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A Spatially Explicit Ecosystem Model of the California Current's Food Web and Oceanography

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A Spatially Explicit Ecosystem Model of the California Current's Food Web and Oceanography

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Table of Contents

List of Figures	v
List of Tables	vii
Executive Summary	ix
Acknowledgments	xi
Acronyms and Abbreviations	xiii
Introduction	1
Northern California Current Ecosystem	1
NCCE Species	2
Food Web Modeling	4
Methods	6
Model Scenario and Application	6
Model Structure	6
Primary Production	8
Invertebrates	18
Vertebrates	18
Nutrients	19
Process Assumptions: Predation and Recruitment	20
Oceanography	20
Data Sources	23
Calibration	25
Results	27
Discussion	49
References	53
Appendix A: California Current Model Documentation	67
Benthic Habitat and Sediment Type	67
Nutrients, Salinity, and Dissolved Oxygen	67
Overview of Biological Parameters	68
Growth and Clearance Rates	68
Beverton Holt Recruitment Parameters	69

Migration	70
Phytoplankton (PS, PL).....	70
Zooplankton (ZL, ZM, ZS, ZG, PWN)	71
Cephalopods (CEP, BMS).....	71
Benthic Invertebrates (BC, BML, BFF, BMD, BG)	71
Small Planktivorous Fish (FPS)	72
Large Planktivorous Fish (FPL)	73
Shallow Piscivorous Fish (FDE)	73
Deep Vertical Migrators (FBP)	73
Deep Demersal Fish (FDD).....	74
Rockfish (FDB, FDC, FDO, SHR, FDS)	74
Flatfish (FDF).....	76
Hake (FMM)	76
Sablefish (FMN).....	77
Large Piscivorous Flatfish (FVD)	77
Large Demersal Predators (FVS)	77
Salmon (FVB)	78
Albacore (FVT).....	78
Skates and Rays (SSK).....	78
Small Demersal Sharks (SHB)	79
Demersal Sharks (SHD)	79
Pelagic Sharks (SHP)	79
Migrating Birds (FVO).....	79
Surface-Feeding Birds (SB)	80
Diving Birds (SP).....	80
Pinnipeds (PIN).....	81
Transient Orcas (REP).....	82
Baleen Whales (WHB).....	82
Toothed Whales (WHT).....	83
Sea Otters (WDG)	83
Appendix B: Predator-Prey Parameters	85

List of Figures

Figure 1. Schematic of Atlantis modules for oceanography, ecology, and fishing.....	5
Figure 2. Map of the Northern California Current model area.	7
Figure 3. Map of Region 1, Washington, defined by bathymetric depth layers..	9
Figure 4. Seasonal salinity	22
Figure 5. Seasonal temperature variation.....	23
Figure 6. Seasonal vector velocity	24
Figure 7. Spatial distribution of chlorophyll a.	27
Figure 8. Spatial distribution of deep benthic filter feeders.....	28
Figure 9. Spatial distribution of small flatfish	29
Figure 10. Abundance of rockfish, skates, and rays over time, spatially aggregated	30
Figure 11. Abundance of groundfish groups over time, spatially aggregated	31
Figure 12. Abundance of pelagic groups over time, spatially aggregated	32
Figure 13. Abundance of shark and seabird groups over time, spatially aggregated.....	33
Figure 14. Abundance of marine mammal groups over time, spatially aggregated.....	34
Figure 15. Abundance of nutrients and carrion over time, spatially aggregated	36
Figure 16. Abundance of filter feeders, kelp, and seagrass groups over time, spatially aggregated..	37
Figure 17. Abundance of invertebrate groups over time, spatially aggregated.....	38
Figure 18. Abundance of plankton groups over time, spatially aggregated.....	39
Figure 19. Abundance of benthic invertebrate groups over time, spatially aggregated.....	40
Figure 20. Unfished biomass predicted by Atlantis versus single species assessments.....	42
Figure 21. Seasonal distribution of hake.....	43
Figure 22. Change in reserve and structural nitrogen for rockfish and skates.	44
Figure 23. Change in reserve and structural nitrogen for other groundfish	45
Figure 24. Change in reserve and structural nitrogen for pelagic groups	46
Figure 25. Change in reserve and structural nitrogen for shark and bird groups.....	47
Figure 26. Change in reserve and structural nitrogen for marine mammals	48
Figure 27. Unfished biomass predicted by Atlantis for groups lacking single species assessments	50

List of Tables

Table 1. Regional division of model area	8
Table 2. List of major species by functional group and respective proportional biomass	10
Table 3. Life history parameters for vertebrates	12
Table 4. Invertebrate and primary producer functional groups and key parameters.....	15
Table 5. Migration data.....	21
Table B-1. Consumption parameters in the calibrated model for predation on groups including birds and fish.....	86
Table B-2. Consumption parameters in the calibrated model for additional prey including fish and sharks.	91
Table B-3. Consumption parameters in the calibrated model for seabird and mammal prey	96
Table B-4. Consumption parameters in the calibrated model of benthic prey.....	99
Table B-5. Consumption parameters in the calibrated model for prey including plankton, shrimp, and squid.....	104
Table B-6. Consumption parameters in the calibrated model for prey including macroalgae, seagrass, bacteria, meiobenthos, detritus, and carrion	109
Table B-7. Ratio of calibrated consumption parameters/initial consumption parameters for birds and fish.....	115
Table B-8. Ratio of calibrated consumption parameters/initial consumption parameters for fish and sharks..	120
Table B-9. Ratio of final values/initial values for consumption parameters after calibration versus before calibration for mammals and seabirds..	125
Table B-10. Ratio of final values/initial values for consumption parameters of benthos prey groups... ..	129
Table B-11. Ratio of final values/initial values for consumption parameters after calibration versus before calibration for plankton, cephalopods, and shrimp prey groups.....	134
Table B-12. Ratio of final values/initial values for consumption parameters of macroalgae, seagrass, bacteria, detritus, and carrion.....	138

Executive Summary

Fisheries managers along the U.S. West Coast must increasingly balance trade-offs between competing species and competing fisheries. They also must build management plans that respond to the dynamic oceanography and productivity of the region. New management tools, such as spatial closures or climate-triggered fishing policies, could help address some of these issues, but a modeling framework is needed against which to test such potential policies. To address this need, an ecosystem model was constructed of the Northern California Current Ecosystem, which extends from the U.S.-Canada border to Point Conception, California, and out to the 1,200 m isobath.

Presented here are the coupled biological-oceanographic model and documented assumptions, parameterization, and data sources. Later versions will include the fisheries and will be used to evaluate management strategies. The model structure, Atlantis, includes the trophic dynamics of 54 functional groups in the food web, using nitrogen as a common currency between groups. Functional groups include habitat-forming species such as kelp, corals and sponges, as well as phytoplankton, detritus, and consumers such as fish and zooplankton.

The model is divided into 62 three-dimensional spatial zones, each with up to 7 depth layers. This allows us to explicitly test hypotheses regarding migrations, movement behavior, and spatial management options such as marine protected areas. The model is forced with hydrodynamic flows, salinity, and temperature outputs from a high-resolution Regional Ocean Modeling System, allowing us to test the impacts that climate-driven changes in upwelling or coastal currents have on nutrients and primary productivity.

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Acronyms and Abbreviations

CalCOFI	California Cooperative Oceanic Fisheries Investigations
COADS	Comprehensive Ocean-Atmosphere Data Set
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
EFH EIS	Essential Fish Habitat Environmental Impact Statement
ERSEM	European Regional Seas Ecosystem Model
IGBEM	Integrated Generic Bay Ecosystem Model
MSE	management strategy evaluation
NCCE	Northern California Current Ecosystem
NCEP	National Center for Environmental Prediction
NEP	Northeast Pacific
NPac	North Pacific
NRC	National Research Council
PDO	Pacific Decadal Oscillation
PFMC	Pacific Fishery Management Council
PRBO	Point Reyes Bird Observatory
RCA	rockfish conservation area
ROMS	Regional Ocean Modeling System

Introduction

The marine area off the coast of Washington, Oregon, and northern California is characterized by an eastern boundary current system flowing over a narrow continental shelf, linking cooler subarctic waters to the north and warmer subtropical water to the south. These currents interact with distinctive oceanographic and geomorphic features of the North American continent to create the complex and dynamic Northern California Current Ecosystem (NCCE). The pronounced latitudinal oceanographic variation of this system directly impacts the physical and chemical variables which drive primary production and affect the growth, survival, and spatial distributions of fauna ranging from zooplankton to large predatory fishes, sea birds, and marine mammals (Croll et al. 1998, Francis 2003).

Populations of species such as Pacific hake (*Merluccius productus*), which migrate through the system en masse, and rockfish (*Sebastes* spp.), which are long-lived, relatively nonmigratory residents, respond dramatically to the climatic and oceanographic variability of this system (Field and Francis 2002). Fishing has depleted many species like bocaccio rockfish (*S. paucispinis*), and their sporadic recruitment linked to climate has led to a slow and partial recovery (Parker et al. 2000, Field et al. 2001, Ruckelshaus et al. 2002).

Management faces the challenge of relating changes in the biology to these physical factors and to fishing and other human activities, and incorporating them into management strategies (Parker et al. 2000, Pikitch et al. 2004). Examples include species rebuilding plans created by the Pacific Fishery Management Council (PFMC) and marine protected areas, such as rockfish conservation areas that have been implemented in recent years to limit targeted and incidental rockfish harvest. Here we offer a simulation tool that includes realistic levels of complexity in the ecosystem, as a way to more fully explore management policy options and to facilitate decision making.

Northern California Current Ecosystem

Three key characteristics of the NCCE underlie its dynamics and its likely response to management actions: 1) the spatial pattern of the biology and physics, 2) large annual, interannual, and interdecadal variability in physical forcing such as currents and upwelling, and 3) the wide variety of life histories of species that live in this patchy and fluctuating environment. The biology and physics of the NCCE are driven by three major currents, the California Current, the Davidson Current, and the California Undercurrent, which shift in strength and distance from shore throughout the year in response to climatic forcing.

The chief current, the California Current, runs widely along the surface pushing cold, nutrient-rich water from the tip of Vancouver Island southward down to Baja California, typically offshore in the fall and winter and inshore during the spring and summer. The California Undercurrent and Davidson Current both run north, bringing warmer, saltier, hypoxic waters from the equator. The subsurface California Undercurrent runs off the shelf break in the

summer and fall, while the Davidson Current runs more nearshore at the surface in the winter and spring (Hickey 1979, Landry and Hickey 1989, Field 2004). These currents drive ecosystem variability, directly impacting the seasonal and annual dynamics of the nutrients and organisms (GLOBEC 1994, Hickey 1998).

The interface of the California Current system and the unique geomorphology and physical oceanography of the U.S. Pacific coastline results in relatively static and latitudinally defined shifts in temperatures and species biomass along the coast throughout the year (Hickey 1979, Chelton et al. 1982, GLOBEC 1994). For example, Cape Flattery, Cape Blanco, Cape Mendocino, and Point Conception influence nearshore cyclonic and anticyclonic eddies and meandering jets, which propagate localized mixing between offshore and shelf water (Batteen 1997, Barth et al. 2000, Field 2004).

Concentrated areas of upwelling are created by the latitudinal variation in continental shelf width and large geographic features like Astoria Canyon and Monterey Bay. Heavier northern flows of fresh water input introduce latitudinally varied levels of nutrients into the system year-round. Habitat-forming marine flora such as kelp and seagrass are limited by these conditions and live scattered along the coast. The headlands and resulting eddies and jets enhance the strong winter storms and spring and summer upwelling that influence the spatiotemporal variation in primary productivity and zooplankton biomass of the NCCE (GLOBEC 1994, Lynn et al. 2003).

The NCCE is sensitive to seasonal current changes as well as large scale climate shifts that significantly alter these typical seasonal patterns. Interannual shifts from El Niño–Southern Oscillation upset these patterns by bringing stronger currents of warmer and less productive water farther north, thus decreasing the influence of the southward California Current (Landry and Hickey 1989).

While El Niño patterns alter the climate of the ecosystem for several years, the longer-scale regime shift known as the Pacific Decadal Oscillation (PDO) can influence the NCCE for decades. The last definitive major regime shift occurred in 1977, bringing warmer water and leading to community shifts and major changes in the biomass of pelagic fish and crustaceans (Field and Francis 2002, McGowan et al. 2003). Climatic studies of the past century indicate the 1977 regime shift may be part of a multidecadal warm-cool regime shift pattern (Trenberth 1990, MacCall 1996, McGowan et al. 2003). There is evidence of a recent PDO shift in 1998 to cooler waters, but that is in dispute at this time (Bond et al. 2003, Peterson and Schwing 2003, Goericke et al. 2004, Hsieh et al. 2005).

NCCE Species

Species in the NCCE have developed specific strategies to maximize their success in this dynamic environment (EPAP 1999, Field and Francis 2002). For example, rockfish have developed a long-living, late-maturing, live-bearing strategy that takes advantage of periodic recruitment opportunities related to annual climatic variability (Love et al. 2002). Metapopulations of anadromous salmon—for example, coho (*Oncorhynchus kisutch*) and Chinook salmon (*O. tshawytscha*)—are another prime example (Groot and Margolis 1991), allowing the species to cope with spatially and temporally variable freshwater and ocean

conditions. The low-frequency variability of pelagic forage fish such as anchovy (*Engraulis mordax*), sardine (*Sardinops sagax*), and mackerel (*Scomber japonicus*), as well as crustacean species like Dungeness crab (*Cancer magister*) and pandalid shrimp (*Pandalus* spp.), appears to be a strategy related to both biological interactions and climate regime shifts of the system (GLOBEC 1994, MacCall 1996). Other species such as Pacific hake, sardines, albacore (*Thunnus alalunga*), sooty shearwaters (*Puffinus griseus*), and a variety of mammals typically migrate south through the system in the fall into warmer waters to reproduce and travel north in the spring to colder waters to feed. This influx in predation significantly impacts prey biomass and ecosystem dynamics (Chelton et al. 1982, Carretta et al. 2002, Field and Francis 2002). It is crucial for sustainable fishery management plans to consider these tailored life history strategies and their ecosystem-level implications.

Traditional single species stock assessments do not address the climate forcing that underlies the system, the different spatial responses to climate forcing and to fishing pressure, and the interactions between the species adapted to this ecosystem. There is increasing evidence that neglecting such aspects will hinder fishery management and the understanding of fish population dynamics. For instance, predation on depleted rockfish stocks by predators such as lingcod (*Ophiodon elongatus*) or Pacific hake can slow their recovery rates (Mangel and Levin 2005, Harvey et al. in press). Ignoring this trophic interaction could cause management plans to miss recovery targets.

Climate patterns strongly influence the recruitment and population dynamics of bocaccio rockfish (Tolimieri and Levin 2005, Zabel et al. in prep.), sablefish (*Anoplopoma fimbria*); (Schirripa and Colbert 2005), sardines (Jacobson and MacCall 1995) and other species. Spatial overlap of abundant migratory predators (notably Pacific hake) with their prey varies annually (Bailey et al. 1982) and could lead to large variations in predation mortality on prey species. Similarly, the spatial overlap of bottom trawling and living substrate determines the impact of fishing on benthic habitat (NRC 2002) and this fluctuates with changes in fishing behavior and regulations. Although the PFMC and the states of Washington, Oregon, and California have management policies in place for individual species or management groups, there is no holistic, integrative model that incorporates interactions between species, management plans, and management jurisdictions.

