447
Larga seal	juv-adult 3-35	1	35	0.082653
wintering (ringed and larga)		ringed=75%, Larga 25%		0.068998

7.4 Marine Mammal Consumption Rates

Consumption rates were calculated for marine mammal using body weights (kg) and individual allometric daily energy requirements (1000 KJ/day) from Hunt et al. (2000, Table 9.3) and estimates of the average caloric content in their prey (calories/gram) from REF. The individual allometric daily energy requirements were converted to calories per day and then to grams per day consumed using the prey caloric values. Percent body weight consumed per day was then calculated and converted to a yearly rate for Q/B. All numbers are presented in Table B5. The Q/B for the porpoise/dolphins group was calculated as the average of the Q/B values for Pacific white-sided dolphins and Dall’s and harbor porpoise.

Table B5. QB marine mammals

	Body Weight [1]	1000 KJ/day[1]	PreyCal/g	Cal/day	G/day	%Body Wt/Day	Q/B
Transient killer whales	2280	437.6	1500	104538939	69693	0.031	11.16
Sperm/beaked whales	18518	2105.5	1500	502986144	335324	0.010	6.61
Resident killers whales	2280	437.6	1500	104538939	69693	0.031	11.16
Dall's porpoises	62	29.3	1500	6999522	4666	0.075	27.47
Harbor porpoises	31	17.4	1500	4156713	2771	0.089	32.63
Pacific white-sided dolphins	79	35.1	1500	8385093	5590	0.071	25.83
Porpoise/Dolphins – EBS	Eastern Bering Sea model has Dall’s porpoise and harbor porpoise						30
Porpoise/Dolphins – ALU	Aleutian Islands model has only Dall’s porpoise						30
Porpoise/Dolphins – GOA	Gulf of Alaska model has Dall’s porpoise, harbor porpoise, and Pacific white-sided dolphins						30
Beluga whales	303	96.3	1500	23005256	15337	0.051	30
Gray whales	16177	1152.3	700	275274725	393250	0.024	8.87
Humpback whales	30408	1849.7	700	441877688	631254	0.021	7.58
Fin whales	55590	2908.3	700	694768275	992526	0.018	6.52
Sei whales	16811	1186	700	283325370	404751	0.024	8.79
Right whales	30000	1552.3	700	370831343	529759	0.022	8
Minke whales	6566	586	1000	139990444	139990	0.021	7.78
Bowhead whales	31506	3136.3	1000	749235547	749236	0.024	8.68
Sea otters	25	24.3	1500	5805065	3870	0.200	73
Walrus/Bearded seals	1200	317.3	1500	75800287	50534	0.042	15.37
N. fur seal juvenile[2]							49.53
N. fur seal adult	28	18.8	1500	4491161	2994	0.107	39.03
East S.S.L. juvenile[2]			1500				39.83

	Body Weight [1]	1000 KJ/day[1]	PreyCal/g	Cal/day	G/day	%Body Wt/Day	Q/B
East S.S.L. adult	198	82	1500	19589107	13059	0.066	24.07
West S.S.L juvenile[2]			1500				39.83
West S.S.L adult	198	82	1500	19589107	13059	0.066	24.07
Resident seals (harbor seal)	60	18	1500	4300048	2867	0.048	17.44
Wintering seals (Spotted & ringed seals)	43	14.2	1500	3392260	2262	0.053	19.20

[1] Hunt et al. 2000; except where noted.

[2] QB calculated from using same growth efficiency as Adults

7.5 Marine Mammal Diet

Both cetaceans and pinnipeds diets were estimated based on feeding habits compiled from multiple published literature. There are multiple references for each species and the information had both species-specific prey and large categories of prey such as “forage fish”; to accommodate all data sources we used the preference method. For multispecies functional groups, the diet for each species within the group was weighted proportionally to the biomass. References for each species diet are shown in Appendix A.

7.6 Seabird Biomass

Colony counts from the Beringean seabird database (maintained by the US Fish and Wildlife Service, USFWS) for 2002-2003 were assigned to geographical areas defined within each ecosystem (EBS, GOA, AI). We defined 10 seabird groups of which only fulmars was made up by only one species; the rest aggregated anywhere from 2 to 8 species. For each seabird species, the counts from all colonies within an area were summed and then converted to biomass by multiplying them by the average body mass for that given species. For those seabird categories which involved more than one species (e.g. unidentified murre, unidentified gull), the average weight of all species involved was calculated and subsequently used to estimate the biomass. Species specific biomasses were then summed to get an estimate of a given seabird group. The table below summarizes the counts and biomass information for each seabird species and the corresponding functional groups.

*Biomass seabird species x = Sum of counts in area * average body mass*

Biomass seabird functional group x = Sum of biomass seabird species in group x

Table B6. Summary of the estimated number and corresponding biomass of nesting birds by species in each ecosystem: Aleutian Islands (AI), Eastern Bering Sea (EBS) and Gulf of Alaska (GOA). Biomass is shown in t. Mean weight by species was taken from Hunt et al. 2000, Numbers from USFWS 2003, Beringean Seabird Catalog. N/A values were estimated by other means, see appendix A.

Common Name	Species	Weight (g)	AI	EBS	GOA
Sooty Shearwater		787	5000	100,000	N/A
Short-tail Shearwater		543	745000	14,900,000	N/A
Total Shearwaters			**750000**	**15000000**	N/A
Biomass (in t)			**408.47**	**8169.40**	**67.39**
Common Murre	*Uria aalge*	992.50	7110	1349355	154269
Thick-billed Murre	*Uria lomvia*	964.00	43023	1856628	10540
Unidentified Murre	*Uria* sp.	978.25	28452	923620	1274552
Total Murres (No. Birds)			**78585**	**4129603**	**1439361**
Biomass (in t)			**76.36**	**4032.56**	**1410.10**
Black-legged Kittiwake	*Rissa tridactyla*	407.00	55317	617914	637699
Red-legged Kittiwake	*Rissa brevirostris*	391.00	12708	196143	0
Total Kittiwakes			**68025**	**814057**	**637699**
Biomass (in t)			**27.48**	**328.18**	**259.54**
Cassin's Auklet	*Ptychoramphus aleuticus*	188.00	105450	400	297893
Parakeet Auklet	*Aethia psittacula*	258.00	64613	284490	57070
Least Auklet	*Aethia pusilla*	84.00	2278250	3250493	20
Whiskered Auklet	*Aethia pygmaea*	121.00	6511	26	175
Crested Auklet	*Aethia cristatella*	264.00	873400	1978555	46050
Rhinoceros Auklet	*Cerorhinca monocerata*	520.00	30	0	8787
Total Auklets			**3328254**	**5513964**	**409995**
Biomass (in t)			**459.25**	**868.86**	**87.48**
Tufted Puffin	*Fratercula cirrhata*	779.00	230888	232577	1826505
Horned Puffin	*Fratercula corniculata*	619.00	87202	87308	758606
Unidentified Puffin	*Fratercula* sp.	699.00	0	0	0
Total Puffins			**318090**	**319885**	**2585111**
Biomass (in t)			**233.84**	**235.22**	**1892.42**
Northern Fulmar	*Fulmarus glacialis*	544.00	510460	473517	440193
Total Fulmars			**510460**	**473517**	**440193**
Biomass (in t)			**277.69**	**257.59**	**239.46**
Fork-tailed Storm-Petrel	*Oceanodrama furcata*	55.30	2004400	7640	865226
Swinhoe’s Storm-Petrel	*Oceanodrama monorhis*	35.80	0	0	0
Leach’s Storm-Petrel	*Oceanodrama leucorhoa*	39.80	2257600	11200	489492
Unidentified Storm-Petrel	*Oceanodrama* sp.	43.63	0	0	0
Total Storm-Petrels			**5283198**	**966132**	**2235343**
Biomass (in t)			**200.70**	**0.868**	**67.33**
Double-crested Cormorant	*Phalacrocorax auritus*	1674.00	0	1928	3334
Brandt’s Cormorant	*Phalacrocorax penicillatus*	2103.00	0	0	0
Great Cormorant	*Phalacrocorax carbo*	2109.50	0	0	0
Temminck’s Cormorant	*Phalacrocorax capillatus*	1938.63	0	0	0
Pelagic Cormorant	*Phalacrocorax pelagicus*	1868.00	5106	19083	17298
Red-faced Cormorant	*Phalacrocorax urile*	2157.00	15886	14738	18250
Unidentified Cormorant	*Phalacrocorax* sp.	1938.63	8859	1815	12668
Total Cormorants			**29851**	**37564**	**51550**
Biomass (in t)			**60.98**	**74.18**	**101.82**
Mew Gull	*Larus canus*	403.50	0	254	2845
Black-tailed Gull	*Larus crassirostris*	533.50	0	0	0
Herring Gull	*Larus argentatus*	1135.00	0	961	0
Slaty-backed Gull	*Larus schistisagus*	1327.00	0	2	0
Glaucous-winged Gull	*Larus glaucescens*	1010.00	32767	36509	163343
Glaucous-winged x Herring Gull	*Larus* sp. hybrid	1072.50	0	0	0
Glaucous Gull	*Larus hyperboreus*	1412.50	0	9799	0
Glaucous-winged x Glaucous Gull	*Larus* sp. hybrid	1072.50	0	2	0
Black-headed Gull	*Larus ridibundus*	284.00	0	0	0
Sabine’s Gull	*Xema sabini*	191.00	0	16	0
Unidentified Gull	*Larus* sp.	1072.50	0	34	0
Total Gulls			**32767**	**47577**	**166188**
Biomass (in t)			**33.09**	**51.95**	**166.12**
All Albatross		3090	1500	N/A	N/A
Biomass (in t)			4.635	49.52175812	67.38598265

7.7 Seabird Production Rates

A constant mortality rate was used to estimate PB of the different seabird categories. Thus:

PB = Ln(survival rate)

When there was more than one rate available, the average was used. The survival/ mortality values used to calculate the corresponding PB values for each seabird functional group are shown below.

Table B7. Production. mortality and survival values for each seabird functional group.

Functional group	PB (or Z, mortality rate)	annual mortality * or survival rate **	Resolution (taxonomic level rates refer to)	Source
Shearwater	0.1	0.1*	manx shearwater	Furness, 1987
Murre	0.169488	0.75-0.95**	order level	Schreiber and Burger, 2002
Kittiwake	0.075804	0.926** Middleton Is. AK; 0.930** St George Bering Sea; 0.925** Shoup Bay AK	black-legged kittiwake	Schreiber and Burger, 2002
Auklet	0.169488	0.75-0.95**	order level contains auks (not auklets)	Schreiber and Burger, 2002
Puffin	0.04	0.04*	Puffins	Furness, 1987
Fulmar	0.055	0.055*	Fulmar	Furness, 1987
Storm Petrel	0.12	0.12*	storm petrel	Furness, 1987
Cormorants	0.158727	0.80-0.91**	order level	Schreiber and Burger, 2002
Gulls	0.165782	0.74-0.97**	order level	Schreiber and Burger, 2002
Albatross Jaeger	0.067566	0.91-0.96**	order level	Schreiber and Burger, 2002

7.8 Seabird Consumption Rates and Diets

Seabird consumption rates were taken from Hunt et al. (2000). Seabird diets were estimated based on the diets used by Hunt et al. (2000). Diets for one species were weighted according to its proportion within all three systems (EBS, AI and GOA together). When more than one diet was available for any given species, the diets were averaged and subsequently weighted by the corresponding proportion. Sometimes only the main species diets were used to calculate the final diet for the whole group. Such is the case of the storm petrels, gulls and cormorants. Because the categories used by Hunt et al. (2000) are much broader than those used as functional groups in the ecosystem models, the final percentage for any given food category used by Hunt et al. (2000) was distributed –using the *Preference* choice for diet type- among all functional groups that fell in such category. Whenever there was a stated preferred prey, an arbitrary higher percentage would be fixed to that prey, the remaining portion being allocated equally among the rest of the functional groups that fell in such category. Small percentages, usually those assigned to “unknown”, were lumped with another category. Details are shown in Table B8.

Table B8. Summarized basic table used for seabird diets.

Proportion of sp. in all 3 systems	Functional group/ species	Miscellaneous inverts ~4kj/g	Gelatinous zoop ~ 3 kj/g	Crustacean zoop ~4kj/g	Small cephal ~3.5 kj/g	large cephal.~4 kj/g	Fish low ~3 kj/g	Fish med~5 kj/g	Fish High~7 kj/g	Bird & mammals ~7 kj/g	Carrion Offal & discards ~5kj/g	Unknown ~5kj/g	Preferred prey
	Murres												
45.	Common	+	0	3.7	1.2		56.2	39	0		0	0	
55.	Thick-billed	0.1	+	17.6	5.3		39.6	36	0.4		0	1	
W	Common		0	1.67	0.54	0	25.29	17.55	0	0	0	0	
W	Thick-billed	0.06		9.68	2.92	0	21.78	19.8	0.22	0	0	0.55	
	Sum	0.06	0.0	11.35	3.46	0	47.07	37.35	0.22	0	0	0.55	
	Kittiwakes												
87.22	Black-legged	0	+	7.3	1		45.3	32.5	11.3		0	2.6	
12.78	Red-legged	+	+	1	1.9		23.8	14.5	57.2		0	1.6	
	Black-legged	2.2	0	11.2	.1		1.2	79.9	0	0	0	5.4	
W	Black-legged	0.96	0	8.07	0.48		20.28	49.02	4.93	0	0	3.49	
W	Red-legged			0.13	0.24	0	3.04	1.85	7.31	0	0	0.2	
	Sum	0.96	0.	8.2	0.72	0.	23.32	50.87	12.24	0	0.0	3.69	
	Puffins												
24.53	Horned	3.9	0	11.1	0.7	0	40.7	39	0	0	0	4.6	Hexagrammos
75.47	Tufted	11.90	0	3.4	1.7	0	17	64.4	0	0	0	1.6	Theragra
	Horned	0.1	0	0.7	0	1.2	0.1	97.5	0	0	0	0.4	Mallotus
	Tufted	0.2	0	11.2	0	7.8	0.6	80.2	0	0	0	0	Mallotus
W	Horned	0.49	0	1.45	0.09	0.15	5	16.74	0	0	0	0.61	
W	Tufted	4.57	0	5.51	0.64	2.94	6.64	54.57	0	0	0	0.6	
	Sum	5.06	0.0	6.96	0.73	3.09	11.65	71.31	0	0	0.0	1.22	
	Auklets												
7.42	Parakeet auklet	23.5	+	48.5	0.4	0	4.5	22.1	0	0	0	1	
54.04	Crested	+	+	98.3	0	0	0	0.8	0	0	0	0.90	
32.8	Least	+	+	92.7	0	0	0.3	0.4	0	0	0	6.6	
5.36	Cassin's	0.1	0	94.2	1.1	0	0	4.6	0	0	0	0	Calanoid
	Parakeet	0	0	58.6	0	0	0	41.4	0	0	0	0	Euphausiidae
	Crested	0	0	99.90	0	0	0	0	0	0	0	0	Acanthomysis
0.32	Rhinoceros	0	0	0	1.2	0	0	94.5	1.5	0	0	2.8	
W	Parakeet	0.87	0	3.97	0.01	0	0.17	2.36	0	0	0	0.04	Misc fish
W	Crested	0	0	53.55	0	0	0	0.22	0	0	0	0.24	
W	Least	0	0	30.41	0	0	0.1	0.13	0	0	0	2.16	
W	Cassin's	0.01	0	5.05	0.06	0	0	0.25	0	0	0	0	
	Sum	0.88	0.0	92.98	0.07	0	0.27	2.95	0	0	0.0	2.45	
		med+unknown			5.39								
	Storm-Petrel												
59.17	Fork-tailed	1.3	0.0	32	60.7		1.7	4.2	0	0	0.0	0.1	Euphausiidae
		1.4			misc inverts and unknown								
	Fulmars												
100	Northern	0	0	6	21.2	0	60.6	12.1	0		0	0.1	Theragra
	Northern	0.2	0	0.90	96	0	0.6	2.2	0	0.1	0	0	Gondatidae
	Sum	0.1	0	3.45	58.6	0	30.6	7.15	0	0.1	0	0.05	
		bird_mammal+unknown				0.15							
	Gulls												
93.99	Glaucous-winged	1.6	0	0.90	0		0.2	96.2	0	+	+	1.1	Misc.
	Gull					unkmown to discards							
	Cormorants*												
54.57	Red-faced	0	0	0	0		4	93	2	0	0	1	Ammodytes
40.37	Pelagic	0.2	0	0.6	0		0.6	98.6	0	0	0	0	hexapterus
	Red-faced	0.1	0	15.2	0		15.4	68.90	0		0	0.4	
W	Red-faced	0.03	0	4.37	0		5.58	46.53	0.57	0	0	0.4	Misc. fish
W	Pelagic	0.09	0	0.26	0	0	0.26	41.93	0	0	0	0	
	Sum	0.11	0.0	4.62	0	0.0	5.83	88.46	0.57	0	0.0	0.4	

*Diet for the double crested cormorant (5.06% of all cormorants) was not incorporated; red-faced and pelagic cormorant’s diets were proportioned to add up to 100% instead of 94.94%

7.9 Fish Biomass

The National Marine Fisheries Service Alaska Fisheries Science Center conducts trawl surveys in all three major ecosystems: the Eastern Bering Sea, the Aleutian Islands, and the Gulf of Alaska. All of these surveys take place during the summer season, starting between late May and early June and ending in late July or early August. Because each ecosystem has fundamentally different physical characteristics, the trawl survey methods vary slightly between areas. In addition, the length of the survey time series and the frequency of surveys differ between areas. In this section, we describe the major characteristics of the bottom trawl surveys of the EBS, AI, and GOA which provide much of the input information for the corresponding ecosystem models.

The EBS region has two separate trawl surveys, one for the shelf and the other for the slope. We first describe the shelf survey and then the slope survey. The EBS shelf survey is the longest running continuous trawl survey in Federal waters off Alaska; it has been conducted annually since 1982. The shelf survey design has fixed stations on a grid covering six sampling strata, and it ranges in depth from 50 m to 200 m. Because the EBS shelf survey is a combined shellfish and groundfish survey, the station density increases in areas of high historical crab abundance around the Pribilof Islands. Survey tows at each station last 30 minutes, which often results in an excess of catch which must then be subsampled on deck. The overall area covered by the survey is 495,000 square km (Fig. 2a). The EBS shelf survey uses a different net from all the other surveys we will describe. Because the EBS shelf is very regular and flat, the survey net has no protective roller gear on the footrope. This allows more complete sampling of benthic animals, including commercial crabs, relative to the nets used in the more rugged habitats found on the EBS slope (and in the AI and GOA regions). The EBS slope survey has been intermittent historically (1979, 1981-82, 1985, 1988, 1991), but was standardized formally in 2000 and has been conducted biennially since then. In contrast to the EBS shelf survey, the EBS slope survey uses a stratified random design, with depth and longitudinal strata extending from 200 m to 1000 m depth. This survey covers 32,723 square km of relatively steep and narrow slope habitat (Fig. 2a). The EBS slope survey uses a net with roller gear on the footrope, which protects the net from rough bottom by raising it slightly. While this allows sampling in rougher areas, it does so at the cost of reducing effective sampling of benthic animals. The EBS slope survey and the AI and GOA trawl surveys which use a similar net now tow a small net under the regular net to examine benthic invertebrates which may not be effectively sampled by the survey net, but this is for qualitative purposes only. Therefore, the EBS slope, AI, and GOA trawl surveys are groundfish oriented surveys, and are not used in shellfish assessments.

The AI and GOA regions have similar trawl survey methods which will be discussed together. Both of these areas were surveyed triennially between 1983 and 1999, in alternating years (with a West Coast survey in the intervening third year of each cycle). However, the order of surveys were changed partway through the series. Therefore, the AI surveys occurred in 1980, 1983, 1986, 1991, 1994, and 1997, while the GOA surveys occurred in 1984, 1987, 1990, 1993, 1996, and 1999. Starting in 2000, these surveys went on a biennial schedule with the AI surveyed on even numbered years (the same years as the EBS slope survey) and the GOA on the odd numbered years. Both surveys use a stratified random design for selecting stations between 50 m and 500 m depth, and each station is towed for 15 minutes. Coverage of depths exceeding 500 m is rare in the AI, but the GOA survey has extended as far as 1000 m depth in some years (1984, 1987, and 1999). The maximum depth covered in the GOA was 700 m in 2003, and 500 m in 1990-1996 and 2001. The area covered by each survey is generally 57,000 square km in the AI and 291,840 square km in the GOA (Fig. 2b and 2c). However, in 1987 and 2001 portions of the eastern GOA were not surveyed. As described above, the nets used for these surveys have roller gear on the footrope. These nets are designed to maximize sampling opportunities in these rougher habitats, but as described above may be less effective at sampling benthic invertebrates than the EBS shelf survey net.

Regardless of differences in design, the data collected aboard each of these surveys is the same. For each tow, the catch is sorted to species and the weight and number of each species caught is recorded. For commercially important species, length frequencies by sex are recorded. Other biological collections include otoliths for ageing, gonads for maturity and fecundity studies, samples for genetic work or other research, and of course, stomach samples for food habits studies.

7.10 Fish Production Rates

Production/biomass (P/B) and consumption/biomass (Q/B) for a given population depend heavily on the age structure, and thus mortality rate of that population. For a population with an equilibrium age structure, assuming exponential mortality and Von Bertalanffy growth, P/B is in fact equal to total mortality Z (Allen 1971) and Q/B is equal to (Z+3K)/A, where K is Von Bertalanffy's K, and A is a scaling factor for indigestible proportions of prey (Aydin 2004). If a population is not in equilibrium, P/B may differ substantially from Z although it will still be a function of mortality.

For the Bering Sea, Aleutian Islands, and Gulf of Alaska ECOPATH models, P/B and Q/B values depend on available mortality rates, which were taken from estimates or literature values used in single-species models of the region. It is noted that the single-species model assumptions of constant natural mortality are violated by definition in multispecies modeling; therefore, these estimates should be seen as "priors" to be input into the ECOPATH balancing procedures or other parameter-fitting (e.g. Bayesian) techniques.

Several methods were used to calculate P/B, depending on the level of data available. Proceeding from most data to least data, the following methods were used:

1. If a population is not in equilibrium, total production P for a given age class over the course of a year can be approximated as ($N_{at} \cdot \Delta W_{at}$), where N_{at} is the number of fish of a given age class in a given year, exponentially averaged to account for mortality throughout the year, and ΔW_{at} is the change in body weight of that age class over that year. For a particular stock, if weight-at-age data existed for multiple years, and stock-assessment reconstructed numbers-at-age were also available, production was calculated by summing this equation over all assessed age classes. Walleye pollock P/B for both the EBS and GOA were calculated using this method: examining the components of this sum over the years showed that numbers-at-age variation was responsible for considerably more variability in overall P/B than was weight-at-age variation.

2. If stock assessment numbers-at-age were available, but a time series of weight-at-age was not available and some weight-at-age data was available, the equation in (1), above, was used, however, the change in body weight over time was estimated using fits to the generalized Von Bertalanffy equations described in the consumption section, below.
3. If no stock assessment of numbers-at-age was available, the population was assumed to be in equilibrium, so that P/B was taken to equal Z. In cases for many nontarget species, estimates of Z were not available so estimates of M were taken from conspecifics with little assumed fishing mortality for this particular calculation.

7.11 Fish Consumption Rates

There are multiple methods for estimating the consumption rates (Q/B, consumption per unit biomass) for fish. Four methods were considered in the construction of these models: bioenergetics models (based on laboratory and field experiments), allometric fitting to weight-at-age data (e.g. Essington et al. 2001), evacuation rate calculation from field stomach contents data (e.g. MAXIMS, Jarre et al. 1991) and empirical methods based on morphological characteristics (Pauly 1986). One goal in selecting methods was to choose options which could be used consistently in all three ecosystem models and thus provide reasonable bases for comparison.

It was determined that insufficient data existed for the application of bioenergetics models or evacuation rate calculations; while models existed for a very limited number species, input data such as foraging rates and water temperature specific to the Alaska region were not consistently available, and lack of these data could result in extremely broad error ranges or bias in estimates. Pauly’s (1986) empirical methods have an order-of-magnitude error range and thus were considered as a worst-case solution only.

While bioenergetics data was limited, weight-at-age data existed for many species throughout the region: the method of fitting the generalized Von Bertalanffy growth equations to these data (Essington et al. 2001) was thus selected. (The solution for Q/B given above, (Z+3K)/A, is a solution for a specialized case of the equations, as described below).