Management agencies and councils have several new policy tools that address some of these interactions between fisheries and the ecosystems within which they are embedded. One example of this is that the PFMC recently proposed a ban on krill (*Euphausiidae* spp.) harvesting, as a way to safeguard forage resources for current target species. State and federal management agencies have also implemented spatial closures and marine reserves (Airame et al. 2003) to reduce fishing mortality and to preserve benthic habitat and biodiversity. Currently, PFMC is in the process of closing all West Coast waters greater than 700 fathoms (>1,280 m, approximately 75% of the U.S. West Coast exclusive economic zone) to bottom trawling.

The outcome of such closures involves movement of adults, dispersal of larvae and recruits (Tuck and Possingham 2000), and predation within closed areas on target species (Martell et al. 2005). Additional new policy tools available to managers include the buyback of trawl permits and the use of specialized trawl gear that reduces rockfish bycatch. A modeling

framework is needed to evaluate the effectiveness of such policies in the northern California Current.

Food Web Modeling

To begin to include ecology and management issues that traditional single species stock assessments neglect, Field (2004) and Field et al. (2006) developed a food web model of the NCCE, using the Ecopath with Ecosim software (Christensen and Walters 2004). The model starts with a mass balance accounting of production and mortality for 62 biomass pools (species or functional groups). In forward simulations, the model projects the biomass dynamics of these pools in response to predation, fishing, and other mortality.

Field's model has been used to identify climate drivers in the system (Field et al. 2006), to weight the importance of such drivers against the direct impact of fishing (Field 2004), to illustrate trade-offs between fleets (Little et al. in prep.), and to identify key trophic interactions within the food web (e.g., between hake and crustaceans). Moreover, Field (2004) identified key data gaps and also derived the first estimate of coast-wide abundance of some species, estimated from the energetic demands and diets of their predators. However, there is a need to go beyond the Ecopath with Ecosim approach to include spatial processes, more realistic nutrient and climate forcing, and finer age structure. Here we used Field's work as the foundation of our spatially explicit model, building on the lessons learned from his model and on his parameterization.

Atlantis, a modeling approach developed by scientists (Fulton 2004, Fulton et al. 2004) with the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO), achieves the crucial goal of integrating physical, chemical, ecological, and fisheries dynamics in a three-dimensional, spatially explicit domain (Fulton et al. 2003). In Atlantis, marine ecosystem dynamics are represented by spatially explicit submodels that simulate hydrographic processes (current-, light- and temperature-driven fluxes of water and nutrients), biogeochemical factors driving primary production, food web relations among functional groups, crude habitat interactions, and fishing fleet behavior (Figure 1).

Fulton developed Atlantis from a series of models that explored optimal ecosystem model complexity (Fulton and Smith 2002, Fulton 2004, Fulton et al. 2004). A precursor to Atlantis, the Integrated Generic Bay Ecosystem Model (IGBEM) (Fulton et al. 2004), was a combination of the biological modules of the European Regional Seas Ecosystem Model (ERSEM) (Baretta and Baretta-Bekker 1997) and the physical processes and spatial layout of the Port Phillip Bay Integrated Model (Murray and Parslow 1997). Efforts to simplify the physiological processes in IGBEM resulted in Bay Model 2 (BM2), a more parsimonious framework that still effectively captures system dynamics (Fulton 2001, 2004). Atlantis is a modified version of BM2, established to improve upon ecosystem based fishery management tools (Fulton et al. 2003). There are 11 applications of Atlantis at this time. Two of the most well developed models are by Fulton et al. and focus on Port Phillip Bay, Australia (Fulton et al. 2003) and the Southeast Australian regional ecosystem (Fulton et al. 2005). Models for nine other systems within Australia and the United States, including the NCCE, are in development.

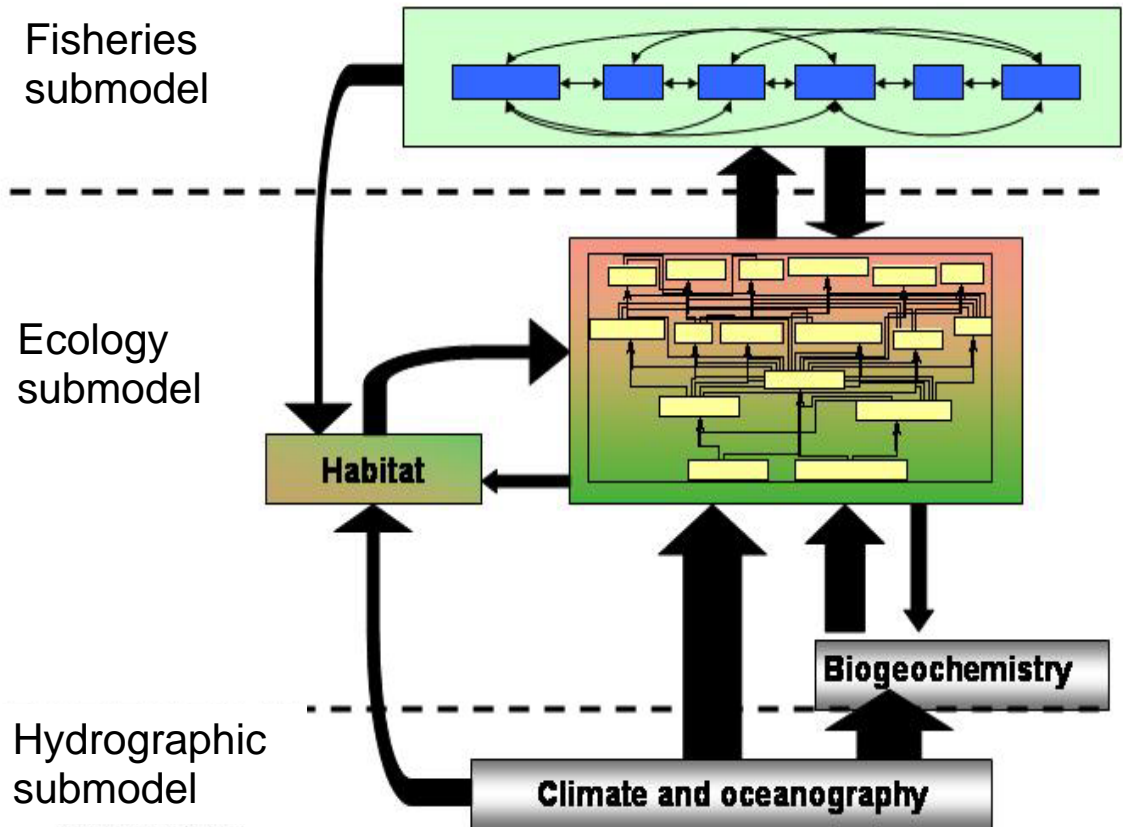


Figure 1. Schematic of Atlantis modules for oceanography, ecology, and fishing. This paper discusses the ecology and hydrographic submodels.

Here we present the first version of a spatially explicit ecosystem model for the NCCE, using the Atlantis framework. This version of the model includes the biology and oceanography of the system, with no fishing or other anthropogenic effects. In this technical memorandum, we document the model structure, parameterization, and assumptions. Future modeling and manuscripts will focus on including fisheries, fitting to historical time series of abundance, and evaluating management strategy. Ultimately, the model is intended as a strategic management tool that will allow the identification of trade-offs between and among species, fleets, and management goals, and to identify direct and indirect effects of management policies. As with any complex simulation model, its use is not intended for making short-term tactical decisions (e.g., annual decisions in fishing mortality rates). However, the Atlantis framework is an ideal operating model to be used in management strategy evaluation (MSE), in which management policies and assessment methods are tested against simulations that represent a real ecosystem and its complexities (Kirkwood 1997, Sainsbury et al. 2000, Hilborn et al. 2002).

In this framework, the NCCE Atlantis model is useful in that it reproduces qualitative behavior of the system and exhibits a range of dynamic responses similar to that observed in the ecosystem. The ecosystem model can serve as a filter to identify which policies (e.g., marine protected areas placement and monitoring) and methods (e.g., stock assessment techniques) are promising and which are flawed or likely to be ineffective.

Methods

The Atlantis model reaches from Cape Flattery, Washington, to Point Conception, California, the region defined as the NCCE (Figure 2). This area totals 144,887 km² and is approximately 1.25 by 10⁵ km³ in volume. To allow explicit representation of migrations, movement behavior, and spatial management such as marine protected areas, the model area is divided into eight coastal regions, each with six depth zones defined by bathymetric contours (Table 1 and Appendix A). Coastal regions and depth zones were defined based on biogeography, management boundaries, and data availability considerations. These 48 boxes are flanked by 14 nondynamic boundary boxes on the seaward, northern, and southern edges. The model also divides the water column into depth layers, ranging from one depth layer for nearshore boxes to seven depth layers for the offshore boundary boxes (Figure 3). Atlantis defines habitat uniformly by box. Proportions of sediment type (hard or soft) and kelp and seagrass coverage per box are delineated from data generated by the West Coast groundfish Essential Fish Habitat Environmental Impact Statement (EFH EIS) (Appendix A).

Model Scenario and Application

The results presented here are from a 42-year period without fishing. The initial conditions for the biological model include abundance and weight-at-age of each vertebrate group in each area, and biomass per area for all other groups. These initial conditions are based on data from approximately 1995–2005. We used this as a starting point, allowing the model without fishing to “spin up” to a quasi-equilibrium unfished state. Growth and abundance of most groups stabilized within the 42 years.

We used this unfished scenario to compare the Atlantis predictions of unfished abundance to the unfished abundance (B_0) predicted by single species stock assessments. On the U.S. West Coast, unfished biomass (B_0) is a management reference point. Walters et al. (2005) found systematic differences between reference points (maximum sustainable yield) estimated under single species versus multispecies assumptions. Here we tested whether similar differences are predicted by single species models versus Atlantis. We calculated the abundance at the end of the unfished Atlantis model run relative to the abundance at initial (fished) conditions. This was compared to stock assessments, primarily PFMC assessments from 2003.

Model Structure

The Atlantis model is fully described in Fulton (2001) and Fulton et al. (2004). Here we give a brief description of the generic model structure and specific attributes of the model for the California Current.

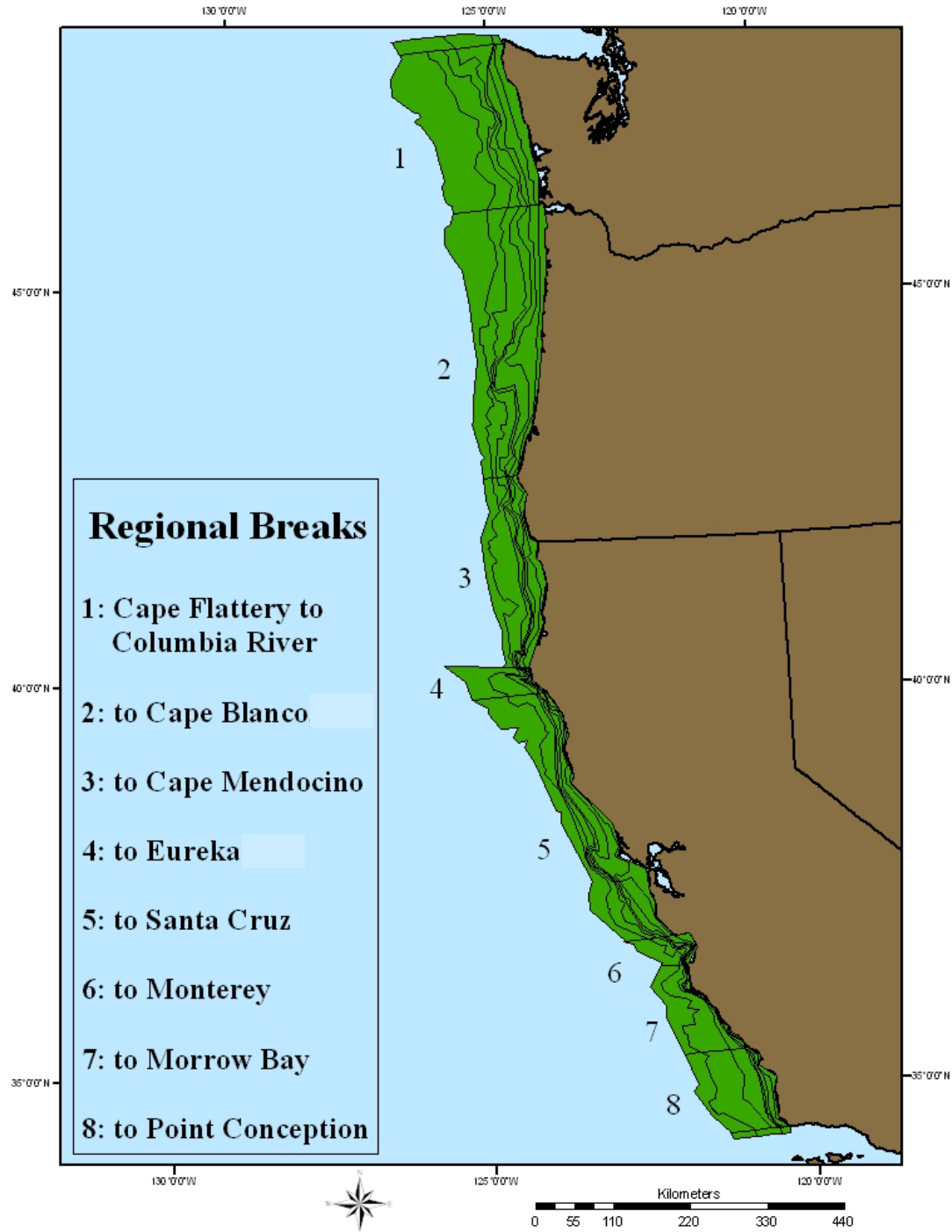


Figure 2. Map of the northern California Current model area, with northern boundary at the U.S.-Canada border, the southern at Point Conception, California, the eastern at the shoreline, and the western at the 2,400 m isobath. Each of the eight regions contains seven spatial boxes, defined by isobaths. The northernmost and southernmost boxes, and the offshore boxes defined by the 1,200-2,400 m isobath, are not dynamic and handle boundary conditions only.

Table 1. Regional division of model area.

Region	Area (km ²)
Total area	144,888.61
Cape Flattery to Columbia River	18,278.03
Columbia River to Cape Blanco	27,167.86
Cape Blanco to Cape Mendocino	13,484.69
Cape Mendocino to Eureka	2,008.22
Eureka to Santa Cruz	16,513.70
Santa Cruz to Monterey	1,533.15
Monterey to Morro Bay	5,545.68
Morro Bay to Point Conception	9,028.18
Total boundary box area	51,329.11

The ecological module of the California Current model simulates the dynamics of 54 functional groups in the food web (Tables 2, 3, and 4), using nitrogen as a common currency between groups. Silica is also handled dynamically, as is oxygen, though in a very rudimentary fashion. Functional groups include habitat forming species such as kelp, corals and sponges, as well as additional benthic invertebrates, vertebrates, phytoplankton, zooplankton, refractory and labile detritus, and carrion.