The generalized Von Bertalanffy growth equation assumes that both consumption and respiration scale allometrically with body weight, and change in body weight over time (dW/dT) is calculated as follows (Paloheimo and Dickie 1965):

$$\frac{dW_t}{dt} = H \cdot W_t^d - k \cdot W_t^n \qquad (1)$$

Here, W_t is body mass, t is the age of the fish (in years), and H, d, k, and n are allometric parameters. The term $H \cdot W_t^d$ is an allometric term for “useable” consumption over a year, in other words, the consumption (in wet weight) by the predator after indigestible portions of the prey have been removed and assuming constant caloric density between predator and prey. Total consumption (Q) is calculated as $(1/A) \cdot H \cdot W_t^d$, where A is a scaling fraction between predator and prey wet weights that accounts for indigestible portions of the prey and differences in caloric density. The term $k \cdot W_t^n$ is an allometric term for the amount of biomass lost yearly as respiration.

Based on an analysis performed across a range of fish species, Essington et al. (2001) suggested that it is reasonable to assume that the respiration exponent *n* is equal to 1 (respiration linearly proportional to body weight). In this case, the differential equation above can be integrated to give the following solution for weight-at-age:

$$W_t = W_\infty \cdot \left(1 - e^{-k(1-d)(t-t_0)}\right)^{\frac{1}{1-d}} \qquad (2)$$

Where W_∞ (asymptotic body mass) is equal to $(H/k)^{\frac{1}{1-d}}$, and t_0 is the weight of the organism at time=0. If the consumption exponent *d* is set equal to 2/3, this equation simplifies into the "specialized" von Bertalanffy length-at-age equation most used in fisheries management, with the "traditional" von Bertalanffy K parameter being equal to the *k* parameter from the above equations divided by 3.

From measurements of body weight and age, equation 2 can be used to fit four parameters (W_∞, *d*, *k*, and t_0) and the relationship between W_∞ and the *H*, *k*, and *d* parameters can then be used to determine the consumption rate $H \cdot W_t^d$ for any given age class of fish. For these calculations, weight-at-age data available and specific to the modeled regions were fit by minimizing the difference between log(observed) and log(predicted) body weights as calculated by minimizing negative log likelihood: observation error was assumed to be in weight but not aging. A process-error model was also examined but did not give significantly different results.

Initial fitting of 4-parameter models showed, in many cases, poor convergence to unique minima and shallow sum-of-squares surfaces: the fits suffered especially from lack of data at the younger age classes that would allow fitting to body weights near t=0 or during juvenile, rapidly growing life stages. To counter this, the following multiple models were tested for goodness-of-fit:

1. All four parameters estimated by minimization;
2. *d* fixed at 2/3 (specialized von Bertalanffy assumption)
3. *d* fixed at 0.8 (median value based on metaanalysis by Essington et al. 2001).
4. t_0 fixed at 0.
5. *d* fixed at 2/3 with t_0 fixed at 0, and *d* fixed at 0.8 with t_0 fixed at 0.

The multiple models were evaluated using Akaike's Information Criterion, AIC (Anderson and Burnham 2002). In general, the different methods resulted in a twofold range of consumption rate estimates; consistently, model #3, *d* fixed at 0.8 while the other three parameters were free, gave the most consistently good results using the AIC. In some cases model #1 was marginally better, but in some cases, model #1 failed to converge. The poorest fits were almost always obtained by assuming that d was fixed at 2/3.

To obtain absolute consumption (*Q*) for a given age class, the additional parameter *A* is required to account for indigestible and otherwise unassimilated portions of prey. We noted that the range of indigestible percentage for a wide range of North Pacific zooplankton and fish summarized in

Davis (2003) was between 5-30%, with major zooplankton (copepods and euphasiids), as well as many forage fish, having a narrower range of indigestible percentages, generally between 10-20%. Further, bioenergetics models, for example for walleye pollock (Buckley and Livingston 1994), indicate that nitrogenous waste (excretion) and egestion resulted in an additional 20-30% loss of consumed biomass. As specific bioenergetics models were not available for most species, we made a uniform assumption of a total non-respirative loss of 40% (from a range of 25-60%) for all fish species, with a corresponding A value of 0.6.

Finally, consumption for a given age class was scaled to population-level consumption using the available numbers-at-age data from stock assessments, or using mortality rates and the assumption of an equilibrium age structure in cases where numbers-at-age reconstructions were not available.

7.12 Diet Queries for Fish

The most central parameter set for food web models are the diet composition matrices, obtainable through stomach sampling or other analyses. In particular, the elaboration of our food web models with respect to fished species depends heavily on the analysis of 250,000+ stomachs collected by the Resource Ecology and Ecosystem Management (REEM) program. Continuation of this collection will allow for a regular update and improvement of these models. Due to the high resolution and coverage of this diet data, we were able to model functional groups at a relatively high resolution: over 120 functional groups are specifically and separately accounted with survey strata-level resolution (rough depth and location), with specific juvenile and adult accounting for several of the commercial groundfish, crab, and pinniped species. Diets estimated directly from stomach samples collected in the same area that a model covers are considered “direct”.

The diet composition for a species is calculated from stomach sampling beginning at the level of the individual survey haul (1), combining across hauls within a survey stratum (2), weighting stratum diet compositions by stratum biomass (3), and finally combining across predator size classes by weighting according to size-specific ration (consumption rate) estimates and biomass from stock assessment estimated age structure (4). Consumption rate calculations are described in detail above.

Notation:
DC = diet composition
W = weight in stomach
n = prey
p = predator
s = predator size class
h = survey haul
r = survey stratum
B = biomass estimate
v = survey
a = assessment
R = Q/B = ration estimate

Diet composition (DC) of prey n in predator p of size s in haul h is the total weight of prey n in all of the stomachs of predator p of size s in the haul divided by the sum over all prey in all of the stomachs for that predator size class in that haul:

$$DC_{n,p,s,h} = W_{n,p,s,h} \Big/ \sum_n W_{n,p,s,h} \qquad (1)$$

Diet composition of prey n in predator p of size s in survey stratum r is the average of the diet compositions across hauls within that stratum:

$$DC_{n,p,s,r} = \sum_h DC_{n,p,s,h} \Big/ h \qquad (2)$$

Diet composition of prey n in predator p of size s for the entire area t is the sum over all strata of the diet composition in stratum r weighted by the survey biomass proportion of predator p of size s in stratum r:

$$DC_{n,p,s,t} = \sum_r DC_{n,p,s,r} * B^v_{p,s,r} \Big/ \sum_r B^v_{p,s,r} \qquad (3)$$

Diet composition of prey n in predator p for the entire area t is the sum over all predator sizes of the diet composition for predator p of size s as weighted by the relative stock assessment biomass of predator size s times the ration of predator p of size s:

$$DC_{n,p,t} = \sum_s DC_{n,p,s,t} * B^a_{p,s} * R_{p,s} \Big/ \sum_s B^a_{p,s} * R_{p,s} \qquad (4)$$

Diets for fish and shellfish not included in the REEM database were taken from published literature sources or the nearest survey samples. For example, diets estimated from stomachs collected in the EBS may be used as surrogates in the AI and GOA if these last systems lack specific diet information. However these diets would be considered “general” for the AI and GOA in the sense that they are not from stomach samples taken as part of the REEM program and are neither weighted by depth nor location (but they would be for the EBS); in these cases prey items were assigned fixed percentages.

7.13 Adult Juvenile Parameters

Adult juvenile “split pool” parameters for the EBS, AI, and GOA (Table B9) are only used during Sense routine execution, and were not perturbed for that routine. Split pool parameters MinTimeJuv, MaxTimeJuv, RecPower, Prep0, and WtGrow were set to respective default values 1.0, 1.0001, 1, 0.3, and 0.8 for all groups. See Christensen et al. 2000 for a description of these parameters.

Table B9. Juvenile adult split pool parameters used in Sense routines.

Split Pool	EBS Time Juv	EBS WavgWk	EBS vonB K	AI Time Juv	AI WavgWk	AI vonB K	GOA Time Juv	GOA WavgWk	GOA vonB K
N. Fur Seal	3	10	0.2	3	10	0.2	3	10	0.2
Steller Sea Lion	3	10	0.2	3	10	0.2	3	10	0.2
W. Pollock	2	2.95	0.23	2	2.95	0.23	2	1.95	0.23
P. Cod	2	4.45	0.23	2	4.45	0.23	2	4.45	0.23
Herring	2	2.36	0.3	2	2.36	0.3	2	2.36	0.3
Arrowtooth	2	5	0.17	2	5	0.17	2	5	0.17
Kamchatka fl.	2	5	0.17	2	5	0.17			
Gr. Turbot	2	10	0.17	2	10	0.17			
P. Halibut	2	10	0.17	2	10	0.17	2	10	0.17
YF. Sole	6	2	0.15	6	2	0.15			
FH. Sole	4	2	0.18	4	2	0.18	4	2	0.18
N. Rock sole	4	2	0.18						
Sablefish	3	3.24	0.13	3	3.24	0.13	3	3.24	0.13
POP							2	10	0.21
Shortspine Thorns							3	3.97	0.02
Atka mackerel	2	2	0.2	2	2	0.44	2	2	0.44
Bairdi	2	2	0.2						
King Crab	2	2	0.2						
Opilio	2	2	0.2						

7.14 Fisheries

7.14.1 Halibut hook and line fishery

Information on landings and discards of Pacific halibut in the directed fisheries is available from the International Pacific Halibut Commission (IPHC) http://www.iphc.washington.edu/halcom/research/sa/sa.data/sa.data.html#removals. All data were converted from units of pounds dressed weight to t round weight by assuming dressed weight is 75% of round weight and then converting to metric units. We summed total directed landings in commercial and sport fisheries and averaged over multiple years in the early 1990’s (specific to each model, see below) to obtain average annual landings of Pacific halibut, and did the same with the “wastage” category to get discards of Pacific halibut. For the EBS, halibut information was taken from IPHC area 4 for 1991. For the AI, halibut information was taken from IPHC area 4B, and the years 1992-1994 were averaged. For the GOA, halibut information was taken from IPHC areas 3A and 3B, and averaged over 1990-1993.

There is no official data on bycatch of other species in directed fisheries for Pacific halibut. In the GOA, we estimated bycatch using data from a combination of recent and past longline surveys conducted by IPHC. Recent survey data are available at http://www.iphc.washington.edu/halcom/survey/ssadata/ssadata.htm, and include bycatch of sablefish, Pacific cod, and rockfish. Additional information on shark bycatch in the survey were obtained from Ken Goldman (who obtained them from IPHC and summarized them in the Ecosystem Considerations chapter in 2000). Additional information from IPHC Scientific Report 77 (Table 4) was used to estimate bycatch of skates, arrowtooth flounder, and sea stars, and to supplement data on Pacific cod and sablefish bycatch. These surveys were conducted in the Gulf of Alaska during 1983 and 1987. Survey bycatch of these species was reported in numbers; we converted to weights using the average weights of these animals from the North Pacific groundfish observer database and or from the Auke Bay sablefish longline survey, reasoning that the IPHC survey and groundfish fisheries targeted roughly the same size distribution of fishes (adults). Bycatch by species was then scaled to legal halibut catch from the surveys and this bycatch rate was applied to the directed halibut catches described above to estimate bycatch in the fishery. EBS halibut fishery bycatch was estimated by assuming similar catch rates as calculated by the above method for the GOA, and scaling them to EBS directed halibut catch. Halibut fishery bycatch was not estimated for the AI model but note total removals (fishing and discards) amount to 3,000 t in this system, compared to ~10,000 and 30,000 t in the GOA and EBS, respectively.

While many assumptions are involved in estimating bycatch for the GOA and EBS halibut fisheries, we felt it was more important to have estimates of bycatch from reasonable sources in these areas than to construct an unrealistic model where hook and line fisheries directed at halibut took no bycatch at all. We look forward to improvements in monitoring of the directed Pacific halibut fishery so that bycatch may be estimated more accurately.

7.14.2 Crab fleet, herring fleet, salmon fleet, and shrimp trawl fisheries

The only data available for these fisheries at this time is directed landings of target species, which were obtained from the Alaska Department of Fish and Game (see http://www.cf.adfg.state.ak.us/cf_home.htm). In contrast to our treatment of the Pacific halibut fishery, we are assuming that bycatch in these fisheries represents a very minor component of catch due to the rather specific gears (pots, seines, gill nets, and small mesh trawls) employed in each fishery. However, more information on bycatch in these fisheries would be highly desirable for future modeling efforts.

In the EBS, catches of king, Tanner, and snow crabs for 1991 are combined within a single crab pot fleet, and herring and shrimp total catches from 1991 are attributed to their respective fleets. In the GOA, the crab fleets are separated into king crab and Tanner crab fisheries, with ADF&G reported landings averaged over 1990-1993 for each fleet (the landings for king crab are trace landings only which were taken in 1990 in Kodiak; the fishery has been closed in the GOA since the early 1980’s). Similarly, GOA herring, salmon, and shrimp trawl catches are the average of 1990-1993 ADF&G reported landings. In the AI model, king crab catches from 1991-1994 were averaged. Catch used was the Adak king crab catch which includes red king *Paralithodes camtschaticus* and golden (brown) king *Lithodes aequispinus*. Likewise, salmon seine and gill net catch for the AI came from half the catch for 1994 for the Aleutian peninsula and Pribilof Islands regional catch, because more specific information could not be found.

7.14.3 Subsistence fishery

The Alaska Department of Fish and Game maintains an extensive database on subsistence fishing, which is available to the public at http://www.state.ak.us/local/akpages/FISH.GAME/subsist/geninfo/publctns/cpdb.htm. This database contains community and year specific estimates of subsistence harvest for marine mammals, salmon, fish other than salmon, and marine invertebrates. The catches are reported by community, so first we assigned each community in the database to a model area, either EBS, AI, or GOA, using the community descriptions listed in the database. Because not all communities were sampled in all years, but some were sampled in multiple years, we elected to average years for better sampled communities and then sum across all communities regardless of year to get an annual estimate of subsistence removals for each area. This method assumes that average annual subsistence catch has been relatively constant between 1982 and 1998, and that all relevant communities were sampled at least once in the database. In the EBS model, only marine mammal indigenous catches were included in the "Indigenous" fishery. The EBS "Subsistence" fishery includes harvest of salmon. In the GOA model, both indigenous marine mammal catches and subsistence harvests of fish and invertebrates by all user groups are included in a single combined fishery called the "Subsistence" fishery. In the AI, the single "Indigenous" fishery includes catch of marine mammals and salmon.

7.14.4 Groundfish fisheries

"Groundfish" are defined by the North Pacific Fishery Management Council (NPFMC) as demersal fish species including walleye pollock, Pacific cod, Atka mackerel, sablefish, rockfish (*Sebastes* sp.), and flatfish species not including Pacific halibut. Federally contracted fishery observers are placed on a large portion of vessels participating in groundfish fisheries to sample catches, and the state of Alaska maintains a database of landings from each vessel and port. Therefore, considerable data are available to characterize groundfish fisheries in terms of area fished, gear used, vessel type, and bycatch. In each model, we designed groundfish fisheries to be gear and species specific so that the bycatch associated with each fleet was relatively distinct, and so that simulated fleet manipulations would give realistic results. We first describe the groundfish fisheries included in each model, and second describe the methods used to estimate the catch associated with each fishery.

In the EBS model there are 15 groundfish fleets. The Pollock Trawl fleet represents the directed pollock fishery which uses pelagic trawl gear. There are three fisheries directed at Pacific cod: Cod Trawl uses bottom trawls, Cod Longline uses hook and line gear, and Cod Pots uses trap gear, all with the intent to catch Pacific cod, but each with a very different suite of bycatch species. Six fisheries use bottom trawls to catch different flatfish species: Rock sole Trawl, Yellowfin sole Trawl, Arrowtooth Trawl, Flathead sole Trawl, Other flatfish Trawl (primarily Alaska plaice), and Turbot Trawl. These fisheries operate in different habitats and at different times of the year, and so have distinct bycatch species even if they happen to be prosecuted on the same vessels. The Other Groundfish Trawl fleet represents the occasional catch of Atka mackerel by bottom trawls in the EBS. The catch of rockfish in bottom trawls in represented by the Rockfish Trawl fleet. This fleet has different catch composition than the Rockfish Longline fleet which targets generally larger, deeper dwelling rockfish. Other hook and line gear fisheries include the Sablefish Longline and Turbot Longline which target the deep-dwelling groundfish species.

In the GOA model there are 8 groundfish fleets. The Pollock Trawl, Cod Longline, Cod Trawl, Cod Pot, Rockfish Trawl, and Other groundfish Trawl fleets are all defined the same as in the EBS model. The GOA had an active Atka mackerel trawl fishery (represented by the Other groundfish Trawl fleet) during the early 1990's which does not exist at present, but is modeled here. Flatfish fisheries do not feature as prominently in the GOA as in the EBS, and do not have the same distinctive nature to define separate fleets, so a single Flatfish Trawl fishery was defined in the GOA. The Sablefish Longline fleet in the GOA also includes catch assigned to the Rockfish Longline fleet in the EBS, because in the GOA these are believed to be a single fleet fishing over a more heterogeneous habitat.

In the AI model there are 11 groundfish fleets. These fleets are structured identically to the EBS fleets, with the exception that the AI has a single Flatfish Trawl fleet similar to the GOA model. In the AI, the Other groundfish Trawl fleet is more properly termed the Atka Mackerel Trawl fleet, since this is the center of the Atka mackerel fishery.

The estimation of catch within each of the groundfish fleets was a two step process, because the two components of the catch; target species and nontarget (bycatch) species within each fleet come from different datasets. **Target species** are defined as the formally managed groundfish in Alaska, including pollock, Pacific cod, all flatfish groups, all rockfish groups, sablefish, and Atka mackerel. These species are referred to as “target species” throughout this section of the document. **Non-target species** are defined as the non-commercial species either managed as complexes or not managed at all under the NPFMC Groundfish Fishery Management Plan or any other management plan. Species in this second group include sharks, skates, sculpins, grenadiers, greenlings, other shelf and slope demersal fishes, forage fish species (aside from herring and salmon), cephalopods, and benthic invertebrates (aside from the tanner, snow, and king crabs). These unmanaged non-commercial groups are referred to as “nontarget species” throughout this section of the document.

Catch of target species was estimated exclusively from the NMFS Alaska Regional Office “Blend” database. The “Blend” database represents the official total catch of target groundfish species for federal waters in Alaska, covering the years 1991-2002. The NMFS Alaska Regional Office tracks the catch of all major groundfish species inseason as part of the quota management system. Reports on target species catch come in weekly from both at-sea fishery observers and groundfish processors; the data in these reports are combined (“blended”) into what is called the Blend database. The Blend contains the estimated catch of all target species by target fishery, gear, and area. (Target fisheries are defined within the Blend based on species composition of the catch.) In addition, the total catch of each target species is divided into the retained portion (that kept after caught) and the discarded portion (thrown overboard); this division is based on estimates made at sea by fishery observers. This official total catch database also contains estimates of halibut, salmon, herring, and crab (tanner, snow, and king) discards in groundfish fisheries (also estimated by fishery observers). In the groundfish fishery context, these species are “prohibited species” because groundfish fisheries may not retain them and they are the targets of separate fisheries (described above). We used the annual Blend summaries of retained and discarded catch of target species (pollock, cod, Atka mackerel, sablefish, rockfish, and flatfish) and prohibited species (halibut, herring, salmon, king, tanner, and snow crabs), by target fishery, area, and gear from the early 1990s in the first step of defining groundfish fleets in the mass balance models of the EBS, GOA, and AI.

Catch of non-target species is recorded by fishery observers in the field, but has not historically been incorporated into the NMFS Alaska Regional Office Blend database; only the target and prohibited species catch composition recorded by observers was incorporated into the Blend catch database. Therefore, non target species catch in the groundfish fleets (both the retained and discarded portions) was estimated from the full catch composition data in the Observer database (housed at the NMFS Alaska Fisheries Science Center). The disadvantage of the Observer database is that it encompasses only the portion of the groundfish fleets that carry observers, so this observed catch information must be extrapolated to the entire groundfish fleet to be comparable to the official total catch of target species (which was the result of “blending” catch from observer reports and landings from groundfish processors without observers). With the existing information for 1991-2002, the best method for extrapolating to estimate total non target catch in groundfish fleets is to stratify the full Observer database for a given year and the Blend database for the same year in the same way, and use the official total catch estimates of target species (pollock, cod, etc) from the Blend database as a basis for extrapolating non target species catch. The method is detailed below.

Within the Observer database containing the full catch composition, we simulated the steps followed in the Blend database to achieve equivalent strata between the Observer database and the Blend database. The Observer catch data was first grouped into units by individual vessel, gear, management area, and week, within each year, and the catch of each species was summed over a unit. Then, “target fisheries” were assigned to each vessel / gear / management area / week unit based upon the composition of target species retained catch, according to the same algorithm used by the Regional office. For example, a vessel with catch that was more than 95% pollock for a week in a given management area would be assigned to a “pollock target fishery,” and in this manner vessels using the same gear in the same area with similar weekly catch compositions are assigned to the same strata for catch accounting purposes. Then the catch of each species is summed over vessels and weeks within the same target, gear type, and management area. In the Blend database, only the catches of target species are included, but in our strata estimated from the Observer database, both target and of non target species were summed for each year by target fishery, gear type, and management area. Then, the catch rates of suites of nontarget species per unit target species were calculated within the Observer database for each target fishery, gear type, and management area. These nontarget species catch rates per ton of target species in the Observer database were then scaled up to the official Blend catch of target species for the same fishery/gear/area strata. For example, we calculated the t of squid and capelin observed per ton of observed pollock in the pollock trawl fishery in the western GOA. Then we scaled this estimate of squid and capelin per ton of pollock in this stratum from the Observer database up to the official total pollock catch within the same stratum from the Blend database. Finally, we summed catches across management areas to arrive at total nontarget species catches for the AI, GOA, and EBS within each target fishery. Because not all nontarget species are discarded, we estimated the percent retained of each nontarget species group in a similar manner (observed retained nontarget catch divided by observed target catch times total target catch equals retained nontarget catch). Discarded nontarget species catch was estimated by subtracting retained nontarget species catch from total nontarget species catch for each fishery gear combination.

The Observer database contains the appropriate information to simulate Blend database target fishery assignment and stratification for the years 1997 to present. Therefore, our nontarget species catch estimates are most appropriate only for the late 1990’s groundfish fisheries. To scale these nontarget catch estimates to the appropriate early 1990’s timeframe for the AI, GOA, and EBS models, the 1997-2000 average nontarget catch in t by fishery was converted to a catch rate per ton of target species. These catch rates were then applied to target species tonnages for the appropriate time period to estimate nontarget catch in t for that time period. This method assumes that average catch rates of nontarget species have remained constant between the early and late 1990s.

The accuracy of catch estimates for non target species groups depends on the level of observer coverage in a given fishery. Observer coverage requirements in Alaska are based upon vessel size. In general, larger vessels fish in the Bering Sea, such that observer coverage levels in some fisheries approach 100%. Our calculations for 1997-2001 suggest that the BSAI region has approximately 70-80% observer coverage overall. The size distribution of vessels fishing in the Gulf of Alaska results in approximately 20-25% observer coverage overall, although some target fisheries (i.e., rockfish) are prosecuted on larger vessels with 100% observer coverage. Therefore, in making these catch estimates, we are assuming that other species catch aboard observed vessels is representative of other species catch aboard unobserved vessels throughout Alaska. Because observer assignment to vessels in the 30% coverage class is not at random, there is a possibility that this assumption is incorrect.

Additional calculations were required to estimate the amount of fishery offal entering the system from groundfish fisheries. We used product recovery rates published in Economic SAFEs from the early 1990s to determine what portion of retained round weight target species catch was turned into product, and assumed a fixed percentage of the remainder was returned to the system as fishery offal.