Primary Production

Primary producer abundance is modeled as an aggregated biomass pool in each spatial box. The model tracks nitrogen abundance (mg N/m³) per box. Biomass growth is limited by nutrient, light, and space availability. Biomass is lost to predation, lysis, and linear and quadratic mortality. Linear mortality represents additional density independent mortality not explicitly modeled. Quadratic mortality represents density dependent mortality (for instance, self shading).

Rate of change for standard water column (w) primary producer (PX) is:

$$\frac{d(PX_w)}{dt} = G_{PX_w} - M_{lys,PX} - M_{lin} - M_{quad} - \sum_{i=predator\ groups} P_{PX_w,i} \quad (1)$$

$$G_{PX} = \mu_{PX} \cdot \delta_{irr} \cdot \delta_N \cdot \delta_{space} \cdot PX \quad (2)$$

where G_{PX} stands for the growth of PX, $M_{lys,PX}$ is the loss of PX due to lysis, M_{lin} and M_{quad} are loss due to linear and quadratic mortality, $P_{PX,I}$ are the losses of PX due to predation, μ_{PX} is the maximum growth rate, and δ_{irr} is light limitation, δ_N is nutrient limitation, and δ_{space} is space limitation. Table 4 contains values for μ , M_{lin} and M_{quad} for our model; M_{lys} was set to 0.

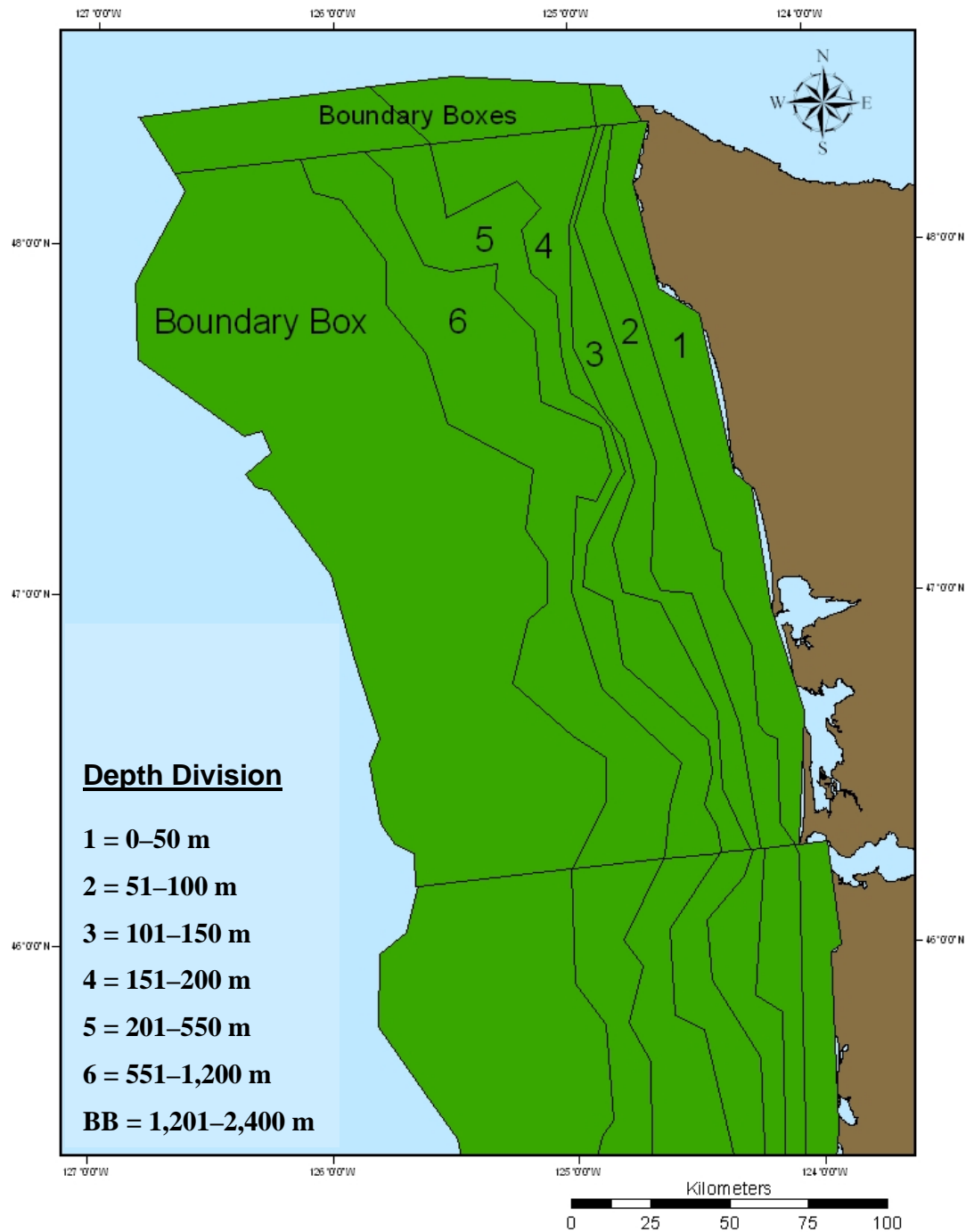


Figure 3. Map of Region 1, Washington, defined by bathymetric depth layers. The map displays the isobaths that divide the seven boxes (from 50 to 2,400 m) within each region. Each box has up to seven depth layers.

Table 2. List of major species by functional group and respective proportional biomass. Relative abundances of miscellaneous nearshore fish (FDE) are not known; life history parameters similar to the white croaker (*Genyonemus lineatus*) were assumed.

Code	Group	Species	Scientific name	Proportion
FBP	Deep vertical migrators	Lampfish	Myctophidae	0.34
		Pacific viperfish	<i>Chauliodus macouni</i>	0.22
		Lanternfish	Myctophidae	0.17
		Longfin dragonfish	<i>Tactostoma macropus</i>	0.15
FDB	Shallow small rockfish	Shortbelly	<i>Sebastes jordani</i>	0.43
		Stripetail	<i>Sebastes saxicola</i>	0.39
		Greenstriped	<i>Sebastes elongatus</i>	0.12
FDC	Deep small rockfish	Longspine thornyhead	<i>Sebastolobus altivelis</i>	0.59
		Sharpchin	<i>Sebastes zacentrus</i>	0.19
		Splitnose	<i>Sebastes diploproa</i>	0.18
		Aurora	<i>Sebastes aurora</i>	0.03
FDD	Deep miscellaneous fish	Pacific grenadier	<i>Coryphaenoides acrolepis</i>	0.41
		Giant grenadier	<i>Albatrossia pectoralis</i>	0.31
		Grenadier	Macrouridae	0.08
		Bigfin eelpout	<i>Lycodes cortezianus</i>	0.05
FDE	Miscellaneous nearshore demersal	White croaker	<i>Genyonemus lineatus</i>	NA*
		Sculpin	Cottidae	NA
		Midshipman	<i>Porichthys notatus</i>	NA
FDF	Small flatfish	Dover sole	<i>Microstomus pacificus</i>	0.72
		Rex sole	<i>Glyptocephalus zachirus</i>	0.13
		Pacific sanddab	<i>Citharichthys sordidus</i>	0.08
FDO	Deep large rockfish	Shortspine thornyhead	<i>Sebastolobus alascanus</i>	0.72
		Darkblotched	<i>Sebastes crameri</i>	0.23
SHR	Shallow large rockfish	Redstriped	<i>Sebastes proriger</i>	0.88
		Yelloweye	<i>Sebastes ruberrimus</i>	0.05
FDS	Midwater rockfish	Chilipepper	<i>Sebastes goodei</i>	0.53
		Widow	<i>Sebastes entomelas</i>	0.18
		Pacific ocean perch	<i>Sebastes alutus</i>	0.14
		Yellowtail	<i>Sebastes flavidus</i>	0.10
FMM	Hake	Pacific hake	<i>Merluccius productus</i>	0.97
FMN	Sablefish	Sablefish	<i>Anoplopoma fimbria</i>	1.00
FPL	Large planktivores	Jack mackerel	<i>Trachurus symmetricus</i>	0.92
		Pacific mackerel	<i>Scomber japonicus</i>	0.08
FPS	Small planktivores	Anchovies	<i>Engraulis mordax</i>	0.59
		Sardines	<i>Sardinops sagax</i>	0.39
		Herring	<i>Clupea pallasii pallasii</i>	0.02
FVB	Salmon	Chinook	<i>Oncorhynchus tshawytscha</i>	0.95
		Coho	<i>Oncorhynchus kisutch</i>	0.05
FVD	Large flatfish	Arrowtooth flounder	<i>Atheresthes stomias</i>	0.71
		Pacific halibut	<i>Hippoglossus stenolepis</i>	0.15
		Petrale sole	<i>Eopsetta jordani</i>	0.14
FVS	Large demersal predators	Lingcod	<i>Ophiodon elongatus</i>	1.00
FVT	Large pelagic predators	Albacore	<i>Thunnus alalunga</i>	1.00

Table 2 continued. List of major species by functional group and respective proportional biomass. Relative abundances of miscellaneous nearshore fish (FDE) are not known; life history parameters similar to the white croaker (*Genyonemus lineatus*) were assumed.

Code	Group	Species	Scientific name	Proportion
SHB	Small demersal sharks	Dogfish	<i>Squalus acanthias</i>	0.73
		Spotted ratfish	<i>Hydrolagus colliei</i>	0.17
		Brown catshark	<i>Apristurus brunneus</i>	0.07
		Pacific angel	<i>Squatina californica</i>	0.06
SHD	Large demersal sharks	Sleeper	<i>Somniosus pacificus</i>	0.97
		Sixgill	<i>Hexanchus griseus</i>	0.03
SHP	Misc. pelagic sharks	Soupfin	<i>Galeorhinus galeus</i>	0.88
SSK	Skates and rays	Longnose skate	<i>Raja rhina</i>	0.63
		Bering skate	<i>Bathyraja interrupta</i>	0.13
		Skate	Rajidae	0.11
		Roughtail skate	<i>Bathyraja trachura</i>	0.07
FVO	Migrating birds	Sooty shearwaters	<i>Puffinus griseus</i>	0.90
SP	Diving seabirds	Common murre	<i>Uria aalge</i>	0.59
		Rhinoceros auklet	<i>Cerorhinca monocerata</i>	0.19
		Cormorants, shags	<i>Phalacrocoracidae</i>	0.16
SB	Surface seabirds	Gulls	<i>Larus glaucescens</i>	0.81
		Brown pelican	<i>Pelecanus occidentalis</i>	0.09
		Storm petrels	<i>Oceanites</i> spp.	0.05
WDG	Sea otters	Sea otter	<i>Enhydra lutris</i>	1.00
PIN	Pinnipeds	Northern fur seals	<i>Callorhinus ursinus</i>	0.25
		Northern elephant seals	<i>Mirounga angustirostris</i>	0.42
		California sea lions	<i>Zalophus californianus</i>	0.35
		Harbor seals	<i>Phoca vitulina</i>	0.20
		Sperm	<i>Physeter macrocephalus</i>	0.67
WHT	Toothed whales	Cuvier's beaked	<i>Ziphius cavirostris</i>	0.17
		Baird's beaked	<i>Berardius bairdii</i>	0.07
		Beaked	<i>Mesoplodon</i> spp.	0.05
		Resident, offshore orca	<i>Orcinus orca</i>	0.03
		Gray	<i>Eschrichtius robustus</i>	0.62
WHB	Baleen whales	Fin	<i>Balaenoptera physalus</i>	0.18
		Blue	<i>Balaenoptera musculus</i>	0.15
REP	Transient orcas	Transient orca	<i>Orcinus orca</i>	1.00

* NA = Not available.

Table 3. Life history parameters for vertebrates. Most life history parameters are from FishBase (Froese and Pauly 2005). Life history parameters for each functional group are the average of life history parameters for each species in the functional group, weighted by their relative abundance. NMFS triennial trawl surveys for 1998-2003 were used to estimate relative abundance of most fish species. *Linf* and *K* are from the von Bertalanffy length-age relationship. Parameters *a* and *b* are from the length-weight relationship ($W = aL^b$). We used the life history parameters to predict size at age; from this we were able to calculate growth per day for each age class (*g* in Equation 10) and consumption per day for each age class (*C* in Equation 10). See the appendix for more details on calculation of *g*, *C*, and Beverton-Holt parameters. *Mlin* and *Mquad* are linear and quadratic mortality terms in Equation 7; values of *Mlin* and *Mquad* shown here are postcalibration.

Group	Code	<i>Linf</i>	<i>K</i>	Mortality	Age mature	Initial biomass (mt)	<i>a</i>	<i>b</i>	Steepness	Bev-Holt alpha	Bev-Holt beta	Max age	Adult <i>Mlin</i> (linear mort.)	Juvenile <i>Mlin</i> (linear mort.)	Adult <i>Mquad</i> (quad. mort.)	Juvenile <i>Mquad</i> (quad. Mort.)
Deep vertical migrators	FBP	24.8	0.35	0.45	2.00	3.09E+05	0.00	3.00	0.50	1.89E+10	7.91E+11	10.00	0	8.00E-12	2.50E-12	24.80
Shallow small rockfish	FDB	27.5	0.15	0.18	5.00	4.82E+04	0.01	3.13	0.50	1.65E+09	2.47E+11	40.00	0	0	6.00E-07	27.50
Deep small rockfish	FDC	30.6	0.10	0.14	13.00	3.38E+05	0.01	3.26	0.50	1.80E+09	4.66E+11	60.00	0	0	5.00E-11	30.63
Deep misc. fish	FDD	82.0	0.06	0.08	25.00	1.79E+05	0.02	3.21	0.50	8.87E+06	1.12E+11	70.00	0	0	1.00E-10	82.00
Misc. nearshore demersal	FDE	60.0	0.04	0.77	2.00	7.06E+04	0.01	3.03	0.50	1.27E+10	4.85E+13	20.00	0	0	1.00E-10	60.00
Small flatfish	FDF	71.1	0.12	0.22	8.00	7.45E+05	0.01	3.16	0.90	1.79E+08	7.24E+10	60.00	0	0	5.00E-09	71.09
Deep large rockfish	FDO	62.3	0.07	0.06	12.00	1.24E+05	0.01	3.25	0.80	6.08E+08	2.22E+10	90.00	0	0	6.50E-08	62.31
Shallow large rockfish	SHR	55.0	0.09	0.11	11.00	6.20E+04	0.03	2.79	0.50	8.25E+08	2.72E+08	70.00	0	0	2.50E-09	55.00
Midwater rockfish	FDS	47.0	0.13	0.19	12.00	4.08E+05	0.04	2.81	0.50	4.02E+07	4.28E+11	80.00	0	0	5.00E-08	47.00
Hake	FMM	86.0	0.13	0.23	3.00	2.70E+06	0.02	2.74	0.90	5.28E+09	1.54E+12	10.00	0	0	1.00E-15	86.00
Sablefish	FMN	78.0	0.20	0.07	4.00	1.18E+05	0.01	3.19	0.90	1.52E+08	4.81E+10	60.00	0	0	1.00E-08	78.00

Table 3 continued. Life history parameters for vertebrates. Most life history parameters are from FishBase (Froese and Pauly 2005). Life history parameters for each functional group are the average of life history parameters for each species in the functional group, weighted by their relative abundance. NMFS triennial trawl surveys for 1998-2003 were used to estimate relative abundance of most fish species. *Linf* and *K* are from the von Bertalanffy length-age relationship. Parameters *a* and *b* are from the length-weight relationship ($W = aL^b$). We used the life history parameters to predict size at age; from this we were able to calculate growth per day for each age class (*g* in Equation 10) and consumption per day for each age class (*C* in Equation 10). See the appendix for more details on calculation of *g*, *C*, and Beverton-Holt parameters. *Mlin* and *Mquad* are linear and quadratic mortality terms in Equation 7; values of *Mlin* and *Mquad* shown here are postcalibration.