7.14.5 Discard and fishery comparisons between models

Discards of whole fish and offal (processed fish parts) are the byproducts of fishery removals within each system, and are estimated from official catch data. Discards are mostly eaten by crabs. Discards might be eaten by fish too, but we have no way to distinguish consumed discarded whole fish from consumed free swimming whole fish in the food habits data. Because there are more crabs in the EBS, more discards are consumed within that system. Most discards come from the flatfish trawl fishery in the EBS and GOA, and the Atka mackerel trawl fishery in the AI. Sablefish hook and line is a secondary source of discard (mostly of grenadiers) in the GOA, as well as the pollock trawl fishery. EBS runners-up include the cod and pollock trawl fisheries, and the rockfish and cod trawl fisheries in the AI. Fishery offal estimates might be high because we have taken everything that was not recovered as product returned it to the ocean, which may not happen in all the systems. However, the EEs for offal are quite high (especially in the GOA where cod and sablefish diets had to be changed to get offal to balance) so apparently the demand is pretty high for offal according to food habits data. In the GOA offal is consumed about equally at 33% each by sablefish and cod (and that is after the reductions for balance) and then by halibut, pollock, bairdi and arrowtooth flounder. In the EBS, cod and pollock account for about a third of consumption each, followed by Alaska skates, flathead sole and arrowtooth flounder. In the AI, Pacific cod eat 45% of offal, followed by pollock at 30%, and then northern rockfish and Atka mackerel. The EE of offal is .65 in the AI, .8 in the EBS, and .92 in the GOA. The offal-balancing assumption in the EBS was that some (2% of) things identified as offal in stomachs were actually naturally scarred fish which looked remarkably similar to a fish that had been processed.

There are different levels of detritus consumption estimated within each system. For example, there was an excess of pelagic detritus created in the GOA, where we estimated less microzooplankton and more phytoplankton relative to the EBS and AI, so the pelagic detritus EE is 0.21 in the GOA. In the other systems the detritus created is pretty much used within the system. Benthic detritus is most tightly wired in the EBS and was engineered to have the same EE as pelagic detritus by sending different proportions of dead stuff into each pool. The benthic detritus EE is 0.6 in the AI, 0.9 in the EBS and 0.5 in the GOA. The large EBS biomass of bivalves feeds on benthic detritus, creating a high demand, which was supplied via the disproportionate assignment of detritus to the benthic loop in the EBS relative to the AI and GOA.

Fisheries were created from the official catch and bycatch data reported in each system, and supplemented with other information as available. The flatfish trawl fishery is a different fishery in each system. It catches primarily arrowtooth flounder in the GOA (not really the target but dominant bycatch everywhere regardless of target), mostly yellowfin sole and rock sole in the EBS. In the AI it is primarily an arrowtooth and turbot fishery. The pollock trawl fisheries overwhelmingly catch pollock in all three systems. The other groundfish trawl fishery is actually the Atka mackerel fishery. Sablefish fisheries catch more grenadiers than sablefish, in the GOA and EBS. In the AI, sablefish fisheries catch mostly sablefish, turbot, arrowtooth flounder and thornyheads, and grenadiers don’t even show up. Turbot hook and line has a big grenadier catch in the EBS and none in the AI. Turbot trawl doesn’t catch grenadiers in the EBS either. The halibut fishery in the AI is totally clean because no bycatch has been entered, while bycatch as been estimated based on halibut survey data in other areas. Crab fisheries have no bycatch (or catch) in the GOA, because they were entered for historical fitting purposes. Crab fisheries have some bycatch in the EBS, and a small catch of mammals in the AI. The shrimp trawl fishery in GOA is also a placeholder. The salmon fleets catch only salmon, which is probably not such a bad assumption. Herring fleets are likewise bycatch free, due to lack of observer data. The indigenous fleet is mammal oriented in the EBS, but includes all fish as well and inverts in the GOA, and is therefore not comparable across systems.

8. Appendix C: Model Inputs and Results: Values of B, EE, PB, QB, TL, Catch and Discards of Target and Non-target Species, and Diets in Each System.

Table C1. Biomass (B, t/ km^2) and ecotrophic efficiency (EE) for the Aleutian Islands (AI), Eastern Bering Sea (EBS) and Gulf of Alaska (GOA). #N/A indicates groups not included in a model.

Group	AI B	AI EE	EBS B	EBS EE	GOA B	GOA EE
Transient Killers	0.00039	0.00000	0.00014	0.00000	0.00014	0.00000
Sperm and beaked whale	0.14647	0.00000	0.01767	0.00000	0.04509	0.00000
Resident Killers	0.00391	0.00000	0.00135	0.17018	0.00136	0.02055
Porpoises	0.06577	0.23353	0.00362	0.05453	0.01507	0.05450
Belugas	#N/A	#N/A	0.01225	0.04051	#N/A	#N/A
Gray Whales	#N/A	#N/A	0.03267	0.03919	0.05543	0.04275
Humpbacks	0.14313	0.30963	0.01210	0.10246	0.17838	0.07181
Fin Whales	0.04394	0.00000	0.45474	0.09309	0.26610	0.10880
Sei whales	0.00633	0.00000	0.00633	0.06206	0.00633	0.06766
Right whales	0.00356	0.00000	0.00355	0.07576	0.00355	0.08259
Minke whales	0.09756	0.22826	0.02404	0.05066	0.00236	0.05294
Bowhead Whales	#N/A	#N/A	0.00717	0.24707	#N/A	#N/A
Sea Otters	0.00687	0.10079	0.00075	0.02159	0.00345	0.02326
Walrus Bd Seals	#N/A	#N/A	0.11425	0.00628	#N/A	#N/A
N. Fur Seal	#N/A	#N/A	0.03263	0.03962	0.00904	0.02983
N. Fur Seal_Juv	#N/A	#N/A	0.00191	0.02144	0.00005	0.02338
Central S.S.L.	#N/A	#N/A	#N/A	#N/A	0.01085	0.04715
Central S.S.L._Juv	#N/A	#N/A	#N/A	#N/A	0.00103	0.00989
West S.S.L.	0.05206	0.12703	0.00147	0.35899	0.00508	0.04569
West S.S.L_Juv	0.00545	0.02363	0.00015	0.00503	0.00066	0.00988
Resident seals	0.00362	0.24674	0.01345	0.04362	0.00329	0.22533
Wintering seals	#N/A	#N/A	0.03029	0.87048	#N/A	#N/A
Shearwater	0.00181	0.24346	0.00040	0.08498	0.00023	0.27538
Murres	0.00134	0.15135	0.00814	0.05014	0.00483	0.16248
Kittiwakes	0.00048	0.33839	0.00066	0.11054	0.00089	0.35819
Auklets	0.00807	0.15135	0.00175	0.05014	0.00030	0.16248
Puffins	0.00411	0.64129	0.00047	0.21246	0.00648	0.68845
Fulmars	0.00488	0.46639	0.00052	0.15451	0.00082	0.50069
Storm Petrels	0.00353	0.21376	0.00000	0.07082	0.00023	0.22948
Cormorants	0.00107	0.16161	0.00015	0.05354	0.00035	0.17349
Gulls	0.00058	0.15473	0.00010	0.05126	0.00057	0.16611
Albatross Jaeger	0.00008	0.37965	0.00010	0.12578	0.00023	0.40757
Sleeper shark	0.01591	0.90384	0.05325	0.16086	0.01765	0.84261
Salmon shark	0.00173	0.87967	#N/A	#N/A	0.03459	0.13512
Dogfish	0.00122	0.96311	#N/A	#N/A	0.09011	0.89714
W. Pollock	5.69288	0.83498	18.48621	0.84405	5.55270	0.98173
W. Pollock_Juv	2.89452	0.80000	2.78384	0.80000	0.67179	0.81664
P. Cod	2.93247	0.49340	2.46497	0.51353	1.39008	0.53591
P. Cod_Juv	0.01590	0.80000	0.30615	0.80000	0.13032	0.80272
Herring	0.01766	0.80000	0.61156	0.57579	0.28063	0.96844
Herring_Juv	0.00419	0.80000	0.07596	0.80000	0.59760	0.77995
Arrowtooth	0.53109	0.37749	0.94434	0.85088	5.76647	0.24254
Arrowtooth_Juv	0.00086	0.80000	0.09443	0.02711	0.54653	0.12502
Kamchatka fl.	0.50776	0.00424	0.05607	0.18138	#N/A	#N/A
Kamchatka fl._Juv	0.00229	0.80000	0.00561	0.00099	#N/A	#N/A
Gr. Turbot	0.28438	0.93625	0.34930	0.54905	#N/A	#N/A
Gr. Turbot_Juv	0.00016	0.00076	0.03493	0.18415	#N/A	#N/A
P. Halibut	0.70447	0.41832	0.22190	0.68985	1.51977	0.40976
P. Halibut_Juv	0.01407	0.80000	0.02219	0.44453	0.18245	0.36829

Table C1. Continued.

Group	AI B	AI EE	EBS B	EBS EE	GOA B	GOA EE
YF. Sole	0.00025	0.80000	4.83331	0.37020	0.23789	0.17200
YF. Sole_Juv	0.00016	0.01399	0.48333	0.28598	#N/A	#N/A
FH. Sole	0.07799	0.37297	1.19385	0.20427	0.73941	0.34620
FH. Sole_Juv	0.00016	0.00904	0.11938	0.41868	0.05780	0.80000
N. Rock sole	0.64577	0.06063	3.22571	0.42726	0.20969	0.27131
N. Rock sole_Juv	#N/A	#N/A	0.32257	0.12131	#N/A	#N/A
S. Rock sole	0.00560	0.03616	#N/A	#N/A	0.35209	0.20336
AK Plaice	0.00000	0.80000	1.06840	0.53714	0.01467	0.14337
Dover Sole	0.00338	0.07811	0.00023	0.40147	0.31847	0.80992
Rex Sole	0.11197	0.80000	0.04063	0.48703	0.31825	0.66750
Misc. Flatfish	0.00455	0.80000	0.22369	0.80000	0.19583	0.53350
Alaska skate	0.14754	0.54002	0.68045	0.19204	0.00235	0.44411
Bering skate	0.00000	0.06130	0.03911	0.31007	0.02908	0.59166
Aleutian skate	0.07257	0.66751	0.03813	0.21719	0.00390	0.85155
Whiteblotched skate	0.10280	0.70715	0.00798	0.11017	0.00047	0.62816
Mud skate	0.01375	0.63799	0.00187	0.11476	0.00000	0.21266
Longnosed skate	0.00000	0.06130	0.00050	0.01373	0.04974	0.78242
Big skate	0.00000	0.06130	0.00200	0.01370	0.10626	0.50942
Black skate	0.00000	0.06130	0.00334	0.01626	0.00000	0.21266
Sablefish	0.14798	0.92352	0.03145	0.51973	0.93149	0.85602
Sablefish_Juv	0.01076	0.80000	0.00666	0.63432	0.00597	0.80000
Eelpouts	0.79884	0.80000	2.37039	0.80000	1.06943	0.80000
Giant Grenadier	5.07601	0.17141	0.86149	0.29868	0.90764	0.32050
Pacific Grenadier	0.00000	0.04814	0.00497	0.01826	0.00103	0.16856
Other Macruids	0.02556	0.80000	0.10163	0.01879	0.00913	0.30919
Misc. fish deep	1.94585	0.80000	0.00809	0.80000	0.02137	0.80000
POP	6.27887	0.31071	0.16664	0.84803	0.84069	0.47480
POP_Juv	#N/A	#N/A	#N/A	#N/A	0.00593	0.00720
Sharpchin Rock	0.05668	0.80000	0.00154	0.80000	0.35545	0.80000
Northern Rock	2.69692	0.47863	0.02807	0.80000	0.36245	0.65053
Dusky Rock	0.00597	0.99770	0.00061	0.52334	0.13955	0.89610
Shortraker Rock	0.42159	0.47473	0.00949	0.45495	0.07740	0.61132
Rougheye Rock	0.21945	0.99751	0.00369	0.61836	0.16437	0.39262
Shortspine Thorns	0.10894	0.31897	0.00461	0.32750	0.06315	0.81817
Shortspine Thorns_Juv	#N/A	#N/A	#N/A	#N/A	0.00061	0.80000
Other Sebastes	0.08012	0.80000	0.01119	0.80000	0.08924	0.80000
Atka mackerel	11.64525	0.96130	0.10685	0.73767	0.45449	0.69802
Atka mackerel_Juv	0.52671	0.80000	0.00011	0.00227	0.06491	0.80000
Greenlings	0.01584	0.80000	0.00119	0.80000	0.01111	0.05330
Lg. Sculpins	0.11433	0.80000	0.54032	0.10351	0.08889	0.67633
Other sculpins	6.27145	0.80000	1.16057	0.80000	0.81687	0.80000
Misc. fish shallow	1.12650	0.80000	1.17887	0.80000	0.83899	0.80000
Octopi	0.38321	0.80000	0.19900	0.80000	0.78347	0.80000
Squids	7.38554	0.80000	0.92788	0.80000	1.26545	0.80000
Salmon returning	0.14020	0.58367	0.16377	0.97420	0.85663	0.49750
Salmon outgoing	0.01402	0.57232	0.01453	0.80000	0.01713	0.12440
Bathylagidae	0.44548	0.80000	0.16164	0.80000	0.07371	0.80000
Myctophidae	25.87673	0.80000	0.79695	0.80000	0.63483	0.80000
Capelin	3.57765	0.80000	1.23928	0.80000	7.02478	0.80000
Sandlance	3.74999	0.80000	2.48365	0.80000	2.44271	0.80000
Eulachon	3.47070	0.80000	0.55245	0.80000	1.15007	0.80000
Oth. managed forage	3.81374	0.80000	1.05387	0.80000	1.42353	0.80000
Oth. pelagic smelt	3.46276	0.80000	0.49905	0.80000	0.64213	0.80000

Table C1. Continued.

Group	AI B	AI EE	EBS B	EBS EE	GOA B	GOA EE
Bairdi	0.40518	0.80000	0.41304	0.61130	0.62836	0.80000
Bairdi_Juv	#N/A	#N/A	0.28421	0.80000	#N/A	#N/A
King Crab	0.13508	0.86390	0.21821	0.57129	0.00615	0.90615
King Crab_Juv	#N/A	#N/A	0.01739	0.80000	#N/A	#N/A
Opilio	#N/A	#N/A	1.86670	0.36827	#N/A	#N/A
Opilio_Juv	#N/A	#N/A	0.63766	0.80000	#N/A	#N/A
Pandalidae	8.28618	0.80000	6.72695	0.80000	10.68705	0.80000
NP shrimp	15.62519	0.80000	12.82204	0.80000	11.54150	0.80000
Sea stars	0.10668	0.80000	2.47136	0.00797	0.09552	0.49185
Brittle stars	0.83244	0.80000	3.08653	0.80000	4.54402	0.20139
Urchins dollars cucumber	0.98783	0.80000	1.11966	0.80000	1.63093	0.35036
Snails	1.13344	0.80000	0.82220	0.80000	0.86388	0.80000
Hermit crabs	0.58692	0.80000	1.78518	0.80000	2.84596	0.80000
Misc. crabs	1.38528	0.80000	0.72725	0.80000	1.73786	0.80000
Misc. Crustacean	2.08385	0.80000	8.84222	0.80000	2.12029	0.80000
Benthic Amphipods	7.43807	0.80000	12.63702	0.80000	5.86887	0.80000
Anemones	0.01205	0.00330	0.10952	0.11854	0.08887	0.00191
Corals	0.08800	0.26798	0.01317	0.03633	0.00519	0.10343
Hydroids	0.03715	0.80000	0.25977	0.80000	0.10507	0.80000
Urochordata	0.24480	0.07507	0.35450	0.03991	0.24480	0.00936
Sea Pens	0.00050	0.13232	0.01342	0.00838	0.00055	0.20133
Sponges	1.12400	0.00664	0.05449	0.64875	0.10750	0.00269
Bivalves	11.09283	0.80000	61.87307	0.35124	13.85198	0.80000
Polychaetes	4.40755	0.80000	21.68738	0.21866	3.92329	0.80000
Misc. worms	2.40662	0.80000	3.71459	0.80000	3.66779	0.80000
Scyphozoid Jellies	0.11000	0.61467	0.33793	0.66095	0.11000	0.48363
Fish Larvae	0.70711	0.80000	0.01167	0.80000	0.00378	0.80000
Chaetognaths	1.62318	0.80000	0.45684	0.80000	0.58533	0.80000
Euphausiids	49.21892	0.80000	15.83468	0.80000	20.16194	0.80000
Mysids	2.25670	0.80000	0.97569	0.80000	0.35794	0.80000
Pelagic Amphipods	6.45118	0.80000	1.54124	0.80000	1.35053	0.80000
Gelatinous filter feeders	3.15682	0.80000	0.70292	0.80000	0.93923	0.80000
Pteropods	0.51029	0.80000	0.18736	0.80000	0.59976	0.80000
Copepods	66.83617	0.80000	22.45891	0.80000	21.86350	0.80000
Pelagic microbes	36.60860	0.80000	45.00000	0.21665	12.25505	0.80000
Benthic microbes	8.03611	0.80000	21.94180	0.80000	7.25230	0.80000
Macroalgae	0.87648	0.80000	0.74829	0.80000	0.87725	0.80000
Lg Phytoplankton	6.98002	0.80000	3.70393	0.80000	7.86063	0.25317
Sm Phytoplankton	35.61068	0.80000	39.10807	0.80000	27.65792	0.34525
Outside Production	3.00016	0.00000	4.00000	0.00000	4.00000	0.00000
Discards	0.00000	0.02926	0.00000	0.09504	0.00000	0.05910
Offal	0.00000	0.65212	0.00000	0.55098	0.00000	0.60840
Pelagic Detritus	0.00000	0.77196	0.00000	0.87545	0.00000	0.19280
Benthic Detritus	0.00000	0.63128	0.00000	0.91806	0.00000	0.51643
Outside Detritus	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table C2. Input parameters production rate P/B, consumption rate Q/B, and resulting trophic level TL for the Aleutian Islands (AI), Eastern Bering Sea (EBS) and Gulf of Alaska (GOA).

Group	AI P/B	AI Q/B	AI TL	EBS P/B	EBS Q/B	EBS TL	GOA P/B	GOA Q/B	GOA TL
Transient Killers	0.025	11.157	5.2	0.025	11.157	4.8	0.025	11.157	4.9
Sperm and beaked whales	0.047	6.609	4.7	0.047	6.609	4.7	0.047	6.609	4.7
Resident Killers	0.025	11.157	4.7	0.025	11.157	4.7	0.025	11.157	4.8
Porpoises	0.050	30.000	4.7	0.050	30.000	4.6	0.050	30.000	4.6
Belugas	#N/A	#N/A	#N/A	0.112	30.000	4.6	#N/A	#N/A	#N/A
Gray Whales	#N/A	#N/A	#N/A	0.063	8.873	3.5	0.063	8.873	3.5
Humpbacks	0.038	7.577	3.9	0.038	7.577	3.9	0.038	7.577	3.9
Fin Whales	0.027	6.517	3.7	0.027	6.517	3.7	0.027	6.517	3.7
Sei whales	0.040	8.788	3.7	0.040	8.788	3.7	0.040	8.788	3.7
Right whales	0.033	8.000	3.5	0.033	8.000	3.5	0.033	8.000	3.5
Minke whales	0.051	7.782	4.1	0.051	7.782	4.1	0.051	7.782	4.1
Bowhead Whales	#N/A	#N/A	#N/A	0.010	8.680	3.5	#N/A	#N/A	#N/A
Sea Otters	0.117	73.000	3.5	0.117	73.000	3.7	0.117	73.000	3.8
Walrus Bd Seals	#N/A	#N/A	#N/A	0.051	15.371	3.6	#N/A	#N/A	#N/A
N. Fur Seal	#N/A	#N/A	#N/A	0.091	39.030	4.6	0.091	39.030	4.6
N. Fur Seal_Juv	#N/A	#N/A	#N/A	0.116	49.534	4.6	0.116	49.534	4.6
Central S.S.L.	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.110	24.074	4.8
Central S.S.L._Juv	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.494	108.321	4.8
West S.S.L.	0.110	24.074	4.8	0.110	24.074	4.7	0.110	24.074	4.7
West S.S.L_Juv	0.494	108.321	4.7	0.494	160.711	4.7	0.494	108.321	4.7
Resident seals	0.083	17.439	4.5	0.083	17.439	4.5	0.083	17.439	4.6
Wintering seals	#N/A	#N/A	#N/A	0.069	19.197	4.6	#N/A	#N/A	#N/A
Shearwater	0.105	73.000	4.5	0.100	73.000	4.5	0.100	73.000	4.5
Murres	0.169	72.000	4.4	0.169	72.000	4.4	0.169	72.000	4.5
Kittiwakes	0.076	110.000	4.4	0.077	110.000	4.4	0.077	110.000	4.4
Auklets	0.169	110.000	3.6	0.169	110.000	3.6	0.169	110.000	3.6
Puffins	0.040	73.000	4.4	0.040	73.000	4.4	0.040	73.000	4.4
Fulmars	0.055	73.000	4.6	0.055	73.000	4.6	0.055	73.000	4.6
Storm Petrels	0.120	144.000	4.3	0.120	144.000	4.3	0.120	144.000	4.3
Cormorants	0.159	73.000	4.5	0.159	73.000	4.5	0.159	73.000	4.5
Gulls	0.166	73.000	4.5	0.166	73.000	4.5	0.166	73.000	4.5
Albatross Jaeger	0.068	75.000	4.6	0.068	75.000	4.6	0.068	75.000	4.6
Sleeper shark	0.100	3.000	4.8	0.100	3.000	4.7	0.100	3.000	4.8
Salmon shark	0.100	6.000	4.8	#N/A	#N/A	#N/A	0.100	6.000	4.9
Dogfish	0.100	3.000	4.3	#N/A	#N/A	#N/A	0.100	3.000	4.3
W. Pollock	0.375	4.445	3.9	0.667	3.170	3.7	0.410	3.780	3.7
W. Pollock_Juv	1.980	6.965	3.6	2.345	5.510	3.5	2.669	6.830	3.6
P. Cod	0.412	2.280	4.2	0.412	2.280	4.1	0.420	2.190	4.1
P. Cod_Juv	1.082	5.680	3.7	1.082	5.680	3.6	2.026	4.590	3.7
Herring	0.320	3.520	3.5	0.320	3.520	3.5	0.400	3.520	3.5
Herring_Juv	2.370	7.240	3.5	2.370	7.240	3.5	1.419	4.334	3.5
Arrowtooth	0.297	2.609	4.3	0.180	1.160	4.3	0.260	1.440	4.3
Arrowtooth_Juv	1.014	3.771	4.0	1.580	3.310	4.0	0.898	2.450	3.9
Kamchatka fl.	0.297	2.609	4.5	0.180	1.160	4.5	#N/A	#N/A	#N/A
Kamchatka fl._Juv	1.014	3.771	4.1	1.580	3.310	4.1	#N/A	#N/A	#N/A
Gr. Turbot	0.180	1.160	4.6	0.180	1.160	4.6	#N/A	#N/A	#N/A
Gr. Turbot_Juv	1.580	3.310	4.1	1.580	3.310	3.5	#N/A	#N/A	#N/A
P. Halibut	0.190	1.100	4.4	0.190	1.100	4.6	0.190	1.100	4.5
P. Halibut_Juv	0.380	1.420	4.0	0.380	1.420	3.8	0.382	1.420	4.0

Table C2. Continued.