Group	Code	<i>Linf</i>	<i>K</i>	Mortality	Age mature	Initial biomass (mt)	<i>a</i>	<i>b</i>	Steepness	Bev-Holt alpha	Bev-Holt beta	Max age	Adult <i>Mlin</i> (linear mort.)	Juvenile <i>Mlin</i> (linear mort.)	Adult <i>Mquad</i> (quad. mort.)	Juvenile <i>Mquad</i> (quad. mort.)
Large planktivores	FPL	60.3	0.09	0.13	1.00	9.81E+05	0.00	3.36	0.80	9.78E+09	8.81E+12	30.00	0	1.00E-12	2.00E-09	60.30
Small planktivores	FPS	22.2	0.30	0.83	2.00	3.74E+06	0.01	2.97	0.80	2.26E+11	1.20E+12	10.00	0	0	5.00E-14	22.16
Salmon	FVB	153.3	0.15	0.20	4.00	3.75E+04	0.01	3.00	0.50	3.63E+06	1.58E+11	10.00	0	0	3.00E-13	153.30
Large flatfish	FVD	92.9	0.13	0.20	7.00	1.19E+05	0.01	3.14	0.50	2.44E+07	1.46E+11	20.00	9.00E-09	0	2.00E-09	92.94
Large demersal predators	FVS	130.2	0.10	0.18	5.00	2.28E+04	0.00	3.40	0.90	2.31E+07	8.76E+06	20.00	1.50E-10	0	2.50E-09	130.20
Large pelagic predators	FVT	140.0	0.23	0.30	5.00	1.31E+03	0.05	2.79	0.80	4.61E+04	6.99E+08	10.00	9.00E-16	0	1.00E-06	140.00
Small demersal sharks	SHB	96.5	0.14	0.16	29.00	1.18E+05	0.01	3.03	0.50	3.55E+07	8.52E+10	50.00	0	0	2.50E-10	96.45
Large demersal sharks	SHD	200.0	0.15	0.05	16.00	9.36E+02	0.01	3.34	0.50	7.63E+03	1.16E+09	50.00	0	0	6.50E-08	200.00
Misc. pelagic sharks	SHP	200.0	0.13	0.23	9.00	3.74E+03	0.01	2.94	0.50	5.44E+05	8.89E+09	30.00	0	0	1.00E-07	200.00
Skates and rays	SSK	107.2	0.17	0.20	8.00	5.40E+04	0.01	3.03	0.50	8.80E+06	7.20E+10	20.00	0	0	1.20E-08	107.20

Table 3 continued. Life history parameters for vertebrates. Most life history parameters are from FishBase (Froese and Pauly 2005). Life history parameters for each functional group are the average of life history parameters for each species in the functional group, weighted by their relative abundance. NMFS triennial trawl surveys for 1998-2003 were used to estimate relative abundance of most fish species. *Linf* and *K* are from the von Bertalanffy length-age relationship. Parameters *a* and *b* are from the length-weight relationship ($W = aL^b$). We used the life history parameters to predict size at age; from this we were able to calculate growth per day for each age class (*g* in Equation 10) and consumption per day for each age class (*C* in Equation 10). See the appendix for more details on calculation of *g*, *C*, and Beverton-Holt parameters. *Mlin* and *Mquad* are linear and quadratic mortality terms in Equation 7; values of *Mlin* and *Mquad* shown here are postcalibration.

Group	Code	<i>Linf</i>	<i>K</i>	Mortality	Age mature	Initial biomass (mt)	<i>a</i>	<i>b</i>	Steepness	Bev-Holt alpha	Bev-Holt beta	Max age	Adult <i>Mlin</i> (linear mort.)	Juvenile <i>Mlin</i> (linear mort.)	Adult <i>Mquad</i> (quad. mort.)	Juvenile <i>Mquad</i> (quad. mort.)
Shearwaters	FVO	103.0	0.51	0.07	6.00	2.42E+03	0.00	3.00	0.33	6.24E+06	4.51E+10	30.00	0	0	1.00E-10	103.00
Diving seabirds	SP	85.0	0.63	0.14	4.00	2.87E+03	0.00	3.00	0.33	6.64E+05	4.92E+09	20.00	0	0	8.00E-09	85.00
Surface seabirds	SB	140.0	0.46	0.14	4.00	3.90E+02	0.00	3.00	0.33	1.53E+05	4.86E+08	30.00	0	0	1.30E-06	140.00
Pinnipeds	PIN	218.0	0.66	0.25	5.00	6.54E+04	0.00	3.63	0.33	5.60E+05	8.14E+11	20.00	0	0	1.00E-09	218.00
Toothed whales	WHT	1313.0	0.21	0.05	10.00	2.60E+04	0.17	2.53	0.33	4.91E+02	1.89E+11	70.00	0	0	1.50E-07	1313.00
Baleen whales	WHB	1667.0	0.16	0.05	8.00	9.79E+05	0.55	2.44	0.33	9.03E+03	8.36E+12	90.00	0	0	1.50E-07	1667.00
Transient orcas	REP	850.0	0.28	0.01	13.00	1.84E+02	0.17	2.44	0.33	2.33E+01	1.23E+09	50.00	2.00E-08	2.00E-08	3.00E-07	850.00
Otters	WDG	120.0	0.92	0.13	3.0	8.25E+01	0.02	3.00	0.33	5.37E+03	1.23E+09	20.00	0	0	3.00E-07	120.00

Table 4. Invertebrate and primary producer functional groups and key parameters. Parameter C is the ingestion rate (mg N/day/m³) from Equation 10. The ‘maximum growth rate’ parameter (mg N/day/m³) corresponds to μ from Equation 2 (for primary producers) and g from Equation 10 (for invertebrates). ML and Mquad are linear and quadratic mortality from Equation 3. C or g in bold font indicate that the calibrated value was less than or equal to 0.1 x initial value. C or g values in gray boxes indicate that the calibrated value was greater than or equal to 10x the initial value. Initial values for C and g for ZG, ZL, ZM, ZS, BFF, BD, BG, BML, BMD, and PWN are converted from Field’s (2004) production/biomass and consumption/biomass ratios. Initial values for other groups simply fall within the range expected for Atlantis models of other systems (e.g. Fulton 2001).

Code	Group	Species	C, post-calibration	C, pre-calibration	g, post-calibration	g, pre-calibration	ML (linear mortality)	Mquad (quadratic mortality)
BC	Carnivorous infauna	Polychaetes, nematodes, burrowing crustacea, peanut worms, flatworms	0.3104	31.047	0.07	2.70384	0	1.00E-09
BD	Deposit feeders	Amphipods, isopods, small crustacea, snails, ghost shrimp, sea cucumber, worms, sea mouse, sea slug, barnacles, solenogaster, hermit crabs	0.248	2.477474	0.6	0.3120166	0	0
BFD	Deep benthic filter feeders	Anemones, deep corals, lampshells, reticulate sea anemone, rough purple sea anemone, swimming sea anemone, gigantic sea anemone, corals, sponges	0.00395	0.00395	0.000344	0.000344	0	0
BFS	Shallow benthic filter feeders	Barnacles, seafan, soft corals, Gorgonian corals, black coral, green colonial tunicate, sea pens, sea whips, sea potato, vase sponge, mussels, scallops	0.0474	0.0474	0.04128	0.004128	0	0
BFF	Other benthic filter feeders	Geoducks, barnacles, razor clams, littleneck, Manila clams, miscellaneous bivalves, Vancouver scallop, glass scallop, green urchin, red urchin	2.0	2.369605	0.4	0.2063656	0	0
BG	Benthic herbivorous grazers	Snails, abalone, nudibranches, sand dollars, make solarelle, Dorid nudibranches, limpets, heart sea urchin, spot prawns, pandalid shrimp	0.12	0.282876	0.012	0.0345023	0	0
PWN	Prawns	Crangon and mysid shrimp	0.13032	0.0013032	0.5068	0.0001166	0	0
ZM	Zooplankton	Meroplankton	0.8	0.3105	1.8	0.0100575	0	0.00001
BMD	Deep macro-zoobenthos	Sea stars, moonsnail, whelk, leather sea star, bat star, sunflower sea star, common mud star, crinoids, brittle sea star, basketstar	0.7938	0.7937948	0.0326	0.0726238	0	0

Table 4 continued. Invertebrate and primary producer functional groups and key parameters. Parameter *C* is the ingestion rate (mg N/day/m³) from Equation 10. The ‘maximum growth rate’ parameter (mg N/day/m³) corresponds to μ from Equation 2 (for primary producers) and *g* from Equation 10 (for invertebrates). *ML* and *Mquad* are linear and quadratic mortality from Equation 3. *C* or *g* in bold font indicate that the calibrated value was less than or equal to 0.1 x initial value. *C* or *g* values in gray boxes indicate that the calibrated value was greater than or equal to 10x the initial value. Initial values for *C* and *g* for ZG, ZL, ZM, ZS, BFF, BD, BG, BML, BMD, and PWN are converted from Field’s (2004) production/biomass and consumption/biomass ratios. Initial values for other groups simply fall within the range expected for Atlantis models of other systems (e.g. Fulton 2001).

Code	Group	Species	C, post-calibration	C, pre-calibration	g, post-calibration	g, pre-calibration	ML (linear mortality)	MQuad (quadratic mortality)
BMS	Shallow macro-zoobenthos	Giant, bigeye, yellowring, and smoothskin octopi, and flapjack devilfish	0.67	0.6698	0.1	0.10234	0	0
BML	Mega-zoobenthos	Dungeness crab, tanner crab, spiny lobster, pinchbug crab, red rock crab, graceful rock crab, spider crab, grooved tanner crab, Bairdi, scarlet king crab, California king crab	0.0571	0.057102	0.174908	0.0074908	0	0
BO	Meiobenthos	Flagellates, ciliates, nematodes	0.079	0.079	0.00688	0.00688	5E-08	0
CEP	Cephalopods	Market squid, japetella, gonatus, chiroteuthis, abraliopsis, robust clubhook, rhomboid squid, sandpaper squid, vampire squid	0.02	0.0005122	0.02	0.00008	0	0.07
ZG	Gelatinous zooplankton	Salps, jellyfish, ctenophores, comb jellies	0.15	0.0030844	0.015	0.0002376	0	0.00005
ZL	Large zooplankton	Euphausiids, chaetognaths, pelagic shrimp, pelagic polychaetes, crimson pasiphaeid	0.767	0.767	0.45	0.035636	0	0
ZM	Mesozooplankton	Copepods, cladocera	0.8	NA	1.8	NA	0	0.00001
ZS	Microzooplankton	Ciliates, dinoflagellates, nanoflagellates, gymnodinoids, protozoa	2.083	2.0838	0.5	0.067497	0.00001	0
PL	Large phytoplankton	Diatoms	NA	NA	0.7	NA	0.00001	0
PS	Small phytoplankton	Picophytoplankton	NA	NA	1	NA	0.0001	0
SG	Seagrass		NA	NA	0.18	NA	0.0001	0
MA	Macroalgae	Kelp	NA	NA	0.25	NA	2E-06	0
BB	Benthic bacteria		NA	NA	2	250	0	0

Table 4 continued. Invertebrate and primary producer functional groups and key parameters. Parameter *C* is the ingestion rate (mg N/day/m³) from Equation 10. The ‘maximum growth rate’ parameter (mg N/day/m³) corresponds to μ from Equation 2 (for primary producers) and *g* from Equation 10 (for invertebrates). *ML* and *Mquad* are linear and quadratic mortality from Equation 3. *C* or *g* in bold font indicate that the calibrated value was less than or equal to 0.1 x initial value. *C* or *g* values in gray boxes indicate that the calibrated value was greater than or equal to 10x the initial value. Initial values for *C* and *g* for ZG, ZL, ZM, ZS, BFF, BD, BG, BML, BMD, and PWN are converted from Field’s (2004) production/biomass and consumption/biomass ratios. Initial values for other groups simply fall within the range expected for Atlantis models of other systems (e.g. Fulton 2001).

Code	Group	Species	C, post-calibration	C, pre-calibration	g, post-calibration	g, pre-calibration	ML (linear mortality)	MQuad (quadratic mortality)
PB	Pelagic bacteria		NA	NA	0.5	50	0.0001	0
BO	Meiobenthos		0.079	NA	0.00688	NA	5E-08	0
DC	Carrion		NA	NA	NA	NA	NA	NA
DL	Labile detritus		NA	NA	NA	NA	NA	NA
DR	Refractory detritus		NA	NA	NA	NA	NA	NA

Invertebrates

Invertebrates are also modeled simply as aggregated biomass pools in each spatial box. The model tracks abundance (mg N/m³) per box, based on growth, predation, and linear and quadratic mortality. Quadratic mortality in this case represents density dependent effects (predation, disease) that are not explicitly modeled; the ultimate effect is to impose a reasonable carrying capacity. In general we attempted to set linear and quadratic mortality to zero when possible (Table 4). We have attempted to explicitly include all significant ecological components. Thus there was limited need to call upon these extra mortality terms, which represent ecological components not treated explicitly.

Rate of change for a standard invertebrate consumer (CX) is:

$$\frac{d(CX)}{dt} = G_{CX} - M_{linCX} - M_{quadCX} - \sum_{i=predatorgroups} P_{CX,i} - F_{CX} \quad (3)$$

$$G_{CX} = \left(\varepsilon_{CX} \cdot \sum_{\substack{i=living \\ prey}} P_{i,CX} + \sum_{j=DL,DR} (P_{j,CX} \cdot \varepsilon_{CX,j}) \right) \cdot \delta_{space} \cdot \delta_{o2} \quad (4)$$

where G_{CX} is growth, M_{linCX} and M_{quadCX} are linear and quadratic mortality, $P_{i,j}$ is predation by group j and group i , and F_{CX} is fishing on this group (this is set to zero for the unfished scenario here). ε_{CX} is the growth efficiency of CX when feeding on live prey, $\varepsilon_{CX,j}$ the efficiency when feeding on detritus (DL treated separately to DR), δ_{space} is space limitation, and δ_{o2} is oxygen limitation. Table 4 contains values for M_{lin} , M_{quad} for our model.

Vertebrates

Vertebrates can have multiple age classes (in this case 10). These classes need not be a single year long, but represent different phases in the life cycle, so that for some groups it may be one year while for other, long-lived groups it could represent a decade or more. This is the most computationally efficient way of representing vertebrates with drastically different longevities within a common model framework. The life span of each vertebrate is detailed in Table 3, and the duration of each of the 10 age classes is 10% of this.

For each age class and each spatial cell, the model tracks the number of individuals and their average structural weight (bones and hard parts, in mg N) and reserve weight (soft tissue, in mg N). Growth and abundance are functions of recruitment, predation, consumption, and linear and quadratic mortality. We tracked abundance, biomass, weight-at-age, and condition (reserve weight/structural weight) of each group through time, in each box and for the entire model domain. We evaluated model performance based upon how closely model-predicted values for these quantities matched expected values, with expected values from von Bertalanffy growth parameters (for weight at age), stock assessments (for unfished abundance), or from an expected ratio of 2.65:1 for reserve weight:structural weight (Fulton 2001).

The rate of change for a vertebrate group (FX) is

$$\frac{d(FX_{i,s})}{dt} = G_{FX_{i,s}} \quad (5)$$

$$\frac{d(FX_{i,r})}{dt} = G_{FX_{i,r}} \quad (6)$$

$$\frac{d(FX_{i,d})}{dt} = T_{IMM,FX_i} - T_{EMM,FX_i} - M_{lin,i} - M_{quad,i} - \sum_{j=predatorgroups} P_{FX,j} - F_{FX_i} \quad (7)$$

where the subscript i represents age group i (there is one equation for each age class included), s stands for structural weight, r for reserve weight, and d for density. The T terms represent the movement of fish in to (T_{IMM,FX_i}) and out of (T_{EMM,FX_i}) the cell. In addition there are short-term spawning and recruitment events which affect the various FX pools. Other notation is as described above. The growth for each fish group is calculated by equations of the same form as (4), but per age group of each fish. The result is then apportioned to structural and reserve weight, favoring replenishment of reserves when the animal is underweight. Life history parameters and values for M_{lin} and M_{quad} are contained in Table 2.

Nutrients

Water column nitrogen (ammonia and nitrate) concentrations are governed by uptake by autotrophs, excretion by consumers, nitrification, and denitrification.

Rates of change for ammonia (NH) and nitrate (NO) in the water column are:

$$\frac{d(NH_w)}{dt} = - \sum_{i=PX_w} P_{NH_w,i} - P_{NH_w,MB_w} - P_{NH_w,MA} - P_{NH_w,PFB} + \sum_{i=CX_w, BF} E_i + \sum_{i=FX} E_i + \sum_{i=pelagic\ bacteria} E_i - S_{NIT,PAB} + R_{NET,w} \quad (8)$$

$$\frac{d(NO_w)}{dt} = - \sum_{i=PX_w} P_{NO_w,i} - P_{NO_w,MB_w} - P_{NO_w,MA} + S_{NIT,PAB} \quad (9)$$

where $P_{N,XX}$ is the uptake of NH or NO by the autotrophs (either generic, microphytobenthos MB, or macroalgae MA), E_{CX} is the production of NH by the consumer CX, $S_{NIT,XB}$ is the amount of NH converted to NO during nitrification by the bacteria XB, and R_{NET} is the amount of NH produced by denitrification.

Full descriptions of the dynamics of other forms of nitrogen, silica, bacteria, detritus, and sediment chemistry, as well as parameterizations specific for dinoflagellates and macrophytes, are contained in Fulton (2004).

Process Assumptions: Predation and Recruitment

Growth of vertebrates is based on von Bertalanffy growth parameters, but varies with consumption. A Holling type II functional response was chosen for predation, as previous work by Fulton et al. (2004) suggests this is simple to parameterize, yet is as effective as other representations given the nature of questions to be asked of strategic models. Alternative feeding functional responses exist within Atlantis and future sensitivity analyses could consider their use when evaluating potential model structural sensitivity. Implementation of the Holling type II functional response is

$$P_{ij} = \frac{B_i \cdot a_{ij} \cdot B_j \cdot C_j}{1 + \frac{C_j}{g_j} \left(E_j^l \cdot \sum_{k=1}^l B_k \cdot a_{k,j} + E_j^f \cdot \sum_{h=1}^f B_h \cdot a_{h,j} + E_j^d \cdot \sum_{x=1}^d B_x \cdot a_{x,j} + E_j^r \cdot \sum_{y=1}^r B_y \cdot a_{y,j} \right)} \quad (10)$$

where P_{ij} is the consumption of prey i by predator j , B_i is the biomass of prey i and B_j is the biomass of predator j , a_{ij} is the availability of prey i to predator j , C_j is the maximum ingestion rate of predator j , g_j is the maximum growth rate of predator j , E_j^l is the efficiency of predator j on live food (the l superscript), E_j^f is the efficiency of predator j on seagrass, macroalgae, or phytoplankton, E_j^d is the efficiency of predator j on labile detritus, and E_j^r is the efficiency of predator j on refractory detritus. The sums in the denominator are simply the sums of each of the available food biomasses (one for live food, one for seagrass, and one each for labile and refractory detritus). Values for C and g are contained in Tables 3 and 4. Values for prey availability parameters (variable a in Equation 10) are detailed in Appendix B.

Recruitment is based on Beverton-Holt parameters, though Atlantis offers many alternative options which could be explored in the future. Details of parameterization of the Beverton-Holt relationship are in Appendix A and Table 3.

For the movement of ecological groups, we allowed density dependent movement of nekton, sea birds, and marine mammals between boxes, as well as advection of plankton. The equations that govern density dependent movement are described in Fulton et al. (2004), but overall movement serves to transfer abundance towards neighboring cells with higher potential growth rates. For several functional groups (e.g., Pacific hake, albacore, marine mammals and birds) we also forced the model with seasonal migrations (Table 5). The differential equations for the system dynamics are solved using a simple adaptive forward difference method, with an overall time step of 12 hours.

Oceanography

The model is forced with circulation, salinity, and temperature outputs from a Regional Ocean Modeling System (ROMS; Figures 4, 5, and 6), allowing us to test the impacts that climate-driven changes in upwelling or coastal currents have on nutrients and primary productivity. ROMS is a state-of-the-art, free surface, hydrostatic primitive equation ocean circulation model developed at Rutgers University and the University of California Los Angeles. ROMS is a terrain-following, finite difference (Arakawa C-grid) model. It features a unified

Table 5. Migration data.

Parameter	Leave date	Return date	Migration window	Juvenile biomass increase^a	Adult biomass increase^a	Proportion migrating
FPS ^b	288	166	30	19.252020	0.1744309	1.00
FVT ^c	244	196	30	7.088320	0.1744300	1.00
FVO ^d	305	46	30	0.496500	0.0104250	1.00
FVB ^e	244	152	60	1.290550	0.3918480	0.25
FMM ^f	305	91	30	2.831966	0.1068130	1.00
PIN ^g	349	213	30	0.591039	0.0352610	0.40
WHB ^h	349	335	30	0.152940	0.0012680	0.65
WHB ^h	349	46	30	0.152949	0.0012680	0.65
WHT ⁱ	305	135	30	0.320200	0.0064980	0.30

^a Proportional increase of biomass per individual while outside model domain.

^b Hart 1943, Hargreaves et al. 1994.

^c Love 1996.

^d Briggs and Chu 1986.

^e Groot and Margolis 1991.

^f Bailey et al. 1992.

^g Carretta et al. 2005.

^h Stern 2002.

ⁱ Carretta et al. 2003.

treatment of surface and bottom boundary layers, based on the Large et al. (1994) and Styles and Glenn (2000) algorithms, and an integrated set of procedures for data assimilation. Numerical details can be found in Haidvogel et al. (2000), Moore et al. (2004) and Shchepetkin and McWilliams (2005), and on the ROMS Web site (<http://www.myroms.org>).

For the work reported here, we used an existing suite of basin and regional scale circulation models based on ROMS, linked via one-way coupling. The nested model domains are a basin scale model encompassing the North Pacific Basin (NPac) at 20–40 km resolution (Curchitser et al. in press), and a regional model at approximately 10 km resolution spanning the Northeast Pacific (NEP) (Hermann et al. in prep.). The NEP domain covers the area from the Baja Peninsula to the Bering Sea and from the coast out to 2,000 km offshore. One-way nesting of the models has been implemented using a hybrid of nudging and radiation approaches, as described in Marchesiello et al. (2001).

In our implementation, the NEP model receives its initial and lateral boundary conditions from prestored NPac model output. The NPac model was forced with coarse-scale COADS (Comprehensive Ocean–Atmosphere Data Set) winds and heat fluxes; the NEP model was forced with winds and heat fluxes from a regional atmospheric model (MM5), implemented at 15–45 km resolution (Bond et al. in prep.). The NEP model was also forced with freshwater runoff time series at the coast, as described in Hermann et al. (in prep.). Surface fluxes of heat and momentum are calculated from the National Center for Environmental Prediction using bulk

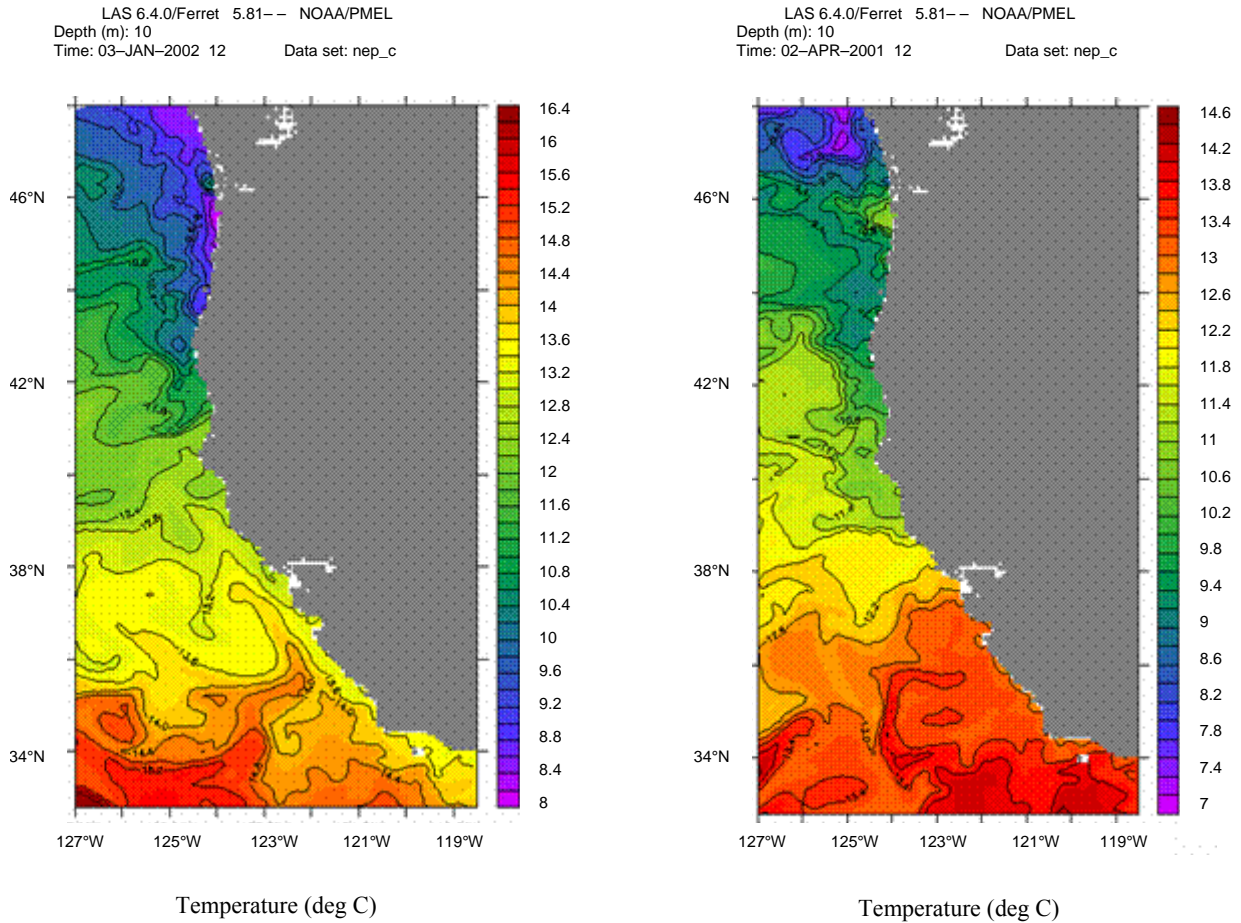


Figure 4. Seasonal salinity. These maps show seasonal shift in salinity from January to April in the California Current. This output was used to force the Atlantis model.

formulae, which include the instantaneous model sea surface temperature (SST). No tides are included in these simulations.

NEP hindcasts were generated for the period 1996–2003, and results stored as 3-day averages. These were interpolated onto the Atlantis model geometry, using the latitude-longitude coordinates of each box (or polygon). Velocities normal to each vertical face of the box, along with the mean salinity and temperature along each face, were then calculated from the stored NEP hindcast. These were interpolated in time onto 12 hourly values. We looped the 8-year oceanographic time series six times to span the 42-year run.