Group	AI P/B	AI Q/B	AI TL	EBS P/B	EBS Q/B	EBS TL	GOA P/B	GOA Q/B	GOA TL
YF. Sole	0.174	0.930	3.5	0.174	0.930	3.5	0.200	2.000	3.6
YF. Sole_Juv	0.601	1.740	3.5	0.601	1.740	3.5	#N/A	#N/A	#N/A
FH. Sole	0.200	1.970	3.8	0.260	1.970	3.7	0.180	1.690	3.8
FH. Sole_Juv	0.930	3.130	3.5	0.930	3.130	3.5	1.100	3.130	3.6
N. Rock sole	0.252	1.705	3.8	0.232	1.140	3.7	0.200	2.000	3.5
N. Rock sole_Juv	#N/A	#N/A	#N/A	0.938	2.310	3.5	#N/A	#N/A	#N/A
S. Rock sole	0.252	1.705	4.0	#N/A	#N/A	#N/A	0.200	2.000	3.5
AK Plaice	0.200	2.000	3.7	0.200	2.000	3.5	0.200	2.000	3.5
Dover Sole	0.200	2.000	3.5	0.200	2.000	3.7	0.200	2.000	3.4
Rex Sole	0.200	2.000	3.5	0.200	2.000	3.7	0.200	2.000	3.5
Misc. Flatfish	0.200	2.000	3.7	0.200	2.000	3.7	0.200	2.000	3.5
Alaska skate	0.200	2.000	4.5	0.200	2.000	4.2	0.200	2.000	4.4
Bering skate	0.200	2.000	3.5	0.200	2.000	4.6	0.200	2.000	3.5
Aleutian skate	0.200	2.000	4.2	0.200	2.000	4.3	0.200	2.000	4.3
Whiteblotched skate	0.200	2.000	4.3	0.200	2.000	4.3	0.200	2.000	4.1
Mud skate	0.200	2.000	4.3	0.200	2.000	4.3	0.200	2.000	4.1
Longnosed skate	0.200	2.000	4.3	0.200	2.000	4.5	0.200	2.000	4.7
Big skate	0.200	2.000	4.0	0.200	2.000	4.5	0.200	2.000	4.3
Black skate	0.200	2.000	4.2	0.200	2.000	4.3	0.200	2.000	4.1
Sablefish	0.190	1.030	3.6	0.190	1.030	4.5	0.190	1.030	4.1
Sablefish_Juv	1.650	3.320	3.5	1.650	3.320	3.6	1.650	3.320	3.6
Eelpouts	0.400	2.000	3.6	0.400	2.000	3.5	0.400	2.000	3.6
Giant Grenadier	0.150	2.000	4.5	0.150	2.000	4.3	0.150	2.000	4.1
Pacific Grenadier	0.150	2.000	4.5	0.150	2.000	4.3	0.150	2.000	4.1
Other Macruids	0.150	2.000	4.5	0.150	2.000	4.3	0.150	2.000	4.1
Misc. fish deep	0.200	2.000	4.3	0.200	2.000	4.3	0.200	2.000	4.3
POP	0.206	1.802	3.6	0.100	2.000	3.5	0.090	1.990	3.6
POP_Juv	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.100	3.480	3.6
Sharpchin Rock	0.100	2.000	3.6	0.100	2.000	3.8	0.100	2.000	3.5
Northern Rock	0.100	2.000	3.6	0.100	2.000	3.6	0.100	2.000	3.5
Dusky Rock	0.100	2.000	3.5	0.100	2.000	3.5	0.100	2.000	4.0
Shortraker Rock	0.100	2.000	3.9	0.100	2.000	3.9	0.100	2.000	3.9
Rougheye Rock	0.100	2.000	3.9	0.100	2.000	4.3	0.100	2.000	3.9
Shortspine Thorns	0.150	0.500	4.0	0.150	0.500	3.6	0.130	0.440	3.9
Shortspine Thorns_Juv	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.210	0.570	3.7
Other Sebastes	0.100	2.000	3.8	0.100	2.000	3.8	0.100	2.000	3.8
Atka mackerel	0.348	5.647	3.7	0.350	5.650	3.5	0.350	5.650	3.5
Atka mackerel_Juv	1.901	8.897	3.5	1.900	8.900	3.5	1.900	8.900	3.5
Greenlings	0.400	2.000	3.6	0.400	2.000	4.2	0.400	2.000	4.2
Lg. Sculpins	0.400	2.000	4.2	0.400	2.000	4.0	0.400	2.000	4.0
Other sculpins	0.400	2.000	3.6	0.400	2.000	3.9	0.400	2.000	3.9
Misc. fish shallow	0.400	2.000	3.6	0.400	2.000	3.7	0.400	2.000	3.5
Octopi	0.800	3.650	3.8	0.800	3.650	3.8	0.800	3.650	3.8
Squids	3.200	10.670	3.7	3.200	10.670	3.7	3.200	10.670	3.7
Salmon returning	1.800	12.123	3.8	1.650	11.600	3.8	1.816	11.827	3.8
Salmon outgoing	1.770	16.005	3.5	1.280	13.560	3.5	1.642	14.386	3.5
Bathylagidae	0.800	3.650	3.5	0.800	3.650	3.5	0.800	3.650	3.5
Myctophidae	0.800	3.650	3.5	0.800	3.650	3.5	0.800	3.650	3.5
Capelin	0.800	3.650	3.5	0.800	3.650	3.5	0.800	3.650	3.5
Sandlance	0.800	3.650	3.5	0.800	3.650	3.5	0.800	3.650	3.5
Eulachon	0.800	3.650	3.5	0.800	3.650	3.5	0.800	3.650	3.5
Oth. managed forage	0.800	3.650	3.5	0.800	3.650	3.5	0.800	3.650	3.5
Oth. pelagic smelt	0.800	3.650	3.5	0.800	3.650	3.5	0.800	3.650	3.5

Table C2. Continued.

Group	AI P/B	AI Q/B	AI TL	EBS P/B	EBS Q/B	EBS TL	GOA P/B	GOA Q/B	GOA TL
Bairdi	1.000	3.000	3.4	1.000	2.754	3.4	1.000	3.000	3.4
Bairdi_Juv	#N/A	#N/A	#N/A	1.500	3.838	3.2	#N/A	#N/A	#N/A
King Crab	0.600	3.000	3.5	0.600	2.700	3.4	0.600	3.000	3.4
King Crab_Juv	#N/A	#N/A	#N/A	1.500	3.700	3.3	#N/A	#N/A	#N/A
Opilio	#N/A	#N/A	#N/A	1.000	2.901	3.4	#N/A	#N/A	#N/A
Opilio_Juv	#N/A	#N/A	#N/A	1.500	3.830	2.8	#N/A	#N/A	#N/A
Pandalidae	0.576	2.410	2.9	0.576	2.409	2.9	0.576	2.410	2.9
NP shrimp	0.576	2.410	2.9	0.576	2.409	2.9	0.576	2.410	2.9
Sea stars	1.210	6.050	3.5	1.210	6.050	3.5	1.210	6.050	3.5
Brittle stars	1.210	6.050	2.2	1.210	6.050	2.2	1.210	6.050	2.2
Urchins dollars cucumbers	0.610	3.050	2.0	0.610	3.050	2.0	0.610	3.050	2.0
Snails	1.810	9.050	2.9	1.810	9.050	2.9	1.810	9.050	2.9
Hermit crabs	0.820	4.100	3.1	0.820	4.100	3.1	0.820	4.100	3.1
Misc. crabs	0.820	4.100	3.1	0.820	4.100	3.1	0.820	4.100	3.1
Misc. Crustacean	7.400	37.000	2.5	7.400	37.000	2.5	7.400	37.000	2.5
Benthic Amphipods	7.400	37.000	2.5	7.400	37.000	2.5	7.400	37.000	2.5
Anemones	1.000	5.000	2.5	1.000	5.000	2.5	1.000	5.000	2.5
Corals	0.046	0.230	2.5	0.046	0.230	2.5	0.046	0.230	2.5
Hydroids	1.000	5.000	2.5	1.000	5.000	2.5	1.000	5.000	2.5
Urochordata	3.580	17.900	2.5	3.580	17.900	2.5	3.580	17.900	2.5
Sea Pens	0.092	0.461	2.5	0.092	0.461	2.5	0.092	0.461	2.5
Sponges	1.000	5.000	2.5	1.000	5.000	2.5	1.000	5.000	2.5
Bivalves	1.300	6.500	2.5	1.300	6.500	2.5	1.300	6.500	2.5
Polychaetes	2.970	14.850	2.5	2.970	14.850	2.5	2.970	14.850	2.5
Misc. worms	2.230	11.150	2.5	2.230	11.150	2.5	2.230	11.150	2.5
Scyphozoid Jellies	0.880	3.000	3.4	0.880	3.000	3.4	0.880	3.000	3.4
Fish Larvae	5.475	15.643	2.5	5.475	15.643	2.5	5.475	15.643	2.5
Chaetognaths	5.475	15.643	2.9	5.475	15.643	2.9	5.475	15.643	2.9
Euphausiids	5.475	15.643	2.5	5.475	15.643	2.5	5.475	15.643	2.5
Mysids	5.475	15.643	2.5	5.475	15.643	2.5	5.475	15.643	2.5
Pelagic Amphipods	2.500	7.143	2.5	2.500	7.143	2.5	2.500	7.143	2.5
Gelatinous filter feeders	5.475	15.643	2.5	5.475	15.643	2.5	5.475	15.643	2.5
Pteropods	5.475	15.643	2.5	5.475	15.643	2.5	5.475	15.643	2.5
Copepods	6.000	27.740	2.5	6.000	27.740	2.5	6.000	27.740	2.5
Pelagic microbes	36.500	104.286	2.0	36.500	104.286	2.0	36.500	104.286	2.0
Benthic microbes	36.500	104.286	2.0	36.500	104.286	2.0	36.500	104.286	2.0
Macroalgae	4.000	0.000	1.0	4.000	0.000	1.0	4.000	0.000	1.0
Lg Phytoplankton	166.500	0.000	1.0	101.794	0.000	1.0	166.481	0.000	1.0
Sm Phytoplankton	113.400	0.000	1.0	110.919	0.000	1.0	113.378	0.000	1.0
Outside Production	1.000	0.000	1.0	1.000	0.000	1.0	1.000	0.000	1.0
Discards	0.000	0.000	1.0	0.000	0.000	1.0	0.000	0.000	1.0
Offal	0.000	0.000	1.0	0.000	0.000	1.0	0.000	0.000	1.0
Pelagic Detritus	0.000	0.000	1.0	0.000	0.000	1.0	0.000	0.000	1.0
Benthic Detritus	0.000	0.000	1.0	0.000	0.000	1.0	0.000	0.000	1.0
Outside Detritus	0.000	0.000	1.0	0.000	0.000	1.0	0.000	0.000	1.0

Table C3. **Total removals (t) as retained catch and discards in each system. Retained catch for target species processed at sea is the product of the raw retained catch times the published product recovery rate for that species; processing waste ("offal") calculated by this method was added to Discarded catch.**

Group	AI Ret	AI Disc	EBS Ret	EBS Disc	GOA Ret	GOA Disc
Transient Killers	0.00	0.00	0.00	0.00	0.00	0.00
Sperm and beaked whales	0.00	0.00	0.00	0.00	0.00	0.00
Resident Killers	0.00	0.00	0.00	2.90	0.00	0.21
Porpoises	0.00	0.01	0.00	0.44	0.04	0.04
Belugas	#N/A	#N/A	12.52	0.01	#N/A	#N/A
Gray Whales	#N/A	#N/A	0.00	0.00	0.03	0.00
Humpbacks	0.00	0.00	0.00	8.29	0.00	0.00
Fin Whales	0.00	0.00	0.00	0.00	0.00	15.16
Sei whales	0.00	0.00	0.00	0.00	0.00	0.00
Right whales	0.00	0.00	0.00	0.00	0.00	0.00
Minke whales	0.00	0.00	0.09	1.19	0.00	0.00
Bowhead Whales	#N/A	#N/A	0.00	0.00	#N/A	#N/A
Sea Otters	0.00	0.04	0.01	0.00	0.01	0.00
Walrus Bd Seals	#N/A	#N/A	15.33	2.96	#N/A	#N/A
N. Fur Seal	#N/A	#N/A	18.26	0.08	0.00	0.00
N. Fur Seal_Juv	#N/A	#N/A	0.00	0.00	0.04	0.00
Central S.S.L.	#N/A	#N/A	#N/A	#N/A	6.90	0.92
Central S.S.L._Juv	#N/A	#N/A	#N/A	#N/A	0.66	0.00
West S.S.L.	5.90	0.84	24.34	2.57	3.23	0.20
West S.S.L_Juv	0.00	0.00	0.00	0.00	0.42	0.00
Resident seals	1.79	0.01	7.36	0.14	15.23	0.06
Wintering seals	#N/A	#N/A	15.70	0.16	#N/A	#N/A
Shearwater	0.00	0.52	0.00	0.77	0.00	0.09
Murres	0.00	0.39	0.01	15.68	0.00	1.92
Kittiwakes	0.00	0.14	0.00	1.28	0.00	0.35
Auklets	0.00	2.33	0.00	3.38	0.00	0.12
Puffins	0.00	1.19	0.00	0.91	0.00	2.57
Fulmars	0.00	1.41	0.00	1.00	0.00	0.33
Storm Petrels	0.00	1.02	0.00	0.00	0.00	0.09
Cormorants	0.00	0.31	0.00	0.29	0.00	0.14
Gulls	0.00	0.17	0.00	0.20	0.00	0.23
Albatross Jaeger	0.00	0.02	0.00	0.19	0.00	0.09
Sleeper shark	0.00	75.31	7.70	345.37	0.02	397.82
Salmon shark	0.37	8.29	#N/A	#N/A	0.91	135.51
Dogfish	0.00	0.42	#N/A	#N/A	50.68	1,200.96
W. Pollock	10,167.08	49,162.78	200,801.13	1,045,743.25	18,048.90	82,016.95
W. Pollock_Juv	0.00	0.00	0.00	0.00	0.00	0.00
P. Cod	13,901.69	13,419.17	111,320.38	98,530.91	35,561.47	37,639.98
P. Cod_Juv	0.00	0.00	0.00	0.00	0.00	0.00
Herring	0.00	0.01	10,693.91	3,788.60	14,732.40	1,482.71
Herring_Juv	0.00	0.00	0.00	0.00	0.00	0.00
Arrowtooth	135.33	1,397.88	2,922.84	14,988.43	1,182.72	18,684.58
Arrowtooth_Juv	0.00	0.00	0.00	0.00	0.00	0.00
Kamchatka fl.	0.00	0.00	0.00	0.00	#N/A	#N/A
Kamchatka fl._Juv	0.00	0.00	0.00	0.00	#N/A	#N/A
Gr. Turbot	1,465.03	1,245.60	2,055.40	2,392.77	#N/A	#N/A
Gr. Turbot_Juv	0.00	0.00	0.00	0.00	#N/A	#N/A
P. Halibut	2,692.04	451.12	4,000.00	5,676.57	24,183.91	4,510.03
P. Halibut_Juv	0.00	0.00	0.00	0.00	0.00	0.00

Table C3. Continued.

Group	AI Ret	AI Disc	EBS Ret	EBS Disc	GOA Ret	GOA Disc
YF. Sole	0.00	1.97	68,258.50	49,047.33	41.82	28.56
YF. Sole_Juv	0.00	0.00	0.00	0.00	#N/A	#N/A
FH. Sole	0.19	14.04	3,197.00	10,999.46	1,282.96	841.52
FH. Sole_Juv	0.00	0.00	0.00	0.00	0.00	0.00
N. Rock sole	71.57	180.82	19,764.14	36,146.65	1,083.89	770.11
N. Rock sole_Juv	#N/A	#N/A	0.00	0.00	#N/A	#N/A
S. Rock sole	0.72	1.83	#N/A	#N/A	1,084.13	770.11
AK Plaice	0.00	0.00	3,379.26	11,625.17	0.35	1.13
Dover Sole	0.00	1.39	0.17	0.46	4,957.10	2,516.67
Rex Sole	0.38	3.93	253.40	85.64	2,031.55	811.22
Misc. Flatfish	2.79	36.56	805.55	2,771.55	2,643.32	2,418.84
Alaska skate	13.84	790.38	1,835.74	10,218.03	4.38	27.43
Bering skate	0.00	0.00	167.88	972.03	157.84	476.03
Aleutian skate	8.62	492.35	114.30	656.69	8.77	136.66
Whiteblotched skate	13.01	743.04	11.66	64.86	4.38	6.97
Mud skate	1.55	88.73	2.87	15.94	#N/A	#N/A
Longnosed skate	#N/A	#N/A	0.00	0.00	306.91	1,347.16
Big skate	#N/A	#N/A	0.00	0.00	394.81	1,445.73
Black skate	#N/A	#N/A	0.13	0.72	#N/A	#N/A
Sablefish	1,033.92	488.35	1,328.70	46.87	11,889.55	6,256.63
Sablefish_Juv	0.00	0.00	0.00	0.00	0.00	0.00
Eelpouts	0.00	0.00	0.00	0.00	2.23	4.85
Giant Grenadier	16.07	5,327.80	18.09	2,112.31	73.85	10,798.35
Pacific Grenadier	0.00	0.00	0.00	0.00	0.04	5.45
Other Macruids	0.00	0.00	0.00	0.00	0.71	103.62
Misc. fish deep	60.17	132.45	0.00	0.00	92.85	268.44
POP	5,249.42	3,965.83	4,127.86	974.43	2,148.50	2,452.71
POP_Juv	#N/A	#N/A	#N/A	#N/A	0.00	0.00
Sharpchin Rock	101.90	90.73	36.18	12.96	3,477.85	3,181.73
Northern Rock	329.05	2,837.09	687.51	210.47	2,298.84	2,499.35
Dusky Rock	4.72	19.96	3.35	6.66	1,792.19	1,055.26
Shortraker Rock	221.21	264.87	121.09	1.94	600.26	350.67
Rougheye Rock	623.73	282.47	75.78	1.94	620.93	350.39
Shortspine Thorns	123.91	3.56	63.44	4.68	1,016.90	454.06
Shortspine Thorns_Juv	#N/A	#N/A	#N/A	#N/A	0.00	0.00
Other Sebastes	168.72	103.57	164.98	189.82	279.00	120.87
Atka mackerel	29,534.79	18,392.55	1,008.37	1,543.52	4,060.70	191.32
Atka mackerel_Juv	0.00	0.00	0.00	0.00	0.00	0.00
Greenlings	0.00	0.00	0.00	0.00	14.51	0.00
Lg. Sculpins	8.52	2,007.16	284.92	4,667.30	56.45	1,241.82
Other sculpins	0.00	0.00	0.00	0.00	0.00	0.00
Misc. fish shallow	60.17	132.45	5.60	17.78	93.29	268.44
Octopi	77.95	74.27	39.67	113.58	48.21	48.99
Squids	48.14	434.60	225.99	434.80	34.83	65.89
Salmon returning	23.49	9.88	84,034.48	333.59	84,756.19	8,688.33
Salmon outgoing	0.00	0.00	0.00	0.00	0.00	0.00
Bathylagidae	0.00	0.00	0.00	0.00	0.00	0.00
Myctophidae	0.14	0.26	0.12	0.10	0.00	0.00
Capelin	0.00	0.00	0.01	0.00	49.60	6.03
Sandlance	0.00	0.00	0.00	0.02	0.12	0.02
Eulachon	0.00	0.00	0.80	0.96	52.68	6.03
Oth. managed forage	0.00	1.90	0.20	2.40	0.57	2.56
Oth. pelagic smelt	0.00	0.02	28.65	25.45	11.62	1.34

Table C3. Continued.

Group	AI Ret	AI Disc	EBS Ret	EBS Disc	GOA Ret	GOA Disc
Bairdi	0.00	3.69	23,562.35	961.26	1,024.04	53.04
Bairdi_Juv	#N/A	#N/A	0.00	0.00	#N/A	#N/A
King Crab	2,843.00	21.52	9,340.89	397.60	20.91	2.01
King Crab_Juv	#N/A	#N/A	0.00	0.00	#N/A	#N/A
Opilio	#N/A	#N/A	149,385.12	3,398.12	#N/A	#N/A
Opilio_Juv	#N/A	#N/A	0.00	0.00	#N/A	#N/A
Pandalidae	0.00	0.16	0.11	0.99	57.17	0.70
NP shrimp	0.00	0.16	0.00	0.00	0.90	0.70
Sea stars	0.01	36.26	19.23	3,223.67	2.70	906.60
Brittle stars	0.00	0.00	0.00	0.00	0.00	0.00
Urchins dollars cucumbers	0.01	8.25	0.17	32.58	1.02	21.66
Snails	0.00	0.00	0.09	8.96	0.10	0.00
Hermit crabs	0.00	0.00	1.64	144.92	0.00	0.00
Misc. crabs	0.68	4.02	171.69	0.17	8.40	15.01
Misc. Crustacean	0.00	0.00	0.00	0.00	0.00	0.00
Benthic Amphipods	0.00	0.00	0.00	0.00	0.00	0.00
Anemones	0.00	2.26	0.21	191.14	0.12	21.57
Corals	0.13	61.70	0.07	9.22	0.87	5.03
Hydroids	0.00	0.00	0.00	0.00	0.00	0.00
Urochordata	0.00	1.42	3.02	748.11	0.00	1.97
Sea Pens	0.00	0.35	0.09	3.37	0.00	2.05
Sponges	0.15	277.32	0.95	321.59	0.08	6.08
Bivalves	0.00	0.00	0.01	0.06	81.91	0.00
Polychaetes	0.00	0.00	0.00	0.00	0.00	0.00
Misc. worms	0.00	0.00	0.00	0.00	0.00	0.00
Scyphozoid Jellies	1.30	1.40	1,671.65	7,586.88	41.22	57.17
Fish Larvae	0.00	0.00	0.00	0.00	0.00	0.00
Chaetognaths	0.00	0.00	0.00	0.00	0.00	0.00
Euphausiids	0.00	0.00	0.00	0.00	0.00	0.00
Mysids	0.00	0.00	0.00	0.00	0.00	0.00
Pelagic Amphipods	0.00	0.00	0.00	0.00	0.00	0.00
Gelatinous filter feeders	0.00	0.00	0.00	0.00	0.00	0.00
Pteropods	0.00	0.00	0.00	0.00	0.00	0.00
Copepods	0.00	0.00	0.00	0.00	0.00	0.00
Pelagic microbes	0.00	0.00	0.00	0.00	0.00	0.00
Benthic microbes	0.00	0.00	0.00	0.00	0.00	0.00
Macroalgae	0.00	0.00	0.00	0.00	0.00	0.00
Lg Phytoplankton	0.00	0.00	0.00	0.00	0.00	0.00
Sm Phytoplankton	0.00	0.00	0.00	0.00	0.00	0.00

Table C4. Sea otter diets in the Aleutian Islands (AI) and Eastern Bering Sea / Gulf of Alaska (EBS/GOA). See main text for “preference” diet calculations which distribute a percentage of the diet over multiple prey groups using prey biomass, and Appendix A for sources. Rounding diet percentages may cause column totals to be slightly more or less than 100.

AI sea otter prey	% by weight	EBS/GOA sea otter prey	% by weight
Urchins, dollars, and cucumbers	60.0	Urchins, dollars, and cucumbers Misc. crabs	75.0 Preference
Misc. shallow fish	18.7	W. pollock W. pollock juv P. cod juv Herring Herring juv P. halibut juv Other *Sebastes* Capelin Sand lance Eulachon Managed forage Other pelagic smelt	20.0 Preference
Greenlings Sand lance Managed forage	10.3 Preference	Squids	5.00
Octopus NP shrimp Sea stars Snails Misc. crabs Misc. crustaceans Bivalves Polychaetes Misc. worms etc.	8.00 Preference		

Table C5. Steller sea lion (SSL) diets, percent by weight, in the Aleutian Islands (AI) Eastern Bering Sea (EBS), Western Gulf of Alaska (WGOA), and Central Gulf of Alaska (CGOA). See main text for "preference" (P) diet calculations which distribute a percentage of the diet over multiple prey groups using prey biomass, and Appendix A for sources.

AI SSL prey	%	EBS SSL prey	%	WGOA SSL prey	%	CGOA SSL prey	%
Atka mackerel	65.2	W. pollock W. pollock juv*	32.9P	W. pollock W. pollock juv*	39.9P	W. pollock W. pollock juv*	40.4P
W. pollock P. cod Misc. shallow fish W. pollock juv* P. cod juv*	15.0P	Octopus	18.0	Salmon outgoing Salmon returning	17.7P	Salmon outgoing Salmon returning	20.2P
Salmon outgoing Salmon returning	7.9P	Yellowfin sole juv Flathead sole juv N rock sole juv AK plaice Dover sole Rex sole Misc. flatfish	12.0P	Herring Herring juv*	7.5P	Arrowtooth Arrowtooth juv*	16.9P
Octopus Squids	6.8P	P. cod	7.0	Atka mackerel	6.6	Sand lance	3.9
Alaska skate Bering skate Aleutian skate Whiteblotched skate Mud skate Pacific ocean perch Sharpchin rockfish Northern rockfish Dusky rockfish Shortraker rockfish Rougheye rockfish Shortspine thornyhead Other *Sebastes*	4.3P	Capelin	6.0	Sand lance	5.0	Other pelagic smelt	3.0
Capelin Sand lance Eulachon Herring Herring juv*	0.8P	Other sculpins	6.0	Misc. shallow fish	3.6	Misc. shallow fish	2.9
		Sand lance	4.0	P. cod P. cod juv*	3.1P	Herring Herring juv*	2.8P
		Squids	3.0	Arrowtooth Arrowtooth juv*	2.5P	P. cod P. cod juv*	2.0P
		Misc. shallow fish	3.0	Large sculpins	2.3	Octopus Squids	1.6P
		Herring juv	3.0	N rock sole S rock sole	2.0P	Capelin	1.1
		Eelpouts	1.0	Managed forage	1.3	Sablefish$^+$ Sablefish juv*	0.9
		Pandalids NP shrimp	1.0P	Octopus Squids	1.3P	Flathead sole AK plaice Dover sole Rex sole Flathead sole juv*	0.8P
		Tanner crab King crab Snow crab Hermit crab Misc. crab	1.0P	Greenlings	1.1	Halibut Halibut juv*	0.6P
		Salmon outgoing	0.5	Pacific ocean perch Sharpchin rockfish Northern rockfish Dusky rockfish Other *Sebastes* Shortraker rockfish$^+$ Rougheye rockfish$^+$ Shortspine thornyhead$^+$	0.9P	Pacific ocean perch Sharpchin rockfish Northern rockfish Dusky rockfish Other *Sebastes* Shortraker rockfish$^+$ Rougheye rockfish$^+$ Shortspine thornyhead$^+$	0.5P
		Salmon returning	0.5	Polychaetes	0.8	Big skate Longnose skate Alaska skate Bering skate Aleutian skate	0.5P
		Pacific ocean perch Sharpchin rockfish Northern rockfish Dusky rockfish Shortraker rockfish Rougheye rockfish Shortspine thornyhead Other *Sebastes*	0.4P	Big skate Longnose skate Alaska skate Bering skate Aleutian skate	0.7P	Managed forage	0.5
		Atka mackerel	0.1	Flathead sole AK plaice Dover sole Rex sole Flathead sole juv*	0.7P	Polychaetes	0.5
		Snails	0.1	Bathylagidae	0.6	N rock sole S rock sole	0.3P
				Halibut Halibut juv*	0.6P	Eulachon	0.3
						Myctophidae	0.2

AI SSL prey	%	EBS SSL prey	%	WGOA SSL prey	%	CGOA SSL prey	%
		Bivalves	0.1	Capelin	0.5	Large sculpins	0.2
				Other sculpins	0.3		
				Other pelagic smelt	0.3		
				Yellowfin sole	0.3		
				Misc. flatfish	0.2		
				Shearwater Murre Kittiwake Auklet Puffin Fulmar Storm Petrel Cormorants Gulls Albatross Jaeger	0.2P		
				Sablefish+ Sablefish juv*	0.2		
				Eulachon	0.1		

*prey eaten only by juvenile SSL
+prey eaten only by adult SSL

Table C6. Pinniped diets, percent by weight, in the Aleutian Islands (AI) Eastern Bering Sea (EBS), and Gulf of Alaska (GOA). See main text for "preference" (P) diet calculations which distribute a percentage of the diet over multiple prey groups using prey biomass, and Appendix A for sources. Rounding diet percentages may cause column totals to be slightly more or less than 100.

Walrus/bearded seal prey	%	EBS N. fur seal prey	%	GOA N. fur seal prey	%	EBS/AI resident seals prey	%	GOA resident seals prey	%	Wintering seals prey	%
Bivalves	70.15	W. pollock juv	30.0	Capelin	38.0	Pandalid shrimp Non-pand. shr.	15.0P	W. pollock W. pollock juv	42.6P	W. pollock W. pollock juv	49.6P
Misc. worm etc.	18.0	Squid	30.0	Sand lance	34.0	W. pollock W. pollock juv	14.3P	Herring Herring juv	32.4P	Misc. shallow fish	10.0
Snails	6.0	Capelin	15.3	W. pollock W. pollock juv*	8.5P	Misc. shallow fish	13.5	Misc. shallow fish	9.7	Capelin	8.6
Pandalid shrimp Non-pand. shrimp	2.0P	Yellowfin so. juv Flathead sole juv N rock sole juv AK plaice Dover sole Rex sole Misc. flatfish	8.0P	Squid	6.5	Octopus	10.0	Salmon returning	4.0	Other sculpins	8.0
Octopus	1.0	Herring juv	6.0	P. cod P. cod juv* Arrowtooth Arrowtooth juv* Halibut Halibut juv* Yellowfin sole Flathead sole Flathead sole juv* N rock sole S rock sole AK plaice Dover sole Rex sole Misc. flatfish Sablefish Sablefish juv Eelpouts Atka mackerel Atka mack juv* Greenlings Large sculpins Other sculpins Misc. shallow fish Salmon outgoing Bathylagidae Myctophidae Eulachon Managed forage Oth. Pelagic smelt	5.5P	Yellowfin so. juv Flathead sole juv N rock sole juv AK plaice Dover sole Rex sole Misc. flatfish	8.0P	Eelpouts Atka mackerel Atka mack juv Greenlings	2.7P	Eelpouts	6.1
Tanner crab King crab Snow crab Hermit crab Misc. crab	1.0P	Myctophidae	4.0			Capelin	5.5	Octopus Squid	2.1P	Pandalid shrimp Non-pand. shrimp	5.5P
Wintering seals	0.10	Salmon returning	1.0			Other sculpins	5.0	P. cod P. cod juv	1.6P	Herring juv	4.5
		Salmon outgoing	1.0			Eelpouts	5.0	Large sculpins Other sculpins	1.2P	Yellowfin so. juv Flathead sole juv N rock sole juv AK plaice Dover sole Rex sole Misc. flatfish	4.0P
		Sand lance	1.0			P. cod juv	4.0	Arrowtooth Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole Flathead sole juv N rock sole S rock sole AK plaice Dover sole Rex sole Misc. flatfish	1.2P	Misc. worm etc.	2.65
		P. cod juv	0.70			Herring juv	2.5	Pacific o. perch Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Other *Sebastes*	1.1P	Octopus	1.0
		Sablefish juv	0.50			Squid	2.5			Hermit crab Misc. crab	1.0P
		Atka mackerel	0.50			Atka mackerel	1.0 4.0[1]			P. cod juv	0.5
		Other sculpins	0.10			Tanner crab King crab Snow crab Hermit crab Misc. crab	1.0P			Squid	0.05
		Octopus	0.10			Pacific o. perch Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Sh. thornyhead Other *Sebastes*	0.4P				
		Pacific o. perch Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Sh. thornyhead Other *Sebastes*	0.1P								

Walrus/bearded seal prey	**%**	**EBS N. fur seal prey**	**%**	**GOA N. fur seal prey**	**%**	**EBS/AI resident seals prey**	**%**	**GOA resident seals prey**	**%**	**Wintering seals prey**	**%**
				Herring Herring juv*	3.5P	Salmon returning	0.25	Sand lance	0.8		
				Salmon returning	2.0	Salmon outgoing	0.25	Capelin Eulachon Managed forage Oth. Pelagic smelt	0.4P		
				Pacific o. perch Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Other *Sebastes*	2.0P			Pandalid shrimp Non-pand. sh. Tanner crab King crab Snow crab Hermit crab Misc. crab	0.2P		

*prey eaten only by juvenile N fur seals

[1] diet percentage in the AI

Table C7. Toothed whales diet percent by weight, in the Aleutian Islands (AI) Eastern Bering Sea (EBS), and Gulf of Alaska (GOA). See main text for “preference” (P) diet calculations which distribute a percentage of the diet over multiple prey groups using prey biomass, and Appendix A for sources. Rounding diet percentages may cause column totals to be slightly more or less than 100.

Transient killer whale prey	%	Sperm/beaked whale prey	%	Resident killer whale prey	%	AI Porpoise prey	%	EBS porpoise prey	%	GOA propoise prey	%
Porpoises Belugas Gray whales Humpback whales Fin whales Sei whales Right whales Minke whales Bowhead whales Sea otters N. fur seal N. fur seal juv Steller sea lion Steller sea lion juv Resident seals	100P	Squid	85.0	W. pollock W. pollock juv P. cod P. cod juv Herring Herring juv Arrowtooth Arrowtooth juv Kamchatka Kamchatka juv Gr. turbot Gr. turbot juv P. Halibut P. Halibut juv Yellowfin sole Yellowfin so. juv Flathead sole Flathead sold juv N. rock sole S. rock sole Alaska plaice Dover sole Rex sole Misc. flatfish Squid Salmon returning Salmon outgoing Bathylagidae Myctophidae Capelin Sand lance Eulachon Managed forage Oth pel. smelt	100P	Squid	90.0	Squid	50.0	Squid	69.3
		Sleeper sharks P. cod Alaska skate Bering skate Aleutian skate Whiteblotched skate Mud skate Sablefish Sablefish juv Eelpouts Giant grenadier Pacific grenadier Other Macrourids Misc. deep fish Pacific o. perch Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Sh. thornyhead Other *Sebastes*	15.0P			Bathylagidae Myctophidae Capelin Sandlance Eulachon Managed Forage Oth pel. smelt	10.0P	Other sculpins Misc shallow fish Salmon returning Salmon outgoing Bathylagidae Myctophidae Capelin Sand lance Eulachon Managed Forage Oth pel. smelt	50P	Bathylagidae Myctophidae Capelin Sand lance Eulachon Managed Forage Oth pel. smelt	18.5P
										Eelpouts Other sculpins Misc. shallow fish	12.2P

Table C8. Baleen whales diet percent by weight, in the Aleutian Islands (AI) Eastern Bering Sea (EBS), and Gulf of Alaska (GOA). See main text for “preference” (P) diet calculations which distribute a percentage of the diet over multiple prey groups using prey biomass, and Appendix A for sources. Rounding diet percentages may cause column totals to be slightly more or less than 100.

Grey whale prey	%	Humpback whale prey	%	Fin whale prey	%	Sei whale prey	%	Right whale prey	%	Minke whale prey	%	Bowhead whale prey	%
Benthic amphipods	90.0	Chaetognaths Euphausiids Mysids Pel. amphipods Pteropods	59.9 P	Chaetognaths Euphausiids Mysids Pel. amphipods Pteropods	60.0 P	Copepods	80.0	Copepods	95.0	W. pollock juv Herring juv Salmon returning Salmon outgoing Capelin Sand lance Eulachon Managed Forage Oth pel. smelt	56.0 P	Chaetognaths Euphausiids Mysids Pel. amphipods Pteropods	55.0 P
Tanner crab King crab Snow crab Pandalid shrimp Non-pand. shrimp Sea star Brittle star Urchins dollars and cucumbers Snails Hermit crabs Misc. crabs Misc. Crustacean Anemones Corals Benth. Hydroid Benth. Urochordata Sea Pens Sponge Bivalves Polychaete Misc. Worm. Etc.	10.0 P	W. pollock juv Herring juv Atka mack juv Misc. shallow fish Salmon returning Salmon outgoing Capelin Sand lance Eulachon Managed Forage Oth pel. smelt	39.9 P	Copepods	20.0	W. pollock juv Herring juv Salmon returning Salmon outgoing Capelin Sand lance Eulachon Managed Forage Oth pel. smelt	10.0 P	Chaetognaths Euphausiids Mysids Pel. amphipods Pteropods	5.0 P	Chaetognaths Euphausiids Mysids Pel. amphipods Pteropods	40.0 P	Copepods	40.0
		Squid	0.5	W. pollock juv Herring juv Misc. shallow fish Salmon returning Salmon outgoing Capelin Sand lance Eulachon Managed Forage Oth pel. smelt	20.0 P	Chaetognaths Euphausiids Mysids Pel. amphipods Pteropods	5.0 P			Squid	2.0	Tanner crab Tanner crab juv King crab King crab juv Snow crab Snow crab juv Pandalid shrimp Non Pand. shrimp Sea star Brittle star Urchins dollars and cucumbers Snails Hermit crabs Misc. crabs Misc. Crustacean Benth. amphipods Anemones Corals Benth. Hydroid Benth. Urochordata Sea pens Sponge Bivalves Polychaete Misc. Worm. Etc.	
		Copepods	0.5			Squid	5.0			Copepods	2.0		

Table C9. Sharks diet percent by weight, in the Aleutian Islands (AI) Eastern Bering Sea (EBS), and Gulf of Alaska (GOA). See main text for "preference" (P) diet calculations which distribute a percentage of the diet over multiple prey groups using prey biomass, and Appendix A for sources. Rounding diet percentages may cause column totals to be slightly more or less than 100.

EBS sleeper shark prey	%
W. pollock	20.0
Giant grenadier	20.0
Squids	20.0
Arrowtooth fl. Kamchatka fl. Gr. turbot P. halibut	20.0P
Offal	10.0
Salmon returning	5.0
Misc. shallow fish	2.0
Octopus	2.0
Pandalid shrimp	0.25
Non-Pandalid shrimp	0.25
Snails	0.25
Hermit crabs	0.25

GOA/AI sleeper shark prey	%
Arrowtooth fl.	67.2
Offal	12.3
W. pollock	5.2
Octopus	4.6
Salmon returning	4.5
Pacific o. perch Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Sh. thornyhead Other *Sebastes*	2.1P
Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole juv N rock sole S rock sole AK plaice Dover sole Rex sole Misc flatfish	1.1P
Flathead sole	1.0
Squids	0.8
Snails	0.7
Misc. shallow fish	0.5
Non-Pandalid shrimp	0.01
Hermit crabs	0.01

Salmon shark prey	%
Salmon returning	39.6
Sablefish	36.0
P. halibut juv	11.0
Squids	7.0
Greenlings Large sculpins Other sculpins Misc. fish shallow	4.0P
Dogfish	1.0
Pacific o. perch Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Sh. thornyhead Other *Sebastes*	1.0P
Herring	0.4

Dogfish prey	%
W. pollock W. pollock juv P. cod P. cod juv Misc. shallow fish	15.4P
Herring	14.2
Euphausiids	12.9
Arrowtooth fl. Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole Flathead sole juv N rock sole S rock sole AK plaice Dover sole Rex sole Misc. flatfish	11.2P
Chaetognaths Mysids Pel. amphipods Pteropods Copepods	9.1P
Pandalid shrimp	7.6
Misc. crabs	6.7
Eulachon	3.7
Tanner crab King crab Non Pand. shrimp Sea star Brittle star Snails Hermit crabs Anemones Benth. Hydroid Bivalves Polychaete Misc. Worm. Etc.	2.9P
Octopus	2.9
Pacific o. perch Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Sh. thornyhead Other *Sebastes*	2.8P

EBS sleeper shark prey	%	GOA/AI sleeper shark prey	%	Salmon shark prey	%	Dogfish prey	%
						Pel. gel. filter feeder	2.3
						Dogfish Alaska skate Bering skate Aleutian skate Whiteblotched skate Mud skate Longnose skate Big skate	2.0P
						Squids	1.8
						Misc. worm etc.	1.2
						Scyphozoid jellies	1.2
						Sand lance	1.1
						Benthic amphipods	0.6
						Urchins dollars and cucumbers	0.3
						Misc. Crustacean	0.1

Table C10. Skates diet percent by weight, in the Aleutian Islands (AI) and Gulf of Alaska (GOA). See main text for “preference” (P) diet calculations which distribute a percentage of the diet over multiple prey groups using prey biomass, and Appendix A for sources. Rounding diet percentages may cause column totals to be slightly more or less than 100.

GOA/AI Alaska skate prey	%	GOA Bering skate prey	%	GOA Aleutian skate prey	%	GOA other skates prey	%	Longnose skate prey	%	GOA/AI Big skate prey	%
Benthic amphipods	16.8	Benthic amphipods	80.5	Pandalid shrimp	26.4	Squids	26.5	W. pollock juv P. cod P. cod juv Herring Herring juv Sablefish juv Eelpouts Atka mackerel Atka mack. juv Greenlings Large sculpins Other sculpins Misc. shallow fish Salmon returning Salmon outgoing Bathylagidae Myctophidae Capelin Sandlance Eulachon Managed Forage Oth pel. smelt	47.5P	Non-Pandalid shrimp	44.1
Atka mackerel	12.2	Misc. worms etc.	10.5	Squids	14.6	Benthic amphipods	25.7	Rex sole	25.4	Arrowtooth fl. Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole Flathead sole juv N rock sole S rock sole AK plaice Misc. flatfish	17.4P
Octopus	12.2	Pandalid shrimp	2.8	W. pollock juv P. cod P. cod juv Herring Herring juv Arrowtooth fl. Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole Flathead sole juv N rock sole S rock sole AK plaice Dover sole Rex sole Misc. flatfish Sablefish Sablefish juv Misc. shallow fish Pacific o. perch Pacific o. perch juv Sharpchin rf. Northern rockfish Dusky rockfish Shortraker rf. Rougheye rf. Sh. thornyhead Sh. thornyhead juv Other *Sebastes* Atka mack. juv Greenlings	9.8P	W. pollock juv P. cod P. cod juv Herring Herring juv Arrowtooth fl. Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole Flathead sole juv N rock sole S rock sole AK plaice Dover sole Rex sole Misc. flatfish Sablefish Sablefish juv Misc. shallow fish Eelpouts Giant grenadier Pacific grenadier Pacific o. perch Pacific o. perch juv Sharpchin rf. Northern rockfish Dusky rockfish Rougheye rf. Sh. thornyhead Sh. thornyhead juv Other *Sebastes* Atka mack. juv	10.4P	Arrowtooth fl. Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole Flathead sole juv N rock sole S rock sole AK plaice Dover sole Misc. flatfish	25.0P	Sand lance	12.1
Squids	11.8	Squids	1.7							W. pollock juv P. cod P. cod juv Herring Herring juv Sablefish juv Atka mack. juv Greenlings Large sculpins Other sculpins Salmon returning Salmon outgoing Capelin Eulachon Managed Forage Oth pel. smelt	11.8P
P. cod P. cod juv Herring Herring juv Arrowtooth fl. Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole Flathead sole juv N rock sole S rock sole AK plaice Dover sole Rex sole Misc. flatfish Sablefish juv Eelpouts Greenlings Capelin Sand lance Eulachon Managed forage Oth. pelagic smelt	7.9P	Non-Pand. shrimp	1.1							Eelpouts	10.0
Other sculpins	7.9	Misc. Crustacean	0.9							Benthic detritus	1.3
Tanner crabs	7.9	Polychaetes	0.9							Mysid	1.0
W. pollock W. pollock juv	3.9P	Benthic detritus	0.9							Misc. shallow fish	0.9
Large sculpins	3.9	Brittle star	0.3								
		W. pollock W. pollock juv P. cod P. cod juv Herring Herring juv Arrowtooth fl. Arrowtooth juv Halibut Halibut juv Yellowfin sole Flathead sole Flathead sole juv N rock sole S rock sole AK plaice Dover sole Rex sole Misc. flatfish Sablefish juv Eelpouts Atka mackerel Atka mack. juv Greenlings	0.2P								

GOA/AI Alaska skate prey	%	GOA Bering skate prey	%	GOA Aleutian skate prey	%	GOA other skates prey	%	Longnose skate prey	%	GOA/AI Big skate prey	%
Misc. shallow fish	3.9	Large sculpins Other sculpins Misc. shallow fish		Bathylagidae Myctophidae Capelin Sandlance Eulachon Managed Forage Oth pel. smelt		Greenlings Capelin Sandlance Eulachon Managed Forage Oth pel. smelt		Non-Pandalid shrimp	2.1	Octopus	0.5
Bathylagidae	3.9									Bivalves	0.4
Non-Pandalid shrimp	3.9	Hermit crabs	0.2							Misc. Crustacean	0.2
Hermit crabs	3.9									Benthic amphipods	0.1
				Tanner crabs	8.8	Pandalid shrimp	9.8			Misc. crabs	0.1
				Other sculpins	7.7	Tanner crabs	4.3				
				Benthic amphipods	6.5	Atka mackerel	3.5				
				Misc. shallow fish	5.4	Hermit crabs	3.0				
				Octopus	4.7	Octopus	2.9				
				Atka mackerel	4.3	Polychaetes	2.7				
				W. pollock	3.0	Benthic detritus	2.7				
				Misc. worm etc.	2.5	Misc. worm, etc.	1.8				
				Benthic detritus	2.5	Other sculpins	1.5				
				Large sculpins	1.3	Myctophidae	1.1				
				Eelpouts	0.8	W. pollock	0.9				
				Bering skate	0.4	Bathylagidae	0.8				
				Non-Pandalid shrimp	0.4	Non-Pandalid shrimp	0.7				
				Hermit crabs	0.4	Mysids	0.4				
				Polychaetes	0.4	Misc. shallow fish	0.3				
						Shortraker rf.	0.2				
						Misc. Crustacean	0.2				
						Other Macrourids	0.1				
						Large sculpins	0.1				
						King crabs	0.1				
						Bivalves	0.1				

Table C11. Skate diets in the Eastern Bering Sea (EBS) and Aleutian Islands (AI), from diet data (direct query method, see Appendix B for details). Values of 0.00% are trace in diet, blanks are not in diet.

Skate prey	AK skate EBS	Bering skate EBS	Aleutian skate EBS	Big skate EBS	Bering skate AI	Aleutian skate AI	Whitebl. skate AI	Mud skate AI
W. pollock juv	0.16%					41.67%		
W. pollock	40.47%	84.18%	16.71%	8.45%			14.29%	
P. cod juv		0.92%						
P. cod	0.64%							
Herring	0.19%							
Arrowtooth fl.	2.63%							
Kamchatka fl.								
Gr. Turbot								
P. halibut juv	0.13%							
P. halibut	0.00%							
Yellowfin sole juv	0.01%							
Yellowfin sole	0.68%		5.70%	41.08%				
Flathead sole	0.00%							
N. rock sole juv	0.02%							
N. rock sole	8.49%		3.67%					
Misc. flatfish	0.17%							
Giant grenadier								
Eelpouts	8.71%	7.54%						
Atka mackerel							26.49%	
Large sculpins	0.00%							
Other sculpins	2.36%		0.32%				6.78%	
Misc. shallow fish	0.37%		6.06%				0.01%	
Octopus							0.04%	
Squids	0.00%						1.83%	83.36%
Salmon returning	2.55%							
Bathylagidae								1.20%
Myctophidae							0.10%	0.02%
Sandlance	2.92%	0.02%						
Managed forage	0.26%	0.09%						
Tanner crab juv	0.09%							
Tanner crab	0.41%	1.29%	6.92%	45.11%			0.96%	
King crab					8.72%	58.33%	2.05%	
Snow crab juv	0.31%						33.09%	
Snow crab	2.81%	0.37%	3.46%	5.37%				
Pandalid shrimp	0.13%							
Non-Pandalid shrimp	6.46%	0.20%	19.96%					
Sea star	0.06%							
Brittle star	0.01%						0.30%	
Urchins dollars and cucumbers	0.00%						9.29%	
Snails	0.03%				13.20%		0.43%	1.87%
Hermit crabs	2.16%	1.03%	35.54%		5.77%		0.00%	0.00%
Misc crabs	0.08%	3.90%	0.13%					
Misc. Crustacean	0.00%							
Benthic amphipods	0.88%	0.45%	0.61%					
Benth. Urochordata	0.00%							
Sea pens					71.29%			0.02%
Sponge	0.00%							
Bivalves	0.00%							
Polychates	0.27%		0.62%					
Misc. worm etc.	0.01%							
Scyphozoid jellies	0.00%						0.04%	0.85%
Fish larvae					1.03%		0.09%	0.88%
Euphausiids	0.00%	0.01%	0.00%					
Mysids	0.05%		0.02%					
Unidentified prey							4.20%	11.80%
Offal	15.44%		0.26%					

Table C12. Pollock and cod diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B).Values of 0.00% are trace in diet, blanks are not in diet.