We forced the biology in Atlantis with the temperature and velocity fields from ROMS. We also imported the ROMS salinity fields, but salinity does not currently affect the biological model. Temperatures influence the respiration rates of each biological group, and each group also has a defined thermal tolerance and a narrower thermal range for spawning. Current velocities across each box face advect nutrients and plankton groups. This has a direct effect on nutrient (NH and NO) availability to primary producers, following Equation 2 above. Advected

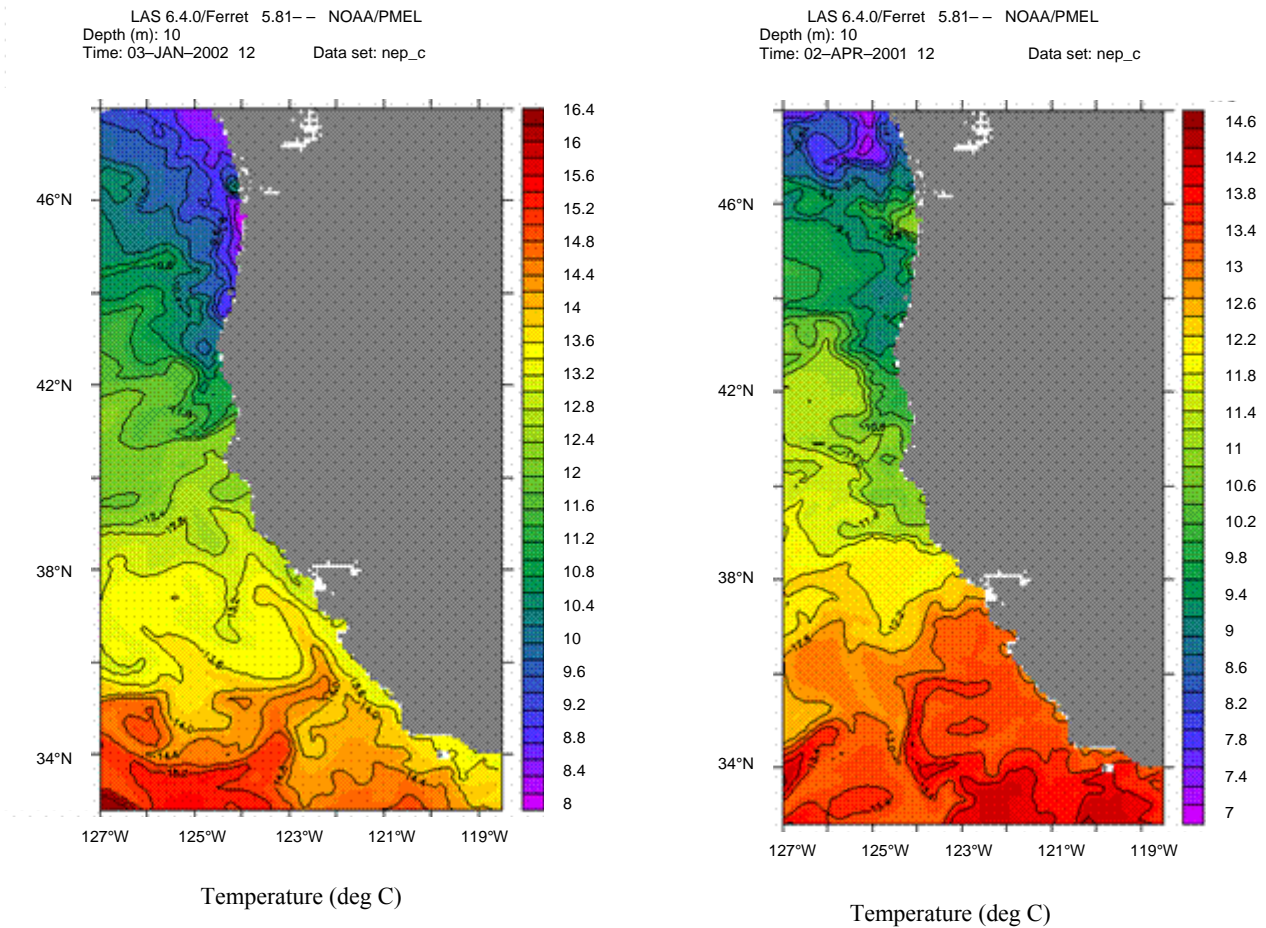


Figure 5. These maps show seasonal change in temperature from January and April in the California Current. This output was used to force the Atlantis model.

plankton groups include large and small phytoplankton and large, gelatinous, meso, and microzooplankton.

Data Sources

Model parameters are necessarily derived from a wide variety of sources, which are detailed in Appendix A. Briefly, fish life history parameters were primarily drawn from Love (1996), Love et al. (2002), Cailliet et al. (2000), or FishBase (Froese and Pauly 2005). Marine mammal life history parameters came from many sources, notably Carretta et al. (2005) and Perrin et al. (2002). Seabird life history parameters were drawn largely from Schreiber and Burger (2002) and Russell (1999). Species-level parameters were weighted by the relative biomass of those species to form life history parameters for the functional group (Tables 2 and 3). Species within each functional group have similar life histories, diets, and distributions. Invertebrate functional groups were fairly coarse, in some cases resolving phyla into one or two functional groups (Table 4). Fish, mammal, and bird functional groups generally contain 3–12 species.

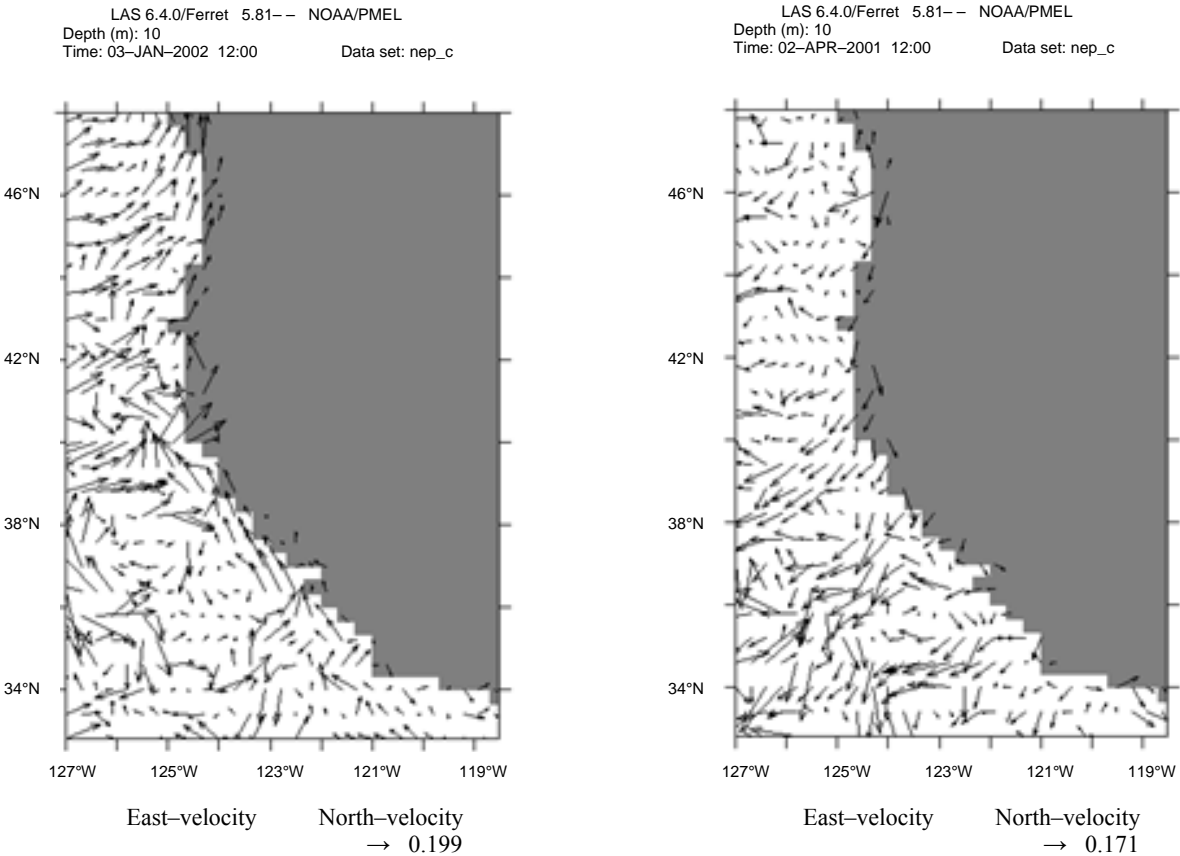


Figure 6. Seasonal vector velocity. These maps show seasonal change in vector velocity from January to April in the California Current. This output was used to force the Atlantis model.

Anticipating future model applications for fisheries management, we attempted to make finfish functional groups incorporate less than five species caught by similar gears. Modeling all species individually is impossible due to limitations in the current code implementation. However, in some cases we devoted a functional group to just one or a few species because of their importance to West Coast fisheries, (e.g., hake, sablefish), or due to their conservation importance (orcas).

Estimates of fish abundance rely on published stock assessments (primarily from 2003), or on two NMFS trawl surveys: the 1998–2002 NWFSC slope survey (Builder Ramsey et al. 2002, Keller et al. 2005, 2006a, 2006b) and the 2003 NWFSC “extended” shelf slope survey. Data for these surveys were extracted from the NWFSC’s West Coast Groundfish Survey Database on 28 December 2004. We adjusted survey catch by catchabilities recommended in Millar and Methot (2002) and Rogers et al. (1996). In cases where neither stock assessments nor reliable trawl survey data were available, we used estimates from Field (2004). Field’s estimates for these data-poor species involve top-down balancing of an Ecopath model, essentially estimating abundance of a functional group based upon the amount necessary to sustain its predators. Estimates of marine mammal abundance were taken from published stock

assessments (Angliss and Lodge 2004, Carretta et al. 2005). Seabird abundances were derived from Parrish and Logerwell (2001).

Atlantis allows two types of migration: small in-domain seasonal migrations and extensive out-of-domain yearly migrations. Seasonal migrations prescribe the proportion of each group's biomass in each spatial box during each quarter of the year. Yearly migrations describe the dates each species enters and leaves the model area, and the boxes through which they enter or exit. Functional groups including Pacific hake, albacore, small pelagic fish, most sea birds, salmon, and marine mammals demonstrate annual migrations in the model (Table 5). Yearly migrations also require parameters that represent the physical changes species experience outside of the area and these parameters are described in more detail in Appendix A.

Unlike models such as Ecosim (Christensen et al. 2000) or Multispecies Virtual Population Analysis (Sparre 1991), Atlantis does not directly incorporate information on observed diets. Instead we simply specify estimates of availability of prey to each predator (interaction parameter a , see tables in Appendix B), and then the proportion of each prey item in the diet is treated as an emergent property that dynamically responds to changes in predator and prey abundance. In the current parameterization, these availability parameters are converted to a Holling type II functional response, with gape limitation such that predators can only consume prey below a size threshold. For instance, for fish this was 40% of the predator size, and for birds 25%. Future work could involve calibrating the model to observed time series of diets from trawl surveys or other work.

Calibration

Model calibration currently involves trial and error, with the aim of finding parameter combinations that 1) allow all or most species to persist in the unfished scenario 2) predict unfished abundances within 50% to 200% of the unfished abundances estimated from stock assessments or monitoring (when available), and 3) predict vertebrate size-at-age within 50% to 150% of the size-at-age reported in the literature (when available). We calibrated the model manually, due to long model run times that prevent us from searching the parameter space with automated procedures.

For vertebrates, model calibration generally involved first modifying consumption rates, growth rates, and diet interactions (parameters C , g , and a in Equation 10 and Table 3) until predicted size-at-age matched expectations from the literature. We then compared predictions of population abundance to expectations from monitoring and stock assessments. In cases where predicted abundance was outside 50% to 200% of our expectation, we modified the strength of diet interactions (parameter a in Equation 10) and linear and quadratic mortality (parameters M_{lin} and M_{quad} in Equation 7). We generally did not alter the starting values for abundance or weight. The sources for our starting estimates of consumption, growth, and diets are detailed in Appendix A. Since much of our diet data was based on small sample sizes from limited geographic range, we treated these data as qualitative, simply beginning the calibration with diet interactions (variable a) that Fulton (2001) suggests roughly correspond with expected interaction strengths.

Calibration of invertebrates and primary producers involved modifying consumption rates, growth rates, and diet interactions (parameters C , g , and a in Equation 10, and μ in Equation 2) until predicted biomass was near our expectations from monitoring and stock assessments. If necessary we also invoked linear and quadratic mortality (parameters M_{lin} and M_{quad} in Equations 1 and 3). Table 4 illustrates how our parameters for invertebrate growth and consumption changed during calibration. In general, we increased consumption and growth rates, particularly for shrimp (PWN), squid (CEP) and zooplankton (ZL and ZM).

For primary producers, model calibration involved adjusting linear and quadratic mortalities (parameters M_{lin} and M_{quad} in Equation 1), growth rate (μ in Equation 2), and the strength of grazing (parameter a in Equation 10).

The diet interaction parameters (variable a) are a useful example of the calibration process, and generally required the most adjustment, both to achieve reasonable size-at-age and for reasonable population abundances. Tables B-1 through B-6 (Appendix B) show the final calibrated values for all diet interaction parameters, and Tables B-7 through B-12 show these calibrated values relative to our initial estimates. In general, we found that we needed lower values of variable a than other Atlantis models (e.g., Fulton 2004). This shift to lower consumption parameters is evidenced by the number of shaded cells in Tables B-7 through B-12. Overall, two patterns emerge from Tables B-7 through B-12: light gray columns indicating prey groups that initially experienced excessive predation, which we decreased during calibration; and dark gray rows indicating predators that were starving, for which we increased diet interactions (variable a) with prey. There were relatively few cases where predators grew excessively due to excessive predation, or where we chose to invoke additional predation to limit the abundance of a prey group.

Results

With no fishing, the model was able to recreate expected growth, abundance, and seasonal patterns for most functional groups (Figures 7 through 14).

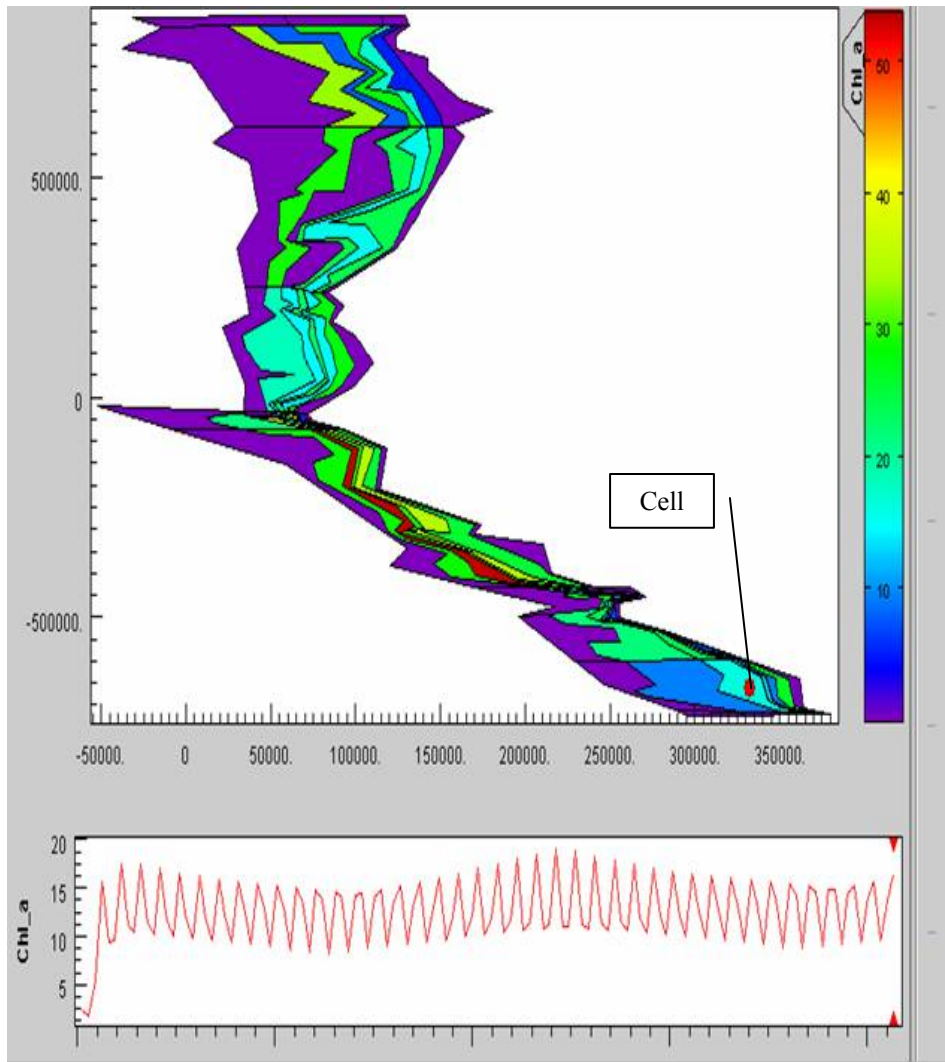


Figure 7. Spatial distribution of chlorophyll a in the surface layer (mg N/m³, 0-50m) at the end of a 42-year run. Each of the 62 spatial areas is colored proportional to chlorophyll a abundance; the region displayed is the same as in Figure 2 (Point Conception to the Canadian border). The bottom panel illustrates the abundance over time in one cell, the southernmost model area between the 200 and 550 m isobaths. Chlorophyll a integrates the abundance of picophytoplankton and diatoms. The annual oscillations are due to seasonal trends in light and nutrient availability.