Prey	AI W. pollock juv	AI W. pollock	AI P. cod juv	AI P. cod	EBS W. pollock juv	EBS W. pollock	EBS P. cod juv	EBS P. cod	GOA W. pollock juv	GOA W. pollock	GOA P. cod juv	GOA P. cod
W. pollock juv		0.13%		0.00%	0.98%	4.41%	0.67%	2.87%	1.65%	0.94%	0.21%	0.94%
W. pollock		0.40%		4.23%		8.51%		25.93%		0.81%		18.79%
P. cod juv				0.12%		0.03%		0.04%		0.00%		
P. cod				0.10%		0.07%		0.54%		0.00%		0.01%
Herring juv		0.02%		0.02%		0.00%		0.18%				0.05%
Herring		0.00%				0.09%		0.04%		0.02%		
Arrowtooth juv				0.01%				0.00%	0.18%	0.05%		0.01%
Arrowtooth fl.						0.08%		0.07%		0.01%		1.34%
Kamchatka fl.				0.00%		0.00%		0.01%				
Gr. turbot juv					0.01%	0.01%		0.01%				
Gr. Turbot						0.03%		0.00%				
P. halibut juv						0.00%		0.01%				0.00%
P. halibut						0.00%		0.09%				0.00%
Yellowfin sole juv								0.02%				
Yellowfin sole						0.00%		0.76%				
Flathead sole juv						0.00%		0.06%		0.04%		0.23%
Flathead sole				0.04%		0.02%		0.29%		0.01%		0.51%
N. rock sole juv						0.00%		0.02%				
N. rock sole						0.00%		1.33%				
Alaska plaice						0.00%		0.01%				
Dover sole										0.08%		
Rex sole				0.25%								0.01%
Misc. flatfish						0.00%		0.13%				0.00%
Alaska skate								0.00%				
Sablefish juv				0.21%								
Eelpouts				1.39%		0.07%	0.01%	4.00%		0.05%		0.99%
Other Macrourids				0.03%								0.00%
Misc. deep fish		0.89%		0.18%		0.00%				0.00%		
Pacific ocean perch juv				0.24%				0.01%				
Pacific ocean perch												0.00%
Shortspine thornyhead												0.00%
Other Sebastes								0.00%				
Atka mackerel juv		2.17%		0.01%								
Atka mackerel		1.34%		15.27%				0.20%				0.06%
Greenlings				0.05%				0.00%				
Large sculpins				0.00%		0.00%		0.15%				
Other sculpins	3.44%	0.06%	0.15%	14.93%	0.00%	0.05%	0.97%	1.07%		0.04%	3.59%	3.27%
Misc. shallow fish		0.02%		1.53%	0.00%	0.01%	0.03%	0.41%		0.11%		0.44%
Octopus		0.02%		1.05%		0.00%		0.65%		0.10%		2.31%
Squids		2.63%		6.10%	0.03%	0.25%		0.09%		0.64%		0.52%
Salmon returning								0.17%				
Bathylagidae		0.57%		0.09%		0.10%		0.00%		0.00%		
Myctophidae	0.05%	24.30%		3.90%	0.09%	0.25%		0.00%		0.03%		0.04%
Capelin				0.01%	0.04%	0.08%	0.00%	0.42%		4.41%		3.53%
Sand lance		0.00%		0.61%	0.14%	0.17%	0.58%	2.39%		1.20%	2.32%	1.26%
Eulachon						0.00%		0.01%		0.38%		0.18%
Managed forage		0.00%		1.48%		0.06%	0.33%	0.75%		0.53%	0.05%	1.01%
Oth pel. smelt						0.00%						
Tanner crab*	0.10%	0.02%	1.72%	2.21%		0.01%	0.00%	1.62%	0.02%	0.04%	0.41%	8.66%
Tanner crab adu						0.00%		3.19%				
King crab*		0.00%		0.02%	0.00%	0.00%	0.02%	0.02%				0.00%
King crab adu						0.00%		0.96%				
Snow crab*					0.00%	0.00%	0.13%	1.87%				
Snow crab adu						0.00%		5.52%				
Pandalid shrimp	0.06%	2.68%	4.07%	11.65%	0.05%	3.58%	1.00%	5.30%	0.60%	10.29%	0.07%	9.64%
Non-Pandalid shrimp	9.81%	1.43%	33.10%	16.66%	0.49%	1.50%	17.66%	7.61%	6.83%	8.09%	16.63%	10.18%
Sea star		0.00%		0.00%		0.00%		0.02%		0.21%		0.22%
Brittle star		0.00%		0.01%	0.00%	0.01%	0.01%	0.02%				0.03%
Urchins dollars and				0.01%		0.00%		0.01%		0.00%		0.00%
Snails		0.08%		0.41%		0.03%	0.00%	0.60%		0.01%		0.46%
Hermit crabs	0.29%	0.04%	0.56%	0.44%	0.04%	0.10%	0.72%	7.03%	8.66%	1.06%	6.37%	10.10%
Misc crabs		0.00%		3.24%	0.00%	0.03%	0.02%	1.41%	0.15%	0.07%	0.11%	4.98%
Misc. Crustacean	0.15%	0.20%		0.18%	1.63%	0.11%	0.71%	0.06%	0.06%	0.10%	0.42%	0.40%
Benthic amphipods	10.85%	7.53%	19.44%	2.92%	5.70%	2.05%	39.21%	2.82%	5.69%	5.99%	45.28%	2.53%
Benth. Hydroid								0.00%				
Benth. Urochordata				0.01%		0.00%		0.07%				0.00%
Sponge		0.00%		0.00%		0.01%		0.01%				0.00%
Bivalves		0.00%		0.04%	0.05%	0.05%	0.00%	0.21%		0.02%		0.24%
Polychates	0.00%	0.33%	18.58%	4.59%	0.61%	0.21%	4.11%	3.59%	0.14%	0.56%	1.60%	6.33%
Misc. worm etc.		0.00%		0.01%	0.00%	0.22%	0.20%	3.44%		0.01%	0.05%	0.38%
Scyphozoid jellies				0.00%		0.00%		0.00%		0.00%		
Fish larvae				0.04%		0.00%		0.00%				0.00%
Chaetognaths etc.	3.23%	1.68%		0.00%	4.84%	0.98%		0.00%	0.25%	0.03%		0.00%
Euphausiids	12.45%	28.58%		0.16%	32.90%	34.96%	3.31%	2.19%	44.60%	50.03%	5.10%	4.33%
Mysids	8.95%	2.01%	0.06%	0.22%	9.38%	1.18%	29.68%	2.46%	1.00%	2.38%	17.78%	0.05%
Pelagic amphipods	0.00%	0.13%		0.00%	0.52%	1.59%	0.02%	0.01%	0.29%	0.52%	0.01%	0.00%
Pel. gel. filter feeder	11.49%	2.84%	17.28%	0.00%	0.58%	1.45%		0.00%	3.51%	5.52%		0.04%
Pteropods	0.03%	0.14%			0.00%	0.06%	0.00%	0.00%	0.00%	0.16%		0.00%
Copepods	39.11%	18.86%	5.04%	0.13%	41.92%	36.42%	0.61%	0.01%	26.38%	5.36%	0.00%	0.01%
Microzooplankton						0.00%	0.00%	0.00%				
Algae								0.00%				0.00%
Offal		0.89%		5.16%		1.13%	0.00%	7.25%		0.08%		3.19%
Benth detritus												2.73%

*all ages in AI, GOA models, juveniles in EBS model

Table C13. Herring diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet, blanks are not in diet.

Prey	AI Herring juv	AI Herring	EBS Herring juv	EBS Herring	GOA Herring juv	GOA Herring
Pandalid shrimp		0.00%				
Non-Pandalid shrimp						
Sea star						
Brittle star						
Urchins dollars and						
Snails						
Hermit crabs						
Misc crabs						
Misc. Crustacean						
Benthic amphipods		0.00%		0.00%		0.00%
Benth. Hydroid						
Benth. Urochordata						
Sponge						
Bivalves						
Polychates		0.04%		0.04%		0.04%
Misc. worm etc.						
Scyphozoid jellies						
Fish larvae						
Chaetognaths etc.						
Euphausiids	87.86%	95.66%	87.86%	95.66%	87.86%	95.66%
Mysids						
Pelagic amphipods		0.04%		0.04%		0.04%
Pel. gel. filter feeder						
Pteropods						
Copepods	12.14%	4.25%	12.14%	4.25%	12.14%	4.25%

Table C14. Arrowtooth flounder and halibut diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Arrow. juv	AI Arrow. fl.	AI P. halibut juv	AI P. halibut	EBS Arrow. juv	EBS Arrow. fl.	EBS P. halibut juv	EBS P. halibut	GOA Arrow. juv	GOA Arrow. fl.	GOA P. halibut juv	GOA P. halibut
W. pollock juv	0.64%	9.94%		0.31%	21.85%	46.91%		1.90%	0.38%	10.11%		0.14%
W. pollock		1.43%		9.08%		19.48%		52.10%		13.92%		48.26%
P. cod juv		0.16%				0.00%		0.00%		0.61%		
P. cod				0.68%		0.00%		4.74%		0.01%		1.36%
Herring juv										6.59%		
Herring		0.18%				1.34%		0.26%		0.79%		0.73%
Arrowtooth juv						0.34%				0.30%		0.23%
Arrowtooth fl.						0.00%		0.09%		0.37%		3.46%
Kamchatka juv				0.14%		0.00%						
P. halibut juv	4.63%			0.00%	0.06%			0.00%		0.00%		0.00%
P. halibut								0.00%				0.00%
Yellowfin sole juv										0.00%		0.00%
Yellowfin sole						0.03%		3.31%				
Flathead sole juv					0.13%	1.13%		0.05%		0.21%		0.05%
Flathead sole				0.29%		0.02%		1.08%		0.02%		0.43%
N. rock sole juv					0.00%	0.00%		0.01%				
N. rock sole						0.00%		3.24%				
S. rock sole									0.00%			0.01%
Alaska plaice								0.49%				
Dover sole												0.30%
Rex sole								0.10%		0.06%		
Misc. flatfish								2.68%				0.00%
Alaska skate								0.00%				
Bering skate								0.01%				
Sablefish juv										0.08%		
Sablefish		1.10%		1.69%				0.10%				0.26%
Eelpouts				0.07%	0.04%	4.29%		0.93%	0.05%	2.22%		0.74%
Other Macrourids						0.00%						
Misc. deep fish		0.05%		0.05%						0.00%		
Pacific ocean perch												0.21%
Shortspine thornyhead										0.01%		
Atka mackerel juv		16.40%		0.39%					0.24%	1.11%		
Atka mackerel		3.82%		15.60%		0.04%		0.49%		0.63%		1.58%
Greenlings								0.04%				
Large sculpins			3.53%	0.05%				0.17%		0.00%	1.06%	0.15%
Other sculpins	3.20%	4.15%	4.09%	4.80%	2.62%	0.86%		2.24%	0.06%	0.37%	1.92%	0.57%
Misc. shallow fish	11.81%	3.26%	3.26%	1.82%	0.19%	0.00%		1.55%		0.57%	0.02%	0.22%
Octopus		0.00%	7.53%	10.70%		0.01%		0.47%		0.00%	0.00%	2.85%
Squids		0.53%		22.28%		0.88%		0.32%		0.30%		0.23%
Salmon returning										2.18%		0.32%
Bathylagidae				0.64%						0.01%		
Myctophidae	4.38%	26.59%		2.08%		0.34%		0.01%	0.01%	0.17%		
Capelin	4.12%	0.61%		0.11%		1.20%		3.86%	23.70%	21.93%		1.83%
Sand lance			20.01%	2.32%		0.04%		3.44%	7.20%	3.67%	0.09%	2.12%
Eulachon						2.12%		0.00%		2.10%		0.00%
Managed forage		3.28%		0.02%	0.42%	0.59%		0.26%	0.13%	2.61%		0.16%
Oth pel. smelt				0.00%								
Tanner crab*				3.05%				1.27%		0.00%		6.36%
Tanner crab adu								1.33%				
King crab*				0.32%				0.01%				0.01%
King crab adu								0.18%				
Snow crab*						0.00%		0.17%				
Snow crab adu								3.23%				
Pandalid shrimp	36.71%	15.55%	20.19%	0.28%	5.43%	3.87%		0.96%	6.54%	9.82%	9.48%	0.64%
Non-Pandalid shrimp	8.56%	3.01%	7.21%	1.63%	41.88%	2.21%	69.30%	0.46%	2.23%	1.74%	30.38%	0.36%
Sea star								0.00%				0.00%
Brittle star					0.00%	0.01%		0.01%		0.00%		0.01%
Urchins dollars and cucumbers				0.42%				0.00%				0.12%
Snails				0.05%	0.02%	0.00%		0.24%		0.00%		0.24%
Hermit crabs			6.72%	3.07%	0.55%	0.02%	0.04%	4.66%		0.00%	31.53%	10.34%
Misc crabs		0.05%	18.04%	11.47%				0.74%		0.01%	8.41%	12.23%
Misc. Crustacean		0.03%		0.02%		0.00%		0.02%	0.01%	0.01%		0.04%
Benthic amphipods	12.21%	2.24%	3.36%	0.20%	0.19%	0.10%	0.00%	0.01%	0.17%	0.05%	15.76%	0.00%
Benth. Hydroid						0.00%						
Benth. Urochordata		0.75%		0.00%		0.00%		0.00%				0.00%
Sponge		0.00%		0.00%		0.00%				0.00%		0.00%
Bivalves				1.14%		0.02%		0.37%		0.02%		0.18%
Polychates	3.09%	0.74%		0.01%	0.02%	0.09%	0.01%	0.01%	0.12%	0.23%		0.14%
Misc. worm etc.				0.00%				0.19%		0.07%		0.00%
Scyphozoid jellies						0.00%						
Fish larvae						0.02%		0.01%				
Chaetognaths etc.	0.82%				0.00%	0.00%				0.00%		
Euphausiids	9.32%	3.81%	3.54%		24.59%	9.17%		0.34%	59.15%	16.86%	0.17%	0.52%
Mysids	0.26%	1.65%	2.52%		1.96%	0.10%	30.65%	0.09%	0.01%	0.06%	1.18%	0.00%
Pelagic amphipods					0.00%	0.00%			0.00%	0.00%		0.00%
Pel. gel. filter feeder		0.01%				0.01%				0.00%		0.00%
Pteropods	0.02%					0.00%			0.02%	0.00%		
Copepods	0.22%	0.03%			0.03%	0.00%			0.00%	0.01%		
Algae								0.00%		0.00%		0.00%
Offal		0.64%		5.22%		4.75%		1.74%		0.15%		2.55%

*all ages in AI, GOA models, juveniles in EBS model

Table C15. Greenland turbot and Kamchatka flounder diets in the Eastern Bering Sea (EBS) and Aleutian Islands (AI) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Kamchatka juv	Ai Kamchatka fl.	AI Gr. turbot juv	AI Gr. Turbot	EBS Kamchatka juv	EBS Kamchatka fl.	EBS Gr. turbot juv	EBS Gr. Turbot
W. pollock juv	8.74%		9.94%		42.28%	58.05%	1.20%	27.15%
W. pollock			1.43%	2.32%		21.29%		10.53%
P. cod juv			0.16%					
P. cod								0.12%
Herring juv								
Herring			0.18%					1.22%
Arrowtooth juv						0.00%		
P. halibut juv	5.22%							
Flathead sole juv						0.01%		
Flathead sole						0.09%		0.00%
Sablefish			1.10%					
Eelpouts						5.25%		7.29%
Other Macrourids								0.00%
Misc. deep fish			0.05%	4.94%				
Pacific ocean perch		4.00%						
Shortspine thornyhead								0.00%
Atka mackerel juv			16.40%					
Atka mackerel			3.82%	3.74%				
Other sculpins	7.21%	2.70%	4.15%	0.05%		0.28%		2.17%
Misc. shallow fish	2.66%		3.26%			0.82%		0.95%
Octopus			0.00%	0.36%				0.01%
Squids		0.91%	0.53%	32.67%		0.21%		32.27%
Salmon returning								
Bathylagidae				5.54%				9.12%
Myctophidae	4.93%	92.20%	26.59%	49.57%		0.12%		5.18%
Capelin	4.64%		0.61%					
Managed forage			3.28%		0.77%	2.96%		0.96%
Oth pel. smelt								
Tanner crab*						0.12%		
Tanner crab adu								0.00%
King crab*								0.00%
Snow crab adu								0.00%
Pandalid shrimp	2.14%		15.55%		2.76%	2.35%		0.25%
Non-Pandalid shrimp	11.32%		3.01%		40.32%	3.91%	0.37%	0.44%
Brittle star						0.00%	0.00%	0.00%
Hermit crabs						0.01%		0.22%
Misc crabs			0.05%					
Misc. Crustacean			0.03%		0.00%	0.01%	0.00%	0.00%
Benthic amphipods	16.74%		2.24%		2.61%	0.72%	0.23%	0.13%
Benth. Urochordata			0.75%					
Sponge		0.19%	0.00%					
Bivalves						0.03%		
Polychates	3.48%		0.74%	0.00%	2.86%	0.25%		
Misc. worm etc.						0.08%		
Chaetognaths etc.	9.29%							
Euphausiids	10.04%		3.81%	0.01%	7.84%	3.04%	97.44%	1.92%
Mysids	2.90%		1.65%	0.68%	0.55%	0.09%	0.00%	0.01%
Pelagic amphipods							0.75%	0.02%
Pel. gel. filter feeder			0.01%				0.00%	
Pteropods	5.71%						0.00%	0.00%
Copepods	4.99%		0.03%					
Offal			0.64%	0.13%		0.30%		0.03%

*all ages in AI, GOA models, juveniles in EBS model

Table C16. Shallow water flatfish diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Yellowfin sole juv	AI Yellowfin sole	AI Flathead sole juv	AI Flathead sole	AI N. rock sole	AI S. rock sole	AI Alaska plaice	EBS Yellowfin sole juv	EBS Yellowfin sole	EBS Flathead sole juv	EBS Flathead sole	EBS N. rock sole juv	EBS N. rock sole	EBS Alaska plaice	GOA Yellowfin sole	GOA Flathead sole juv	GOA Flathead sole	GOA N. rock sole	GOA S. rock sole	GOA Alaska plaice
W. pollock juv		6.02%							1.00%	0.05%	16.77%		0.09%				0.37%		0.50%	
P. cod juv		1.26%				3.22%			0.00%	0.00%	0.01%								0.41%	
Herring juv													0.18%							
Arrowtooth juv		0.00%							0.00%											
Gr. turbot juv		2.67%							0.00%		0.00%									
P. halibut juv		0.91%				8.35%			0.02%					0.01%					0.01%	0.01%
Flathead sole juv		0.00%							0.00%		0.16%									
N. rock sole juv								0.00%	0.04%		0.00%									
Alaska plaice		2.13%							0.04%		0.00%									
Misc. flatfish		0.75%							0.00%											
Eelpouts		4.90%					3.50%		0.01%	0.35%	0.19%		0.07%	0.00%			0.40%			0.00%
Large sculpins		3.89%							0.01%											
Other sculpins		1.15%			7.34%	7.00%			0.19%	0.82%	0.06%	0.09%	0.00%				0.84%	0.01%	0.33%	
Misc. shallow fish	2.78%	1.64%				1.80%		0.00%	0.00%		0.51%								0.02%	
Octopus		0.73%							0.01%		0.02%									
Squids										0.29%	0.00%		0.00%							
Bathylagidae											0.00%									
Myctophidae											0.00%									
Capelin		0.00%							0.00%		0.10%						0.02%			
Sand lance	11.40%	4.03%			3.81%	9.63%	6.55%	0.20%	0.63%		0.35%		14.14%	0.74%				0.65%	1.15%	0.74%
Eulachon							0.00%							0.01%						0.01%
Managed forage		6.20%				3.97%			0.10%		0.79%		0.06%				0.00%		0.05%	
Oth pel. smelt																				
Tanner crab*					7.34%	5.27%		0.00%	0.28%	0.00%	0.74%		0.00%		0.05%	2.53%	1.88%	0.01%	0.48%	0.60%
King crab*							2.29%		0.01%											
Snow crab*									0.66%	0.00%	0.96%		0.05%	0.60%						
Pandalid shrimp	0.00%	0.96%		0.58%				0.00%	0.02%	6.15%	10.85%	0.16%	0.03%			1.80%	47.08%			
Non-Pandalid shrimp	3.49%	4.90%		82.45%	7.00%	2.76%	2.32%	6.07%	7.34%	11.12%	10.15%	1.02%	3.10%	0.01%	5.69%	9.75%	10.42%	1.01%	4.46%	0.01%
Sea star		0.00%				3.72%			0.00%		0.00%		0.00%	0.00%					0.05%	0.00%
Brittle star	5.85%	2.14%		0.37%	2.48%	1.43%	1.95%	1.02%	3.18%	14.16%	24.77%	0.09%	1.26%	0.17%	4.21%	14.94%	18.17%	7.81%	10.42%	0.17%
Urchins dollars and cucumbers	12.67%	2.82%			4.77%	10.20%	2.32%	2.20%	4.62%		0.03%	0.61%	2.27%	1.51%	2.19%			10.57%	12.89%	1.51%
Snails	3.84%	6.31%			10.06%	1.54%	9.91%	0.67%	1.05%		2.00%	0.02%	0.14%	0.35%	0.11%		0.27%	1.62%	0.02%	0.35%
Hermit crabs	1.48%	1.56%		0.25%	7.36%	1.62%	5.33%	0.02%	2.59%	0.00%	1.60%	0.00%	0.56%	0.01%	10.86%	5.06%	5.23%	1.01%	2.07%	0.01%
Misc crabs	3.76%	1.10%			7.94%	1.77%	5.04%	0.07%	0.18%	0.00%	0.12%		0.11%	0.03%	0.30%		0.89%	1.64%	3.58%	0.03%
Misc. Crustacean	2.50%	5.67%	100.00%		9.26%	4.68%	3.96%	43.52%	0.94%	1.23%	0.13%	0.44%	1.22%	0.17%	0.56%		0.27%	1.52%	5.83%	0.17%
Benthic amphipods	13.14%	4.54%			5.35%	10.00%	5.66%	20.85%	7.53%	27.43%	2.34%	34.86%	9.57%	9.97%	1.13%	0.02%	0.59%	9.26%	13.59%	9.97%
Benth. Hydroid	2.32%	3.05%						0.00%	0.01%		0.00%		0.00%							
Benth. Urochordata	2.89%	3.47%			3.20%	2.53%	2.83%	0.50%	0.53%	0.00%	0.13%	0.09%	0.07%	0.05%				0.51%	0.03%	0.05%
Sponge		1.76%					0.00%		0.03%				0.00%	0.00%						0.00%
Bivalves	3.06%	1.26%		4.52%	1.90%	11.32%	3.75%	5.33%	11.52%	0.18%	2.42%	6.12%	7.31%	15.50%	42.04%		6.98%	4.71%	11.13%	15.50%
Polychates	8.18%	1.53%		0.61%	2.77%	1.41%	6.56%	14.23%	25.27%	1.16%	3.88%	53.63%	47.24%	58.41%	32.51%	14.94%	1.33%	56.33%	28.76%	58.41%
Misc. worm etc.	4.86%	0.94%		11.22%	2.26%	3.66%	3.81%	0.85%	15.62%	1.01%	0.55%	0.64%	11.00%	12.32%			1.01%	3.02%	2.60%	12.32%
Scyphozoid jellies		1.53%					1.74%		0.51%		0.00%		0.01%	0.00%						0.00%
Fish larvae	1.64%	0.00%					0.00%	0.00%	0.00%					0.00%						0.00%
Chaetognaths etc.		4.08%							0.01%	0.25%	0.09%		0.00%			7.47%			0.06%	
Euphausiids	1.50%	0.83%			5.36%	0.00%	14.12%	2.62%	13.83%	15.21%	11.67%	0.53%	1.25%	0.11%	0.31%	25.30%	3.41%	0.09%	0.00%	0.11%
Mysids	6.26%	2.99%					0.00%	1.09%	0.49%	19.59%	4.60%	1.69%	0.13%	0.00%		17.94%	0.83%	0.03%		0.00%
Pelagic amphipods	2.16%	2.61%				0.00%	0.00%	0.00%	0.04%	0.01%	0.02%	0.00%	0.00%	0.00%				0.00%	1.57%	0.00%
Pel. gel. filter feeder	0.00%	2.69%					8.03%	0.00%	0.19%	0.00%	0.00%		0.05%	0.00%						0.00%
Pteropods	0.00%	2.81%			11.80%		0.00%	0.00%	0.42%	0.58%	0.00%		0.05%	0.00%				0.19%		0.00%
Copepods	2.52%	0.98%			0.00%	4.14%	0.00%	0.44%	0.02%	0.39%	0.01%	0.00%	0.01%	0.00%	0.04%	0.25%		0.00%	0.01%	0.00%
Microzooplankton	2.02%	2.25%					10.33%	0.02%	0.04%	0.00%	0.00%	0.00%	0.03%	0.01%						0.01%
Algae													0.00%							
Offal		2.41%							4.62%	5.28%	2.14%		3.87%				5.47%		6.91%	

*all ages in AI, GOA models, juveniles in EBS model

Table C17. Deep water and miscellaneous flatfish diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Dover sole	AI Rex sole	AI Misc. flatfish	EBS Dover sole	EBS Rex sole	EBS Misc. flatfish	GOA Dover sole	GOA Rex sole	GOA Misc. flatfish
W. pollock juv						3.18%			
P. cod juv						0.03%			
Eelpouts						4.20%			
Misc. shallow fish								0.51%	
Octopus			23.16%			0.01%			0.07%
Capelin						4.55%			
Managed forage						0.82%			
Oth pel. smelt									
Tanner crab*				1.54%		0.63%	0.30%	0.10%	
Snow crab*						0.00%			
Pandalid shrimp				22.24%		9.60%		1.87%	
Non-Pandalid shrimp		6.60%		26.47%	54.55%	10.02%	1.36%	2.51%	
Sea star							0.30%		
Brittle star	5.82%		23.04%	1.03%		6.00%	32.02%	1.10%	6.70%
Urchins dollars and cucumbers						0.02%	8.94%		
Snails			5.00%			0.04%		0.37%	0.15%
Hermit crabs						0.11%	0.00%	0.01%	
Misc crabs							2.26%	0.76%	
Misc. Crustacean			31.92%	0.19%		0.47%	0.12%	1.13%	92.80%
Benthic amphipods	41.29%		7.56%	8.92%	11.80%	6.40%	1.18%	3.17%	0.02%
Benth. Hydroid						0.00%			
Bivalves				1.05%	0.01%	7.01%	1.48%	0.04%	
Polychates	43.31%	37.05%	9.33%	28.17%	20.45%	24.43%	30.54%	51.80%	0.27%
Misc. worm etc.	9.57%	31.02%		5.45%	3.31%	2.00%	14.96%	7.21%	
Euphausiids		25.33%		3.52%	9.88%	0.12%	6.53%	27.72%	
Mysids				0.24%		19.52%		0.01%	
Pelagic amphipods				1.18%		0.51%			
Pteropods								0.00%	
Copepods						0.35%		1.68%	
Offal						6.50%			

*all ages in AI, GOA models, juveniles in EBS model

Table C18. Sablefish, eelpout, all Macrourids (grenadiers), and other deepwater fish diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Sablefish juv	AI Sablefish	AI Eelpouts	AI Macrourids	AI Misc. deep fish	EBS Sablefish juv	EBS Sablefish	EBS Eelpouts	EBS Macrourids	EBS Misc. deep fish	GOA Sablefish juv	GOA Sablefish	GOA Eelpouts	GOA Macrourids	GOA Misc. deep fish
W. pollock juv		0.45%	0.00%					0.00%			0.26%	2.00%	0.00%		
W. pollock		4.85%	0.39%				45.92%	0.39%				18.85%	0.39%		
P. cod juv												0.47%			
Herring juv												3.56%			
Herring			0.07%				0.04%	0.07%				0.00%	0.07%		
Arrowtooth juv							0.02%								
Flathead sole juv								0.00%					0.00%		
Flathead sole			0.00%												
Eelpouts			1.85%				0.03%	1.85%				0.01%	1.85%		
Shortspine thornyhead		0.01%										0.01%			
Other Sebastes												0.44%			
Large sculpins												0.38%			
Other sculpins		0.00%	1.35%					1.35%				0.75%	1.35%		
Misc. shallow fish			0.10%				0.01%	0.10%				0.21%	0.10%		
Octopus		0.11%					3.88%					4.34%		16.18%	
Squids		3.04%		44.73%	50.00%	10.00%	11.11%		50.00%	50.00%	9.49%	21.20%		3.04%	50.00%
Bathylagidae				1.00%			1.79%							2.34%	
Myctophidae		0.10%		46.88%			0.11%					1.46%			
Capelin			0.03%					0.03%			0.35%	0.08%	0.03%		
Sand lance												0.03%			
Eulachon												0.31%			
Managed forage			1.21%				30.81%	1.21%				0.00%	1.21%		
Tanner crab*								0.07%			0.00%	0.84%			
Snow crab*								9.33%							
Pandalid shrimp		0.01%					0.14%					4.57%		11.50%	
Non-Pandalid shrimp		1.66%	1.37%		50.00%		0.52%	1.37%	50.00%	50.00%		0.74%	1.37%	66.94%	50.00%
Sea star							0.05%					0.00%			
Brittle star		0.00%	18.23%				0.03%	18.23%				0.00%	18.23%		
Urchins dollars and cucumbers												0.00%			
Snails		0.00%										0.08%			
Hermit crabs		0.00%	0.25%				0.00%	0.25%			0.03%	1.33%	0.25%		
Misc crabs			9.89%					0.49%			0.98%	0.63%	9.89%		
Misc. Crustacean		0.00%	0.54%					0.54%			0.02%	0.01%	0.54%		
Benthic amphipods		3.48%	32.80%	1.70%			0.02%	32.80%			0.27%	2.42%	32.80%		
Benth. Hydroid			0.17%					0.17%					0.17%		
Benth. Urochordata		0.05%				15.00%					16.54%	0.04%			
Sea pens												0.00%			
Sponge												0.00%			
Bivalves			5.26%					5.26%				0.00%	5.26%		
Polychates		5.30%	23.87%				0.00%	23.87%			0.55%	0.97%	23.87%	0.00%	
Misc. worm etc.		0.00%	2.37%					2.37%				0.02%	2.37%		
Scyphozoid jellies		0.29%					1.56%					2.96%			
Chaetognaths etc.												0.00%			
Euphausiids	99.90%	20.05%	0.02%	0.18%		50.00%	0.03%	0.02%			46.68%	12.26%	0.02%		
Mysids		0.52%	0.01%					0.01%				0.12%	0.01%		
Pelagic amphipods			0.11%				0.01%	0.11%			1.54%	1.14%	0.11%		
Pel. gel. filter feeder		29.87%		5.50%								12.50%			
Pteropods		29.69%				10.00%					8.91%	0.02%			
Copepods						15.00%					14.38%	0.00%			
Microzooplankton	0.10%	0.00%	0.07%					0.07%					0.07%		
Algae												0.00%			
Offal		0.52%	0.06%				3.92%	0.06%				5.24%	0.06%		

*all ages in AI, GOA models, juveniles in EBS model

Table C19. Shallow water and pelagic rockfish diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Pacific ocean perch	AI Sharpchin rockfish	AI Northern rockfish	AI Dusky rockfish	EBS Pacific ocean perch	EBS Sharpchin rockfish	EBS Northern rockfish	EBS Dusky rockfish	GOA Pacific ocean perch juv	GOA Pacific ocean perch adu	GOA Sharpchin rockfish	GOA Northern rockfish	GOA Dusky rockfish
W. pollock juv	0.01%												
Arrowtooth juv										0.31%		0.13%	
Eelpouts		0.00%											
Other Macrourids	0.01%												
Misc. deep fish	0.34%				0.57%					0.11%			
Northern rockfish		0.00%	0.00%										
Atka mackerel		0.00%											
Other sculpins		0.19%				0.13%							
Misc. shallow fish		0.00%				0.03%				0.02%			
Octopus	0.05%	0.00%								0.25%			
Squids	0.45%	1.94%	4.97%		0.06%	13.13%	2.78%			0.24%		0.02%	0.00%
Bathylagidae	0.00%	0.00%			1.09%								
Myctophidae	2.54%	1.06%	0.25%		1.54%	0.09%				1.15%			
Managed forage										0.63%			
Tanner crab*		0.00%	0.00%			0.00%	0.01%			0.00%		0.01%	
King crab*		1.00%											
Pandalid shrimp		10.78%				16.66%				0.78%	0.08%		0.10%
Non-Pandalid shrimp	0.07%	6.93%	2.42%		0.05%	6.44%	3.05%			0.53%	3.07%	0.36%	4.13%
Brittle star		0.48%	1.43%										
Snails	0.00%	0.01%	0.02%									0.02%	0.00%
Hermit crabs		0.10%	0.02%			0.38%	1.88%			0.04%	0.00%	0.01%	58.84%
Misc crabs		0.00%	0.00%							0.00%			0.00%
Misc. Crustacean	0.00%	0.03%	0.00%							0.00%	0.00%		0.00%
Benthic amphipods	0.88%	26.44%	0.40%	100.00%	0.21%	8.45%	0.00%	4.65%		4.44%	23.09%	0.21%	0.97%
Polychates	1.57%	1.08%	0.64%		0.04%	1.67%		8.36%					0.00%
Misc. worm etc.					0.00%								
Scyphozoid jellies		0.02%	0.07%										0.00%
Chaetognaths etc.	2.24%	2.39%	6.78%		0.23%	1.61%	8.03%		8.36%	3.24%	2.22%	0.12%	15.29%
Euphausiids	13.83%	15.18%	24.99%		24.71%	18.76%	4.36%	68.03%	91.21%	75.36%	26.16%	94.59%	8.71%
Mysids	0.34%	0.08%	0.02%		63.60%	12.87%	0.29%			0.43%			0.46%
Pelagic amphipods	0.13%	4.56%	1.43%		0.00%	0.04%	0.18%		0.34%	0.97%			
Pel. gel. filter feeder	1.14%	0.02%	0.07%		0.02%								11.28%
Pteropods	0.03%	0.20%	0.63%		0.02%	0.08%	0.42%			0.03%	4.44%		
Copepods	76.34%	27.16%	54.43%		7.86%	19.67%	78.98%	18.96%	0.08%	10.92%	40.94%	4.54%	0.23%
Microzooplankton	0.04%												
Offal		0.37%	1.44%							0.54%			

*all ages in AI, GOA models, juveniles in EBS model

Table C20. Deep water and other rockfish diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Shortraker rockfish	AI Rougheye rockfish	AI Shortspine thornyhead	AI Other *Sebastes*	EBS Shortraker rockfish	EBS Rougheye rockfish	EBS Shortspine thornyhead	EBS Other *Sebastes*	GOA Shortraker rockfish	GOA Rougheye rockfish	GOA Shortspine thornyhead juv	GOA Shortspine thornyhead adu	GOA Other *Sebastes*
W. pollock juv				4.96%								0.01%	14.53%
Arrowtooth juv													
Eelpouts			0.00%								1.76%	0.23%	
Shortspine thornyhead juv												0.35%	
Atka mackerel		0.00%	0.00%										
Other sculpins	0.01%		4.29%		0.65%			0.13%				1.15%	
Misc. shallow fish		0.17%	0.01%			0.14%	0.02%	0.03%	0.00%	0.00%		0.04%	
Octopus	0.00%		0.08%								0.53%	1.46%	
Squids	0.01%	0.08%			0.88%	62.01%		13.13%	4.26%			0.08%	
Bathylagidae	0.00%								0.17%				
Myctophidae	0.26%	0.01%			0.28%	0.15%		0.09%	0.62%			0.08%	
Capelin												0.00%	
Sand lance				4.63%									1.36%
Managed forage												0.14%	
Tanner crab*								0.00%		0.00%		2.57%	
King crab*			22.37%									0.00%	
Pandalid shrimp	0.18%	99.44%	47.92%		83.02%	0.08%	0.19%	16.66%	92.47%	99.99%	33.63%	38.28%	
Non-Pandalid shrimp	99.47%	0.21%	4.62%	4.94%		13.80%	15.33%	6.44%	2.39%	0.01%	8.09%	32.01%	14.47%
Snails												0.03%	
Hermit crabs								0.38%		0.00%		7.31%	
Misc crabs	0.05%		0.01%									0.63%	
Misc. Crustacean	0.00%	0.00%	0.55%	28.13%						0.00%		1.49%	8.23%
Benthic amphipods	0.01%	0.02%	14.73%	8.00%		1.43%	36.18%	8.45%	0.00%	0.00%	29.06%	5.51%	0.23%
Benth. Urochordata				4.66%									1.04%
Bivalves												0.00%	
Polychates	0.00%	0.03%	0.00%					1.67%			2.37%	2.38%	
Scyphozoid jellies				13.40%									7.85%
Chaetognaths etc.								1.61%		0.00%	0.00%	0.00%	
Euphausiids	0.00%	0.02%	5.18%	5.34%	2.00%	19.38%		18.76%	0.00%	0.00%	12.50%	0.03%	15.62%
Mysids	0.00%	0.00%	0.23%		13.17%	2.61%	48.28%	12.87%	0.07%	0.00%	11.95%	6.01%	
Pelagic amphipods								0.04%	0.01%	0.00%			
Pel. gel. filter feeder	0.00%			13.40%								0.03%	
Pteropods								0.08%				0.14%	
Copepods	0.00%			12.53%		0.39%		19.67%			0.11%		36.67%
Offal												0.04%	

*all ages in AI, GOA models, juveniles in EBS model

Table C21. Atka mackerel and other greenlings diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Atka mackerel juv	AI Atka mackerel	AI Greenlings	EBS Atka mackerel juv	EBS Atka mackerel	EBS Greenlings	GOA Atka mackerel juv	GOA Atka mackerel	GOA Greenlings
W. pollock juv		6.23%				4.73%			4.73%
Kamchatka juv		0.00%							
P. halibut juv		0.00%						0.01%	
Misc. flatfish						2.97%			2.97%
Eelpouts		0.20%							
Misc. deep fish		0.00%							
Large sculpins						17.79%			17.79%
Other sculpins		0.01%				15.01%		0.01%	15.01%
Misc. shallow fish		0.01%							
Octopus		0.07%							
Squids		10.44%							
Bathylagidae		0.01%							
Myctophidae		0.90%							
Sand lance								0.02%	
Eulachon		0.00%							
Managed forage		0.01%							
Tanner crab*		0.00%			0.63%				
Pandalid shrimp		0.16%							
Non-Pandalid shrimp		0.32%				42.96%		0.00%	42.96%
Brittle star		0.00%							
Snails		1.08%	29.93%			0.00%		0.32%	0.00%
Hermit crabs		0.00%						0.10%	
Misc crabs		0.14%				0.44%		0.26%	0.44%
Misc. Crustacean		0.04%				0.06%		0.00%	0.06%
Benthic amphipods		4.73%	58.85%			3.25%		0.12%	3.25%
Benth. Hydroid		0.00%				0.12%			0.12%
Benth. Urochordata		0.01%							
Sponge		0.00%						0.00%	
Bivalves		0.00%	0.60%			1.19%		0.01%	1.19%
Polychates		0.58%	2.40%			7.08%		0.01%	7.08%
Misc. worm etc.		0.01%	8.22%						
Scyphozoid jellies		0.05%						0.03%	
Fish larvae		4.68%							
Chaetognaths etc.		0.71%							
Euphausiids	100.00%	24.26%		90.00%	98.37%		90.00%	84.78%	
Mysids		0.03%				4.33%			4.33%
Pelagic amphipods		0.35%				0.07%		0.00%	0.07%
Pel. gel. filter feeder		5.36%			0.37%			2.18%	
Pteropods		0.55%						0.70%	
Copepods		39.01%		10.00%	0.63%		10.00%	11.44%	
Offal		0.07%							

*all ages in AI, GOA models, juveniles in EBS model

Table C22. Sculpins and other miscellaneous fish diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from diet query (see Appendix B). Values of 0.00% are trace in diet.

Prey	AI Large sculpins	AI Other sculpins	AI Misc. shallow fish	EBS Large sculpins	EBS Other sculpins	EBS Misc. shallow fish	GOA Large sculpins	GOA Other sculpins	GOA Misc. shallow fish
W. pollock juv	2.43%			9.53%			9.53%		
W. pollock	0.01%			3.45%			3.45%		
P. cod juv				0.00%	4.03%		0.00%	4.03%	
P. cod				0.09%			0.09%		
Herring juv				0.47%			0.47%		
Herring				0.20%			0.20%		
Arrowtooth fl.				0.01%			0.04%		
Kamchatka fl.				0.03%					
P. halibut juv				0.00%			0.00%		
Yellowfin sole juv				2.16%	0.97%		2.61%		
Yellowfin sole				0.45%					
Flathead sole juv				0.02%		0.74%	0.02%	0.97%	
Flathead sole				0.18%			0.18%		
N. rock sole juv				0.74%			0.48%		
N. rock sole				0.23%					
S. rock sole							0.48%		
Alaska plaice				0.12%			0.12%		
Dover sole									0.08%
Misc. flatfish				0.10%			0.10%		
Eelpouts				3.33%			3.33%		
Misc. deep fish									
Atka mackerel	22.61%			0.00%			0.00%		
Large sculpins				0.18%			0.18%		
Other sculpins	0.39%			2.11%			2.11%		
Misc. shallow fish	10.73%			1.90%	4.99%		1.90%	4.99%	
Octopus	0.66%		0.58%	1.44%			1.44%		
Squids	0.18%	1.08%		0.01%			0.01%		
Myctophidae	0.25%	0.72%							
Capelin				1.23%			1.23%		
Sand lance				0.94%			0.94%		
Eulachon				0.00%			0.00%		
Managed forage				5.76%			5.76%		
Oth pel. smelt				0.03%			0.03%		
Tanner crab*	9.20%			0.47%	3.54%		4.41%	3.54%	
Tanner crab adu				0.07%					
King crab*	0.29%			1.75%			1.75%		
Snow crab*				3.00%					
Snow crab adu				0.86%					
Pandalid shrimp		10.32%	6.57%	0.75%	4.20%	1.87%	0.75%	4.20%	2.57%
Non-Pandalid shrimp	0.41%	0.77%	3.06%	18.98%	50.14%	20.67%	18.98%	50.14%	3.58%
Sea star	9.47%	0.61%		0.01%			0.01%		
Brittle star	2.65%	2.59%		0.01%	0.02%		0.01%	0.02%	
Urchins dollars and cucumbers	0.17%			0.00%			0.00%		
Snails	1.15%	0.53%		0.14%			0.14%		
Hermit crabs				1.92%		0.05%	1.92%		
Misc crabs	29.99%			1.95%	1.92%		1.95%	1.92%	
Misc. Crustacean	0.00%	0.67%	0.28%	0.08%	1.44%	0.00%	0.08%	1.44%	
Benthic amphipods	0.03%	26.66%	17.49%	5.96%	19.47%	9.18%	5.96%	19.47%	0.36%
Benth. Hydroid				0.00%	3.70%		0.00%	3.70%	
Benth. Urochordata	0.01%								
Bivalves				0.04%			0.04%		
Polychaetes	2.36%	33.40%	0.88%	10.98%	2.55%	0.00%	10.98%	2.55%	
Misc. worm etc.	0.84%	0.24%		1.92%			1.92%		
Scyphozoid jellies			0.14%	0.00%		6.43%	0.00%		0.00%
Chaetognaths etc.		0.03%							
Euphausiids	1.42%	7.37%	0.11%	0.96%		1.16%	0.96%		
Mysids		11.21%	0.03%	7.60%	0.31%	3.46%	7.60%	0.31%	0.16%
Pelagic amphipods	0.00%		0.38%	4.57%	0.83%	1.40%	4.57%	0.83%	
Pel. gel. filter feeder		3.73%	70.43%	2.48%		55.00%	2.48%		92.97%
Pteropods				0.00%			0.00%		
Copepods	0.00%	0.07%	0.07%	0.00%	1.87%	0.03%	0.00%	1.87%	0.28%
Offal	4.74%			0.80%			0.80%		

*all ages in AI, GOA models, juveniles in EBS model

Table C23. Cephalopod, salmon, and forage fish diets in all systems and those specific to the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from generalized diet query and or literature values (see Appendix A for details). Values of 0.00% are trace in diet.

Prey	All Squids	All Salmon returning	All Salmon outgoing	All Bathylagidae	All Capelin	All Sand lance	All Eulachon	All Managed forage	All Oth pel. smelt	AI Octopus	AI Myctophidae	EBS Octopus	EBS/GOA Myctophidae	GOA Octopus
Squids		20.00%												
Myctophidae	2.50%										0.47%			
Capelin	2.50%													
Sand lance	2.50%													
Eulachon	2.50%													
Managed forage	2.50%													
Oth pel. smelt	2.50%													
Tanner crab*												5.00%		
Snow crab*												5.00%		
Snails												40.00%		40.00%
Hermit crabs										40.00%		10.00%		10.00%
Misc crabs										20.00%				10.00%
Misc. Crustacean											1.72%			
Benthic amphipods											3.93%			
Bivalves										40.00%		40.00%		40.00%
Chaetognaths etc.	2.50%	20.00%									2.75%			
Euphausiids	42.00%	20.00%	25.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%		76.55%		90.00%	
Mysids	2.50%										2.92%			
Pelagic amphipods	14.00%		25.00%								0.01%			
Pel. gel. filter feeder	4.00%													
Pteropods		20.00%												
Copepods	20.00%	20.00%	50.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%		11.64%		10.00%	

*all ages in AI, GOA models, juveniles in EBS model

Table C24. Commerical shellfish diets in the Eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) from generalized diet query and or literature values (see Appendix A for details). Values of 0.00% are trace in diet.

Prey	AI Tanner crab	AI King crab	AI Snow crab	EBS Tanner crab juv	EBS Tanner crab adu	EBS King crab juv	EBS King crab adu	EBS Snow crab juv	EBS Snow crab adu	GOA Tanner crab	GOA King crab	GOA Snow crab	All Pandalid shrimp
Sea star		0.80%					0.82%	0.30%			0.80%		
Brittle star	3.31%	3.50%	8.03%	20.11%	3.31%		3.56%	3.76%	8.03%	4.00%	3.50%	4.00%	
Urchins dollars and cucumbers	2.09%	22.20%	0.69%		2.09%	34.79%	11.24%	0.93%	0.69%	2.00%	22.20%	2.00%	
Snails	3.91%	20.00%	5.90%	3.40%	3.91%	14.99%	21.19%	0.62%	5.90%	3.00%	20.00%	3.00%	
Hermit crabs	1.53%	2.00%	3.65%	0.99%	1.53%		2.11%	0.46%	3.65%	1.00%	2.00%	1.00%	
Misc crabs	1.53%	2.00%	3.65%	0.99%	1.53%		2.11%	0.46%	3.65%	1.00%	2.00%	1.00%	
Misc. Crustacean	0.68%	2.00%	1.93%		0.68%		1.96%	0.92%	1.93%	0.50%	2.00%	0.50%	
Benthic amphipods	5.40%	2.00%	4.28%		5.40%	2.28%	0.54%	6.77%	4.28%	2.00%	1.20%	2.00%	30.00%
Anemones			0.08%						0.23%				
Corals			0.08%										
Benth. Hydroid	0.52%	5.00%	0.71%	2.67%	0.52%	2.28%	5.26%	0.30%	0.71%	1.00%	5.00%	1.00%	
Benth. Urochordata		0.50%				2.28%	0.54%				0.50%		
Sea pens			0.08%										
Sponge			0.25%	0.63%				0.30%	0.25%				
Bivalves	27.03%	20.00%	28.31%	39.65%	27.03%	19.81%	17.99%	13.19%	28.31%	30.00%	18.00%	30.00%	10.00%
Polychates	47.95%	15.00%	29.34%	15.46%	47.95%	11.04%	21.19%	25.05%	29.34%	49.00%	15.00%	49.00%	
Misc. worm etc.		5.00%	2.24%			7.71%	1.07%	3.00%	2.24%		2.00%		
Euphausiids								0.30%					20.00%
Mysids			0.52%						0.52%				
Benthic bacteria													
Algae			0.48%				3.23%	0.30%	0.48%				
Discards	0.89%		0.62%		0.89%		0.41%	0.46%	0.62%	0.80%	0.40%	0.80%	
Offal	0.89%		0.62%		0.89%		0.41%	0.46%	0.62%	0.70%	0.40%	0.70%	
Benth detritus	4.28%		8.54%	16.11%	4.28%	4.82%	6.37%	42.43%	8.54%	5.00%	5.00%	5.00%	40.00%

Table C25. Benthic invertebrate diets in all systems and those specific to the Eastern Bering Sea (EBS) from from generalized diet query and or literature values (see Appendix A for details). Values of 0.00% are trace in diet.

Prey	All Non-Pandalid shrimp	All Brittle star	All Urchins dollars and cucum-bers	All Snails	All Hermit crabs	All Misc crabs	All Misc. Crusta-cean	All Sea star	All Anem-ones	All Corals	All Benth. Hydroid	All Benth. Uro-chordata	All Sea pens	All Sponge	All Bivalves	All Benth. Amphi-pods	All Poly-chates and Misc. worms	EBS Sea star
Tanner crab*								1.00%										0.50%
Snow crab*																		0.50%
Pandalid shrimp								0.50%										0.50%
Non-Pandalid shrimp								0.50%										0.50%
Brittle star								3.00%										3.00%
Snails								0.50%										0.50%
Hermit crabs								0.50%										0.50%
Misc. Crustacean									12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%			
Benthic amphipods	30.00%	10.00%							12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%			
Bivalves	10.00%			20.00%	25.00%	25.00%		91.00%										91.00%
Polychates				20.00%	25.00%	25.00%		2.00%										2.00%
Misc. worm etc.				20.00%	25.00%	25.00%		1.00%										1.00%
Euphausiids	20.00%																	
Benthic bacteria							50.00%		15.00%	15.00%	15.00%	15.00%	15.00%	15.00%	15.00%	50.00%	50.00%	
Algae			25.00%	20.00%														
Benth detritus	40.00%	90.00%	75.00%	20.00%	25.00%	25.00%	50.00%		60.00%	60.00%	60.00%	60.00%	60.00%	60.00%	60.00%	50.00%	50.00%	

*all ages in AI, GOA models, juveniles in EBS model

Table C26. Plankton and microbial diets all systems from from generalized literature values (see Appendix A). Values of 0.00% are trace in diet.