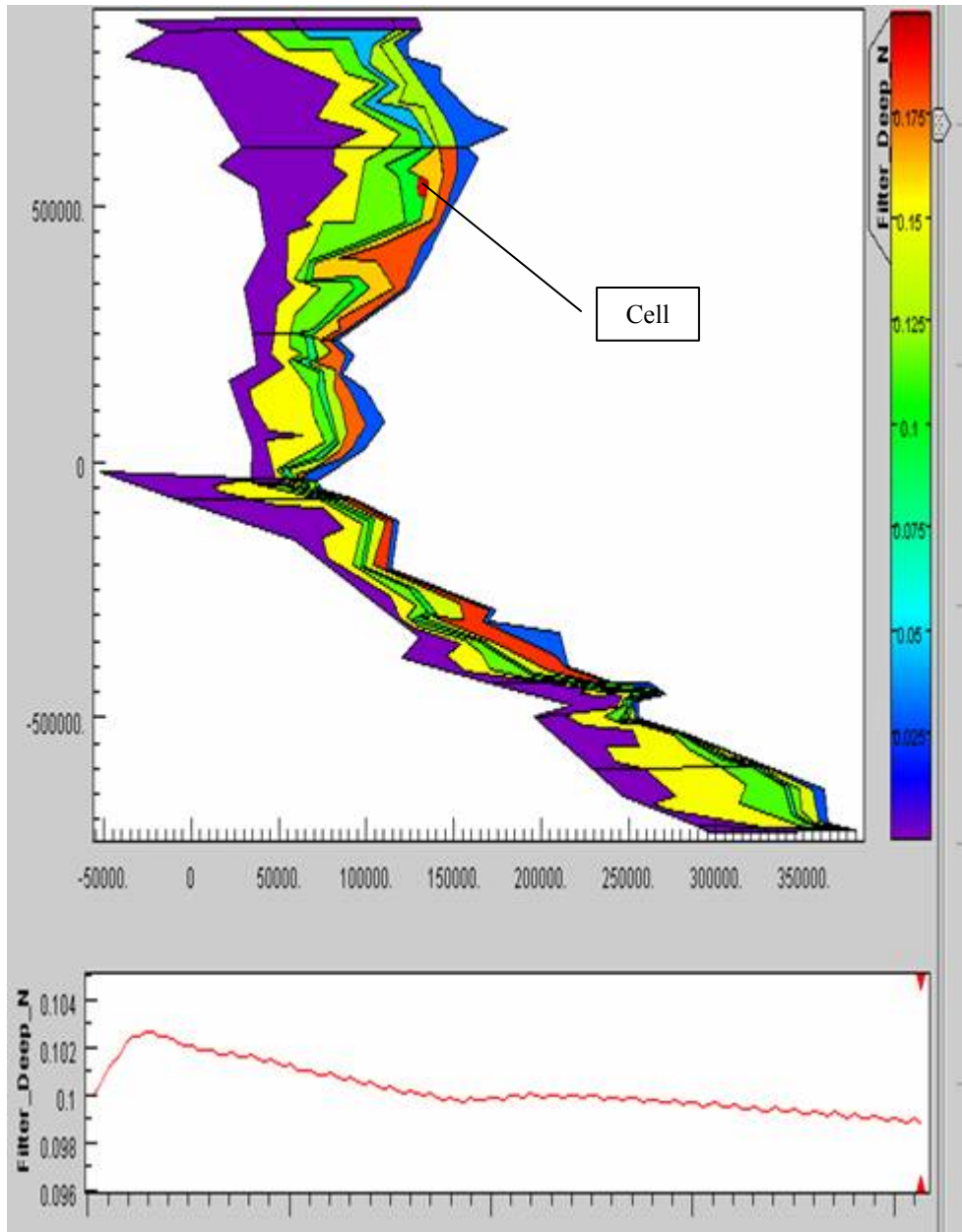


Figure 8. Spatial distribution of deep benthic filter feeders (BFD, in mg N/m²) at the end of a 42-year run. The bottom panel illustrates the abundance over time in one cell, a region off Oregon between the 150 and 200 m isobaths.

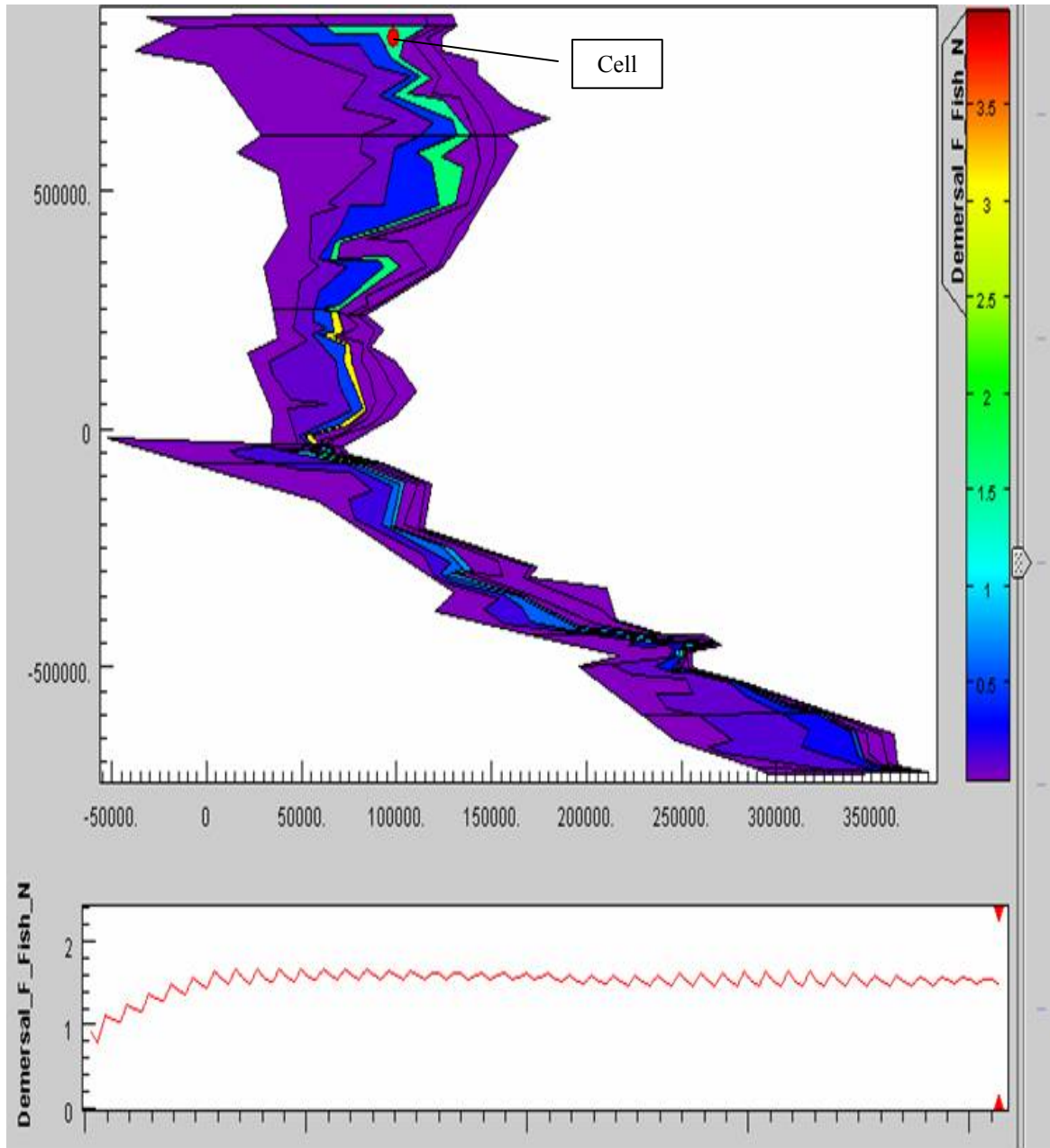


Figure 9. Spatial distribution of small flatfish, (FDF, mg N/m³) at the end of a 42-year run. The bottom panel illustrates the abundance over time in one cell, a region off Oregon between the 150 and 200 m isobaths. The annual oscillation is due to seasonal patterns of recruitment and growth.

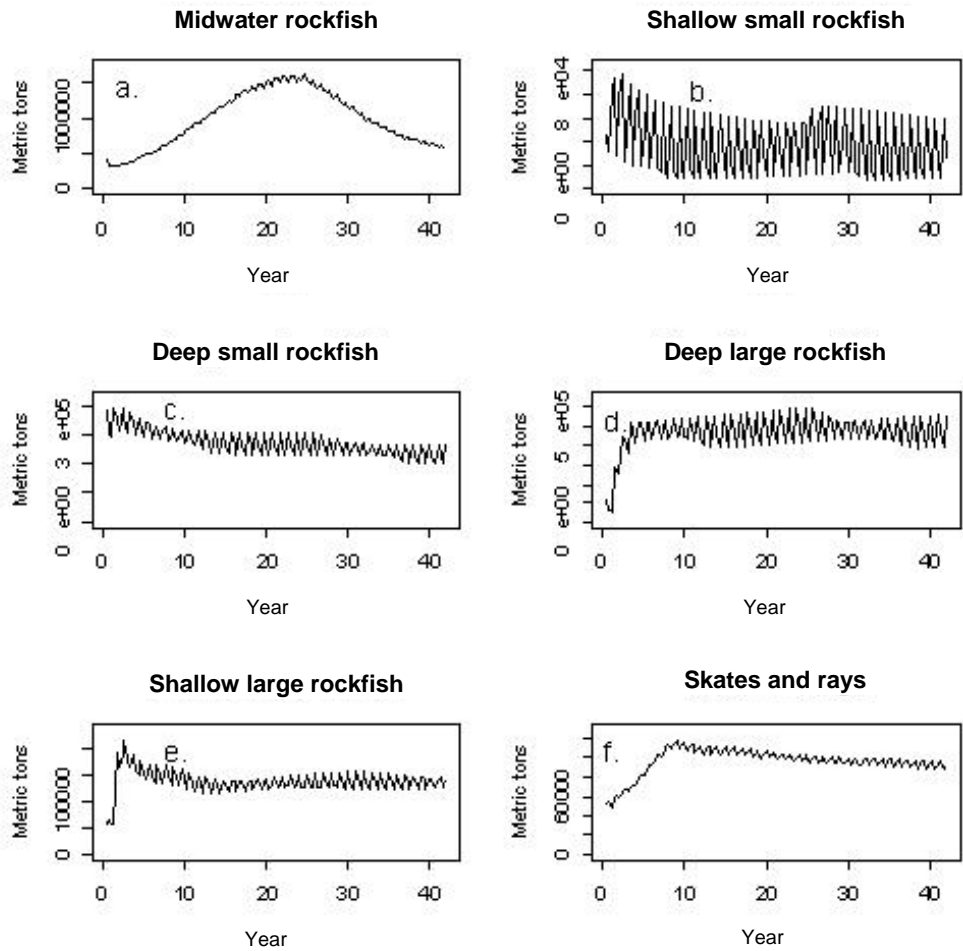


Figure 10. Abundance over the 42-year run for rockfish, skates, and rays spatially aggregated. The six groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m³ show the average concentration in the model region. Abundances illustrate the seasonal effects of recruitment and growth.

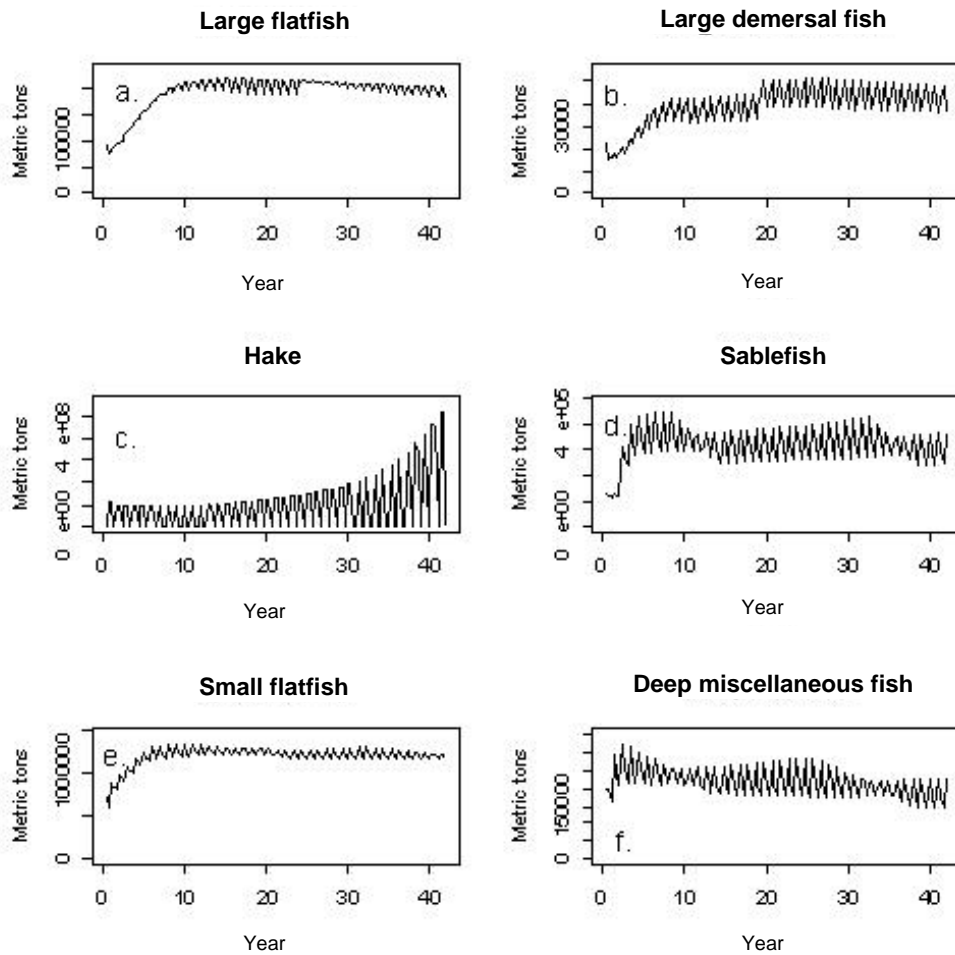


Figure 11. Abundance of groundfish over the 42-year run for six groundfish groups. Groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m³ show the average concentration in the model region. Abundances illustrate the seasonal effects of recruitment and growth. Migratory groups (hake) show additional variability because abundance outside the model region is excluded.