Prey	Scyphozoid jellies	Fish larvae	Chaetognaths etc.	Euphausiids	Mysids	Pelagic amphipods	Pel. gel. filter feeder	Pteropods	Copepods	Micro-zooplankton	Benthic bacteria
W. pollock juv	0.10%										
Herring juv	0.10%										
Squids	0.10%										
Bathylagidae	0.10%										
Myctophidae	0.10%										
Capelin	0.10%										
Sand lance	0.10%										
Eulachon	0.10%										
Managed forage	0.10%										
Oth pel. smelt	0.10%										
Fish larvae	5.00%										
Euphausiids	64.00%		5.00%								
Mysids			5.00%								
Pelagic amphipods			5.00%								
Pel. gel. filter feeder	5.00%		5.00%								
Pteropods			5.00%								
Copepods	15.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%			
Microzooplankton	5.00%	15.00%	15.00%	15.00%	15.00%	15.00%	15.00%	15.00%	50.00%		
Large phytoplankton	5.00%	50.00%	25.00%	50.00%	50.00%	50.00%	50.00%	50.00%	25.00%		
Small phytoplankton		10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	25.00%	70.00%	
Pelagic detritus										30.00%	
Benth detritus											100.00%

Table C27. Data quality ratings ("pedigree") for EBS model parameters. Ratings scale from 1 (highest data quality) to 8 (lowest data quality). See Table 6 in section 2.3 for a detailed explanation of the ratings.

EBS Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
Transient Killers	7	3	6	6	1			2
Sperm and beaked whale	6	6	6	6	1			2
Resident Killers	4	3	6	6	1			2
Porpoises	3	6	6	6	1			2
Belugas	4	6	6	6	1			2
Gray Whales	5	6	6	6	1			2
Humpbacks	5	2	6	6	1			2
Fin Whales	4	6	6	6	1			2
Sei whales	7	6	6	6	1			2
Right whales	7	6	6	6	1			2
Minke whales	4	6	6	6	1			2
Bowhead Whales	5	1	6	6	1			2
Sea Otters	4	6	6	7	1			2
Walrus Bd Seals	5	6	6	5	1			2
N. Fur Seal	4	4	5	5	1			2
N. Fur Seal_Juv	3	4	7	5	1			2
Central S.S.L.	-	-	-	-	-	-	-	-
Central S.S.L._Juv	-	-	-	-	-	-	-	-
West S.S.L.	2	4	5	5	1			2
West S.S.L_Juv	2	4	7	5	1			2
Resident seals	5	6	6	5	1			2
Wintering seals	5	6	6	5	1			2
Shearwater	6	6	6	6	4			2
Murres	4	6	6	6	4			2
Kittiwakes	4	6	6	6	4			2
Auklets	4	6	6	6	4			2
Puffins	4	6	6	6	4			2
Fulmars	4	6	6	6	4			2
Storm Petrels	4	6	6	6	4			2
Cormorants	4	6	6	6	4			2
Gulls	4	6	6	6	4			2
Albatross Jaeger	6	6	6	6	4			2
Sleeper shark	5	7	7	6	3	7		2
Salmon shark	-	-	-	-	-	-	-	-
Dogfish	-	-	-	-	-	-	-	-
W. Pollock	1	3	3	1	1			2
W. Pollock_Juv	4	4	4	1	1			2
P. Cod	2	3	3	1	1	5		2
P. Cod_Juv	8	4	4	1	1			2
Herring	3	3	3	4	1		1	2
Herring_Juv	8	4	4	5	1			2
Arrowtooth	2	4	4	1	1	5		2
Arrowtooth_Juv	8	5	5	1	1			2
Kamchatka fl.	3	5	5	2	2			2
Kamchatka fl._Juv	8	6	6	2	1			2
Gr. Turbot	2	5	5	1	1			2
Gr. Turbot_Juv	8	6	6	2	1			2
P. Halibut	2	5	5	1	2	1		2
P. Halibut_Juv	8	6	6	1	1			2

Table C27 Continued.

EBS Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
YF. Sole	2	3	3	1	1			2
YF. Sole_Juv	8	4	4	1	1			2
FH. Sole	2	4	4	1	2			2
FH. Sole_Juv	8	5	5	1	2			2
N. Rock sole	2	3	3	1	1			2
N. Rock sole_Juv	8	4	4	1	1			2
S. Rock sole	-	-	-	-	-	-	-	-
AK Plaice	2	6	6	1	1			2
Dover Sole	2	6	6	6	1			2
Rex Sole	2	6	6	2	1			2
Misc. Flatfish	8	6	6	2	2			2
Alaska skate	2	7	7	1	4	7		2
Bering skate	3	7	7	4	4	7		2
Aleutian skate	3	7	7	4	4	7		2
Whiteblotched skate	3	7	7	5	4	7		2
Mud skate	3	7	7	5	4	7		2
Longnosed skate	3	7	7	5	4	7		2
Big skate	3	7	7	5	4	7		2
Black skate	2	7	7	5	4	7		2
Sablefish	2	5	5	1	1	5		2
Sablefish_Juv	8	6	6	6	1	5		2
Eelpouts	8	7	7	6	7			2
Giant Grenadier	3	7	7	2	4			2
Pacific Grenadier	3	7	7	5	4			2
Other Macruids	3	7	7	5	4			2
Misc. fish deep	8	7	7	7	7			2
POP	3	6	6	1	1	6		2
POP_Juv	-	-	-	-	-	-	-	-
Sharpchin Rock	8	6	6	5	2	6		2
Northern Rock	8	6	6	2	2	6		2
Dusky Rock	7	6	6	2	1	6		2
Shortraker Rock	7	6	6	2	2	6		2
Rougheye Rock	7	6	6	2	2	6		2
Shortspine Thorns	7	6	6	2	1	6		2
Shortspine Thorns_Juv	-	-	-	-	-	-	-	-
Other Sebastes	8	6	6	6	2	6		2
Atka mackerel	4	5	5	2	1			2
Atka mackerel_Juv	8	6	6	7	1			2
Greenlings	8	7	7	2	7			2
Lg. Sculpins	2	7	7	2	4	6		2
Other sculpins	8	7	7	2	4	6		2
Misc. fish shallow	8	7	7	5	7			2
Octopi	8	7	7	7	3			2
Squids	8	7	7	7	3			2
Salmon returning	6	5	5	5	2		1	2
Salmon outgoing	7	6	6	6	2			2
Bathylagidae	8	7	7	7	4			2
Myctophidae	8	7	7	7	4			2
Capelin	8	7	7	7	4			2
Sandlance	8	7	7	7	4			2
Eulachon	8	7	7	7	4			2
Oth. managed forage	8	7	7	7	4			2
Oth. pelagic smelt	8	7	7	7	4			2

Table C27 Continued.

EBS Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
Bairdi	2	6	5	5	2		1	2
Bairdi_Juv	8	6	5	5	2			2
King Crab	2	6	5	5	2		1	2
King Crab_Juv	8	6	5	5	2			2
Opilio	2	6	5	5	2		1	2
Opilio_Juv	8	6	5	5	2			2
Pandalidae	8	5	5	7	4			2
NP shrimp	8	6	6	7	4			2
Sea stars	3	6	7	7	4	6		2
Brittle stars	8	6	7	7	4			2
Urchins dollars cucumber	8	6	7	7	4			2
Snails	8	6	7	7	4			2
Hermit crabs	8	6	7	7	4			2
Misc. crabs	8	6	7	7	4			2
Misc. Crustacean	8	6	7	7	4			2
Benthic Amphipods	8	6	7	7	4			2
Anemones	3	6	7	7	4			2
Corals	3	6	7	7	4			2
Hydroids	8	6	7	7	4			2
Urochordata	3	6	7	7	4			2
Sea Pens	3	6	7	7	4			2
Sponges	3	6	7	7	4			2
Bivalves	7	6	7	7	4			2
Polychaetes	7	6	7	7	4			2
Misc. worms	8	6	7	7	4			2
Scyphozoid Jellies	4	6	6	7	4			2
Fish Larvae	8	7	7	7	1			2
Chaetognaths	8	7	7	7	1			2
Euphausiids	8	5	5	7	1			2
Mysids	8	7	7	7	1			2
Pelagic Amphipods	8	6	6	7	1			2
Gelatinous filter feeders	8	7	7	7	1			2
Pteropods	8	7	7	7	1			2
Copepods	8	7	5	7	1			2
Pelagic microbes	7	7	7	7	1			2
Benthic microbes	8	7	7	1	1			2
Macroalgae	8	7	7	0	1			2
Lg Phytoplankton	8	5	0	0	1			2
Sm Phytoplankton	8	5	0	0	1			2
Outside Production	8	7	0	0	1			2
Discards	8			0	1			2
Offal	8			0	1			2
Pelagic Detritus	8			0	1			2
Benthic Detritus	8			0	1			2
Outside Detritus	8			0	1			2

Table C28. Data quality ratings ("pedigree") for GOA model parameters. Ratings scale from 1 (highest data quality) to 8 (lowest data quality). See Table 6 in section 2.3 for a detailed explanation of the ratings.

GOA Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
Transient Killers	7	3	6	6	1			2
Sperm and beaked whale	6	6	6	6	1			2
Resident Killers	3	3	6	6	1			2
Porpoises	3	6	6	6	1			2
Belugas	-	-	-	-	-	-	-	-
Gray Whales	5	6	6	6	1			2
Humpbacks	4	2	6	6	1			2
Fin Whales	4	6	6	6	1			2
Sei whales	7	6	6	6	1			2
Right whales	7	6	6	6	1			2
Minke whales	4	6	6	6	1			2
Bowhead Whales	-	-	-	-	-	-	-	-
Sea Otters	4	6	6	7	1			2
Walrus Bd Seals	-	-	-	-	-	-	-	-
N. Fur Seal	4	4	5	5	1			2
N. Fur Seal_Juv	4	4	7	5	1			2
Central S.S.L.	2	4	5	4	1			2
Central S.S.L._Juv	2	4	7	4	1			2
West S.S.L.	2	4	5	4	1			2
West S.S.L_Juv	2	4	7	4	1			2
Resident seals	5	6	6	5	1			2
Wintering seals	-	-	-	-	-	-	-	-
Shearwater	6	6	6	6	4			2
Murres	4	6	6	6	4			2
Kittiwakes	4	6	6	6	4			2
Auklets	4	6	6	6	4			2
Puffins	4	6	6	6	4			2
Fulmars	4	6	6	6	4			2
Storm Petrels	4	6	6	6	4			2
Cormorants	4	6	6	6	4			2
Gulls	4	6	6	6	4			2
Albatross Jaeger	6	6	6	6	4			2
Sleeper shark	4	7	7	4	3	7		2
Salmon shark	5	7	7	6	3	5		2
Dogfish	6	7	7	7	3	5		2
W. Pollock	1	4	4	1	1			2
W. Pollock_Juv	8	4	4	1	1			2
P. Cod	2	3	3	1	1	5		2
P. Cod_Juv	8	4	4	1	1			2
Herring	3	6	6	5	1		1	2
Herring_Juv	8	4	4	6	1			2
Arrowtooth	1	3	3	1	1	5		2
Arrowtooth_Juv	4	4	4	1	1			2
Kamchatka fl.	-	-	-	-	-	-	-	-
Kamchatka fl._Juv	-	-	-	-	-	-	-	-
Gr. Turbot	-	-	-	-	-	-	-	-
Gr. Turbot_Juv	-	-	-	-	-	-	-	-
P. Halibut	2	3	3	1	2	1		2
P. Halibut_Juv	4	4	4	1	1			2

Table C28. Continued.

GOA Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
YF. Sole	2	6	6	1	1			2
YF. Sole_Juv	-	-	-	-	-	-	-	-
FH. Sole	2	3	3	1	1			2
FH. Sole_Juv	8	4	4	1	1			2
N. Rock sole	3	6	6	1	2			2
N. Rock sole_Juv	-	-	-	-	-	-	-	-
S. Rock sole	3	6	6	1	2			2
AK Plaice	2	6	6	5	1			2
Dover Sole	3	6	6	2	1			2
Rex Sole	3	6	6	2	1			2
Misc. Flatfish	3	6	6	2	2			2
Alaska skate	2	7	7	6	4	7		2
Bering skate	3	7	7	6	4	7		2
Aleutian skate	3	7	7	6	4	7		2
Whiteblotched skate	3	7	7	6	4	7		2
Mud skate	2	7	7	6	4	7		2
Longnosed skate	3	7	7	6	4	7		2
Big skate	3	7	7	6	4	7		2
Black skate	2	7	7	6	4	7		2
Sablefish	3	5	5	4	1	5		2
Sablefish_Juv	8	6	6	4	1	5		2
Eelpouts	8	7	7	6	7			2
Giant Grenadier	3	7	7	2	4			2
Pacific Grenadier	2	7	7	5	4			2
Other Macruids	3	7	7	5	4			2
Misc. fish deep	8	7	7	7	7			2
POP	2	3	3	1	1	6		2
POP_Juv	4	4	4	1	1	6		2
Sharpchin Rock	8	6	6	2	2	6		2
Northern Rock	2	6	6	2	2	6		2
Dusky Rock	3	6	6	2	1	6		2
Shortraker Rock	3	6	6	2	2	6		2
Rougheye Rock	3	6	6	2	2	6		2
Shortspine Thorns	4	3	3	2	1	6		2
Shortspine Thorns_Juv	8	4	4	2	1	6		2
Other Sebastes	8	6	6	5	2	6		2
Atka mackerel	4	5	5	5	1			2
Atka mackerel_Juv	8	6	6	7	1			2
Greenlings	2	7	7	6	7			2
Lg. Sculpins	2	7	7	6	4	6		2
Other sculpins	8	7	7	6	4	6		2
Misc. fish shallow	8	7	7	5	7			2
Octopi	8	7	7	7	3			2
Squids	8	7	7	7	3			2
Salmon returning	6	5	5	5	2		1	2
Salmon outgoing	7	6	6	6	2			2
Bathylagidae	8	7	7	7	4			2
Myctophidae	8	7	7	7	4			2
Capelin	8	7	7	7	4			2
Sandlance	8	7	7	7	4			2
Eulachon	8	7	7	7	4			2
Oth. managed forage	8	7	7	7	4			2
Oth. pelagic smelt	8	7	7	7	4			2

Table C28. Continued.

GOA Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
Bairdi	8	6	5	7	2		1	2
Bairdi_Juv	-	-	-	-	-	-	-	-
King Crab	5	6	5	7	2		1	2
King Crab_Juv	-	-	-	-	-	-	-	-
Opilio	-	-	-	-	-	-	-	-
Opilio_Juv	-	-	-	-	-	-	-	-
Pandalidae	8	5	5	7	4			2
NP shrimp	8	6	6	7	4			2
Sea stars	4	6	7	7	4	6		2
Brittle stars	4	6	7	7	4			2
Urchins dollars cucumber	4	6	7	7	4			2
Snails	8	6	7	7	4			2
Hermit crabs	8	6	7	7	4			2
Misc. crabs	8	6	7	7	4			2
Misc. Crustacean	8	6	7	7	4			2
Benthic Amphipods	8	6	7	7	4			2
Anemones	3	6	7	7	4			2
Corals	2	6	7	7	4			2
Hydroids	8	6	7	7	4			2
Urochordata	6	6	7	7	4			2
Sea Pens	2	6	7	7	4			2
Sponges	3	6	7	7	4			2
Bivalves	8	6	7	7	4			2
Polychaetes	8	6	7	7	4			2
Misc. worms	8	6	7	7	4			2
Scyphozoid Jellies	5	6	6	7	4			2
Fish Larvae	8	7	7	7	1			2
Chaetognaths	8	7	7	7	1			2
Euphausiids	8	6	6	7	1			2
Mysids	8	7	7	7	1			2
Pelagic Amphipods	8	6	6	7	1			2
Gelatinous filter feeders	8	7	7	7	1			2
Pteropods	8	7	7	7	1			2
Copepods	8	7	6	7	1			2
Pelagic microbes	8	7	7	7	1			2
Benthic microbes	8	7	7	1	1			2
Macroalgae	8	7	7	0	1			2
Lg Phytoplankton	6	5	0	0	1			2
Sm Phytoplankton	6	5	0	0	1			2
Outside Production	8	7	0	0	1			2
Discards	8			0	1			2
Offal	8			0	1			2
Pelagic Detritus	8			0	1			2
Benthic Detritus	8			0	1			2
Outside Detritus	8			0	1			2

Table C29. Data quality ratings ("pedigree") for AI model parameters. Ratings scale from 1 (highest data quality) to 8 (lowest data quality). See Table 6 in section 2.3 for a detailed explanation of the ratings.

AI Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
Transient Killers	7	3	6	6	1			2
Sperm and beaked whale	6	6	6	6	1			2
Resident Killers	4	3	6	6	1			2
Porpoises	4	6	6	6	1			2
Belugas	-	-	-	-	-	-	-	-
Gray Whales	-	-	-	-	-	-	-	-
Humpbacks	4	2	6	6	1			2
Fin Whales	4	6	6	6	1			2
Sei whales	7	6	6	6	1			2
Right whales	7	6	6	6	1			2
Minke whales	4	6	6	6	1			2
Bowhead Whales	-	-	-	-	-	-	-	-
Sea Otters	4	6	6	5	1			2
Walrus Bd Seals	-	-	-	-	-	-	-	-
N. Fur Seal	-	-	-	-	-	-	-	-
N. Fur Seal_Juv	-	-	-	-	-	-	-	-
Central S.S.L.	-	-	-	-	-	-	-	-
Central S.S.L._Juv	-	-	-	-	-	-	-	-
West S.S.L.	2	4	5	4	1			2
West S.S.L_Juv	2	4	7	4	1			2
Resident seals	5	6	6	5	1			2
Wintering seals	-	-	-	-	-	-	-	-
Shearwater	6	6	6	6	4			2
Murres	4	6	6	6	4			2
Kittiwakes	4	6	6	6	4			2
Auklets	4	6	6	6	4			2
Puffins	4	6	6	6	4			2
Fulmars	4	6	6	6	4			2
Storm Petrels	4	6	6	6	4			2
Cormorants	4	6	6	6	4			2
Gulls	4	6	6	6	4			2
Albatross Jaeger	6	6	6	6	4			2
Sleeper shark	5	7	7	6	3	7		2
Salmon shark	5	7	7	7	3	5		2
Dogfish	6	7	7	7	3	5		2
W. Pollock	3	5	5	1	1			2
W. Pollock_Juv	8	6	6	1	1			2
P. Cod	2	5	5	1	1	5		2
P. Cod_Juv	8	6	6	1	1			2
Herring	8	7	7	5	1		1	2
Herring_Juv	8	6	6	6	1			2
Arrowtooth	2	5	5	1	1	5		2
Arrowtooth_Juv	8	6	6	1	1			2
Kamchatka fl.	3	5	5	2	2			2
Kamchatka fl._Juv	8	6	6	6	1			2
Gr. Turbot	2	5	5	1	1			2
Gr. Turbot_Juv	8	6	6	6	1			2
P. Halibut	2	5	5	1	2	1		2
P. Halibut_Juv	8	6	6	6	1			2

Table C29. Continued.

AI Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
YF. Sole	8	5	5	6	1			2
YF. Sole_Juv	8	6	6	6	1			2
FH. Sole	2	5	5	1	1			2
FH. Sole_Juv	8	6	6	1	1			2
N. Rock sole	3	5	5	6	2			2
N. Rock sole_Juv	-	-	-	-	-	-	-	-
S. Rock sole	3	6	6	6	2			2
AK Plaice	8	6	6	6	1			2
Dover Sole	2	6	6	6	1			2
Rex Sole	8	6	6	6	1			2
Misc. Flatfish	8	6	6	6	2			2
Alaska skate	2	7	7	2	4	7		2
Bering skate	2	7	7	4	4	7		2
Aleutian skate	2	7	7	4	4	7		2
Whiteblotched skate	2	7	7	2	4	7		2
Mud skate	2	7	7	2	4	7		2
Longnosed skate	2	7	7	5	4	7		2
Big skate	2	7	7	5	4	7		2
Black skate	2	7	7	5	4	7		2
Sablefish	3	5	5	4	1	5		2
Sablefish_Juv	8	6	6	6	1	5		2
Eelpouts	8	7	7	6	7			2
Giant Grenadier	6	7	7	3	4			2
Pacific Grenadier	6	7	7	5	4			2
Other Macruids	8	7	7	5	4			2
Misc. fish deep	8	7	7	7	7			2
POP	2	3	3	1	1	6		2
POP_Juv	-	-	-	-	-	-	-	2
Sharpchin Rock	8	6	6	5	2	6		2
Northern Rock	2	6	6	2	2	6		2
Dusky Rock	2	6	6	2	1	6		2
Shortraker Rock	2	6	6	2	2	6		2
Rougheye Rock	2	6	6	2	2	6		2
Shortspine Thorns	2	6	6	2	1	6		2
Shortspine Thorns_Juv	-	-	-	-	-	-	-	-
Other Sebastes	8	6	6	6	2	6		2
Atka mackerel	1	3	3	1	1			2
Atka mackerel_Juv	8	4	4	2	1			2
Greenlings	8	7	7	2	7			2
Lg. Sculpins	8	7	7	2	4	6		2
Other sculpins	8	7	7	2	4	6		2
Misc. fish shallow	8	7	7	5	7			2
Octopi	8	7	7	7	3			2
Squids	8	7	7	7	3			2
Salmon returning	6	5	5	5	2		1	2
Salmon outgoing	7	6	6	6	2			2
Bathylagidae	8	7	7	7	4			2
Myctophidae	8	7	7	5	4			2
Capelin	8	7	7	7	4			2
Sandlance	8	7	7	7	4			2
Eulachon	8	7	7	7	4			2
Oth. managed forage	8	7	7	7	4			2
Oth. pelagic smelt	8	7	7	7	4			2

Table C29. Continued.

AI Group	Biomass	P/B	Q/B	Diet	Catch: Fed	Halibut	State	Subsistence
Bairdi	8	6	5	7	2		1	2
Bairdi_Juv	-	-	-	-	-	-	-	-
King Crab	7	6	5	7	2		1	2
King Crab_Juv	-	-	-	-	-	-	-	-
Opilio	-	-	-	-	-	-	-	-
Opilio_Juv	-	-	-	-	-	-	-	-
Pandalidae	8	5	5	7	4			2
NP shrimp	8	6	6	7	4			2
Sea stars	8	6	7	7	4	6		2
Brittle stars	8	6	7	7	4			2
Urchins dollars cucumber	8	6	7	7	4			2
Snails	8	6	7	7	4			2
Hermit crabs	8	6	7	7	4			2
Misc. crabs	8	6	7	7	4			2
Misc. Crustacean	8	6	7	7	4			2
Benthic Amphipods	8	6	7	7	4			2
Anemones	5	6	7	7	4			2
Corals	5	6	7	7	4			2
Hydroids	8	6	7	7	4			2
Urochordata	6	6	7	7	4			2
Sea Pens	5	6	7	7	4			2
Sponges	6	6	7	7	4			2
Bivalves	8	6	7	7	4			2
Polychaetes	8	6	7	7	4			2
Misc. worms	8	6	7	7	4			2
Scyphozoid Jellies	7	6	6	7	4			2
Fish Larvae	8	7	7	7	1			2
Chaetognaths	8	7	7	7	1			2
Euphausiids	8	6	6	7	1			2
Mysids	8	7	7	7	1			2
Pelagic Amphipods	8	6	6	7	1			2
Gelatinous filter feeders	8	7	7	7	1			2
Pteropods	8	7	7	7	1			2
Copepods	8	7	6	7	1			2
Pelagic microbes	8	7	7	7	1			2
Benthic microbes	8	7	7	1	1			2
Macroalgae	8	7	7	0	1			2
Lg Phytoplankton	8	6	0	0	1			2
Sm Phytoplankton	8	6	0	0	1			2
Outside Production	8	7	0	0	1			2
Discards	8			0	1			2
Offal	8			0	1			2
Pelagic Detritus	8			0	1			2
Benthic Detritus	8			0	1			2
Outside Detritus	8			0	1			2

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