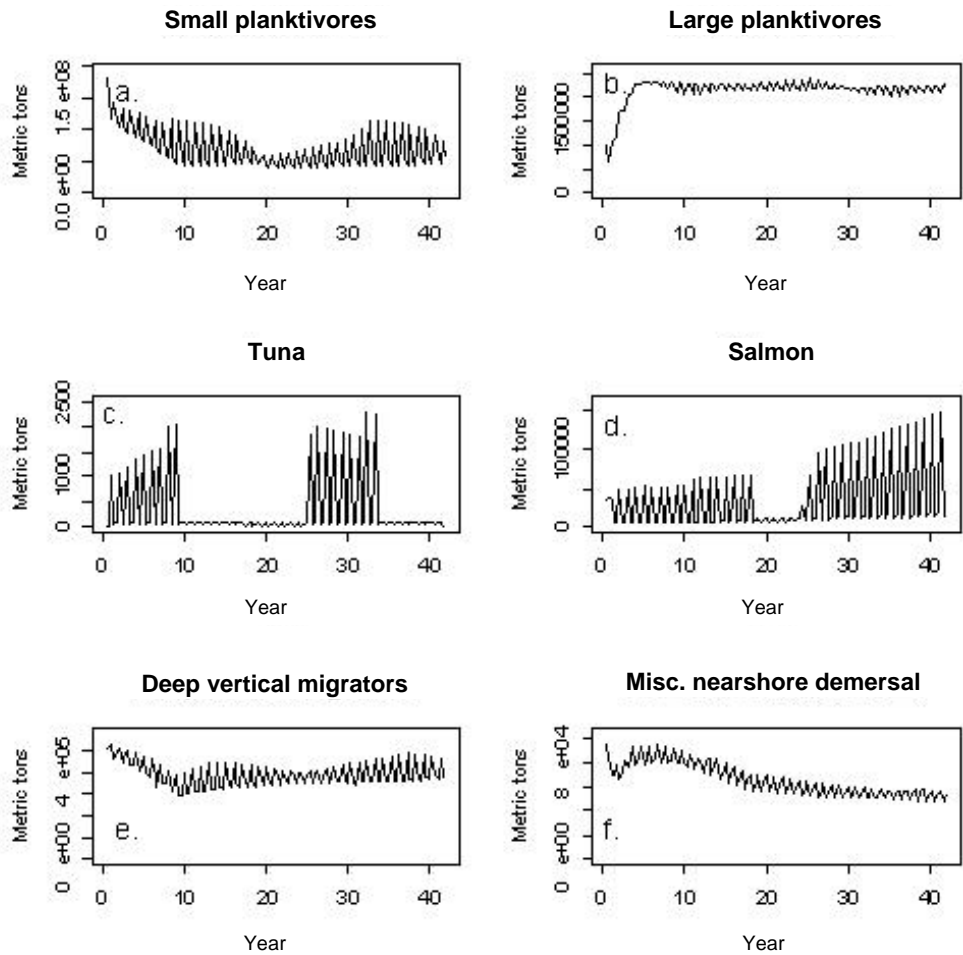


Figure 12. Abundance of six pelagic groups over the 42-year run. Groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m^3 show the average concentration in the model region. Abundances illustrate the seasonal effects of recruitment and growth. Migratory groups (small planktivores, tuna, salmon) show additional variability because abundance outside the model region is excluded.

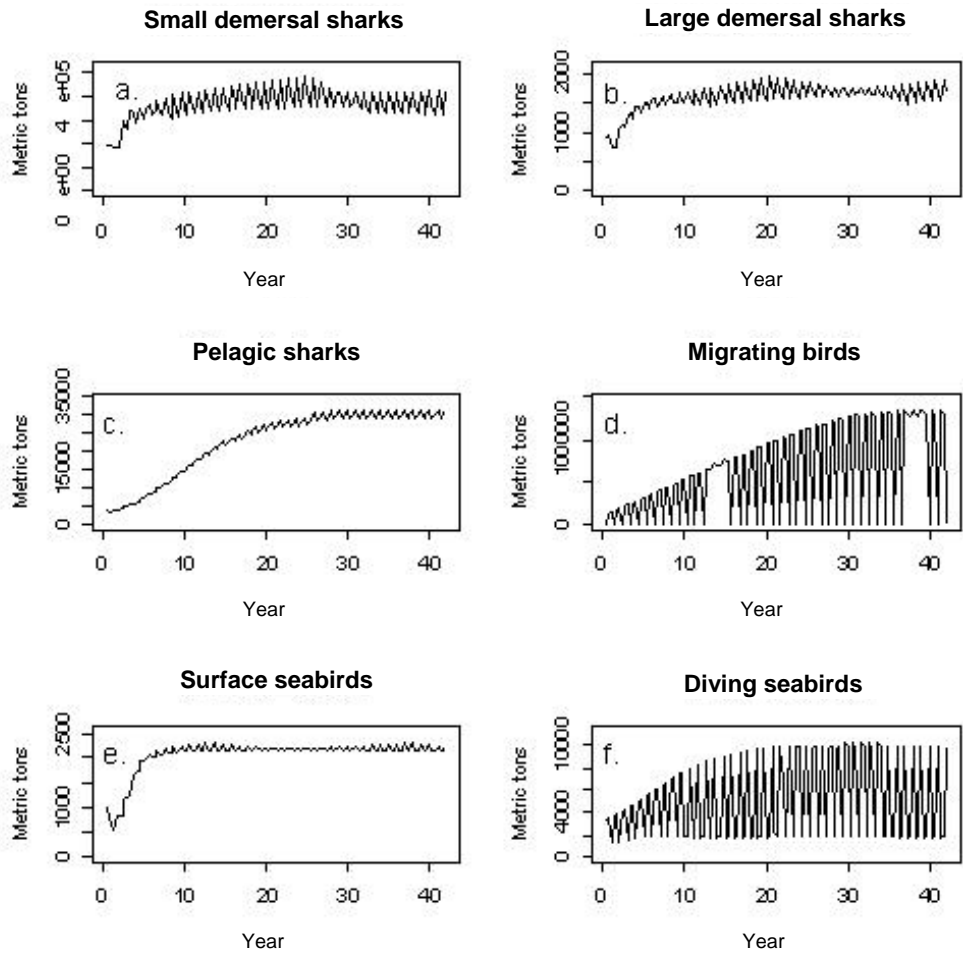


Figure 13. Abundance over the 42-year run for shark and seabird groups, spatially aggregated. The six groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m³ show the average concentration in the model region. Vertebrate abundances illustrate the seasonal effects of recruitment and growth. Migratory groups (migrating birds) show additional variability because abundance outside the model region is excluded.

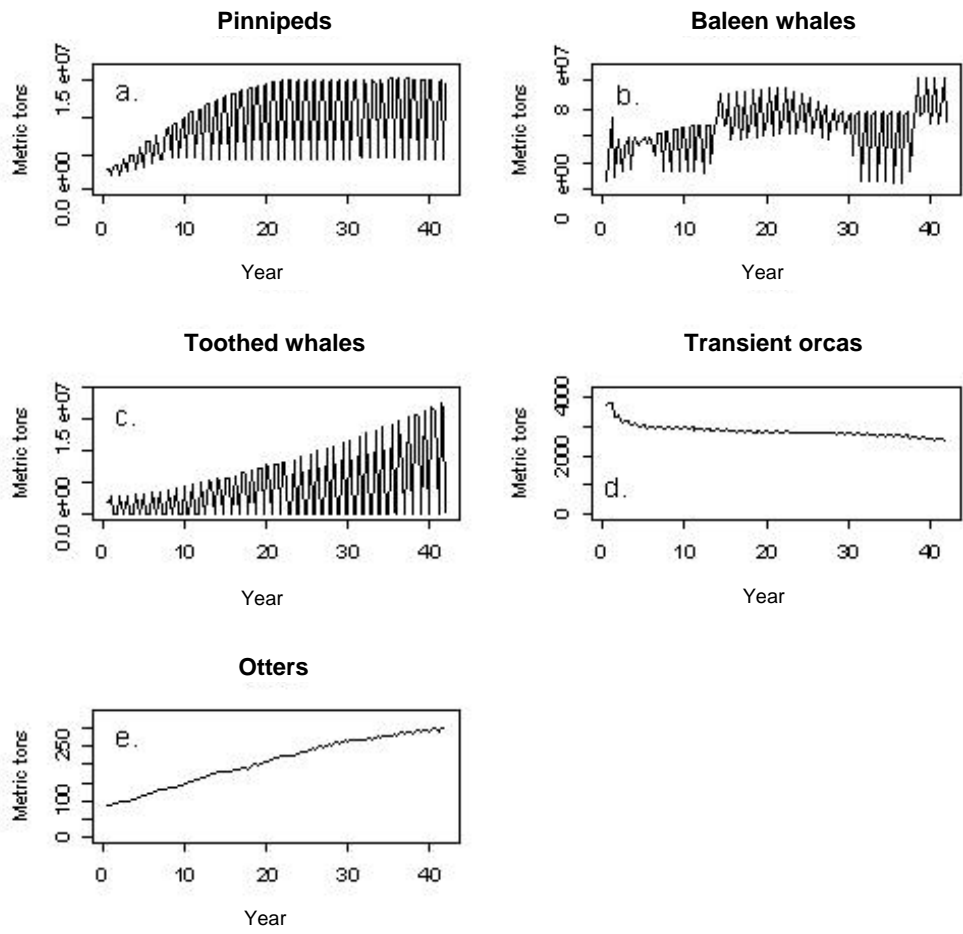


Figure 14. Abundance over the 42-year run for five marine mammal groups. Groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m^3 show the average concentration in the model region. Abundances illustrate the seasonal effects of recruitment and growth. Migratory groups (pinnipeds, baleen whales, and toothed whales) show additional variability because abundance outside the model region is excluded.

Abundance of large and small phytoplankton (Figures 7 and 15) fluctuated seasonally as expected, based on light intensity and nutrient availability driven by advection from the ROMS current fields. Seasonal mean phytoplankton abundance increased fourfold from our initial estimates, which were based on field observations from winter or early spring. This increase may in part be due to unrealistic levels of NH_3^+ and NO_3^- accumulation that probably released phytoplankton from nutrient limitation. Despite the fact that we looped the eight-year oceanographic time series, phytoplankton does not show a strong eight-year periodicity. Seagrass declined in abundance (Figure 16) due to light limitation, but adjusting the depth of seagrass upwards from the middepth of inshore boxes (25m) should address this issue.

Invertebrates lack age structure and therefore generally had smooth population dynamics (Figures 8, 17, 18, and 19). Zooplankton groups showed strong seasonal effects due to a strong trophic link with primary production. Most zooplankton groups also increased in abundance from our initial estimate, tracking the increase in primary producers. Of the zooplankton groups, relative abundance of microzooplankton increased the most, possibly because they experience little predation by vertebrate groups that increased during this unfished scenario. Benthos exhibited smoother dynamics that were less affected by seasonal variation in primary productivity. Deposit feeders (amphipods) and other filter feeders (barnacles [*Cirripedia* spp.] and bivalves [*Bivalvia* spp.]) went extinct due to excessive predation (probably excessive values of a in Equation 10). Similarly shrimp and shallow macrobenthos (octopus [*Octopoda* spp.]) declined to low levels of abundance as populations of their predators, such as finfish, increased.

Vertebrates showed strong seasonal changes in total biomass, due to annual recruitment, growth, and migration (Figures 9 and 10 through 14). Most vertebrate groups reached equilibrium levels of abundance by the end of the 42-year model run, with the notable exception of midwater rockfish, which experienced an increase in predation after year 25. The dominant trend was an increase in biomass from the initial conditions (\approx 1995–2005 abundance) due in part to the lack of fishing mortality. This was especially true for the rockfish, flatfish, and marine mammal groups, which are currently depleted. Recovery of depleted large rockfish was rapid (<10 years) relative to expectations (e.g., Parker et al. 2000), perhaps due to excessively high recruitment parameters (Figure 10). High recruitment in shallow small rockfish resulted in large intraannual fluctuations in total biomass of those groups.

Trophic effects were evident for some fish species, particularly forage species. Small planktivores (e.g., anchovies), deep vertical migrators (e.g., Myctophidae), and miscellaneous nearshore demersal fish (e.g., white croaker) declined in abundance, with fluctuations in this declining trend due to the abundance of their predators (Figure 12). Midwater rockfish (Figure 10) increased in abundance but then declined as predation mortality increased. Small deep rockfish (longspine thornyhead, Figures 10 and 11) declined in part due to an increase in abundance of their predator sablefish (Figure 11). Large demersal fish (lingcod, Figure 11) showed an increasing trend like most species recovering from depletion, but with a sharp increase in abundance at year 20 due to a drop in predation mortality.

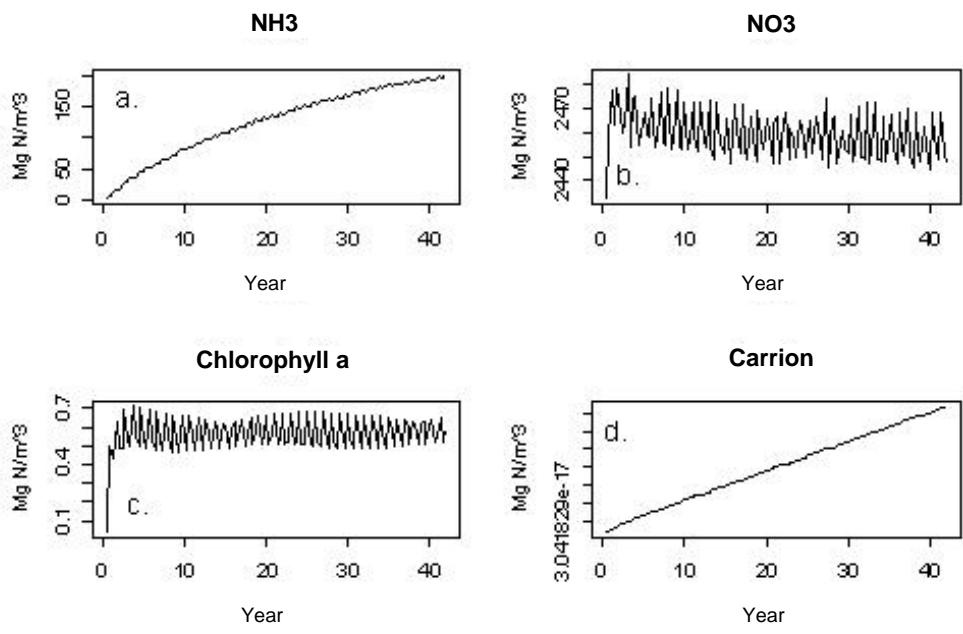


Figure 15. Abundance over the 42-year run for nutrients and carrion. Groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m³ show the average concentration in the model region.

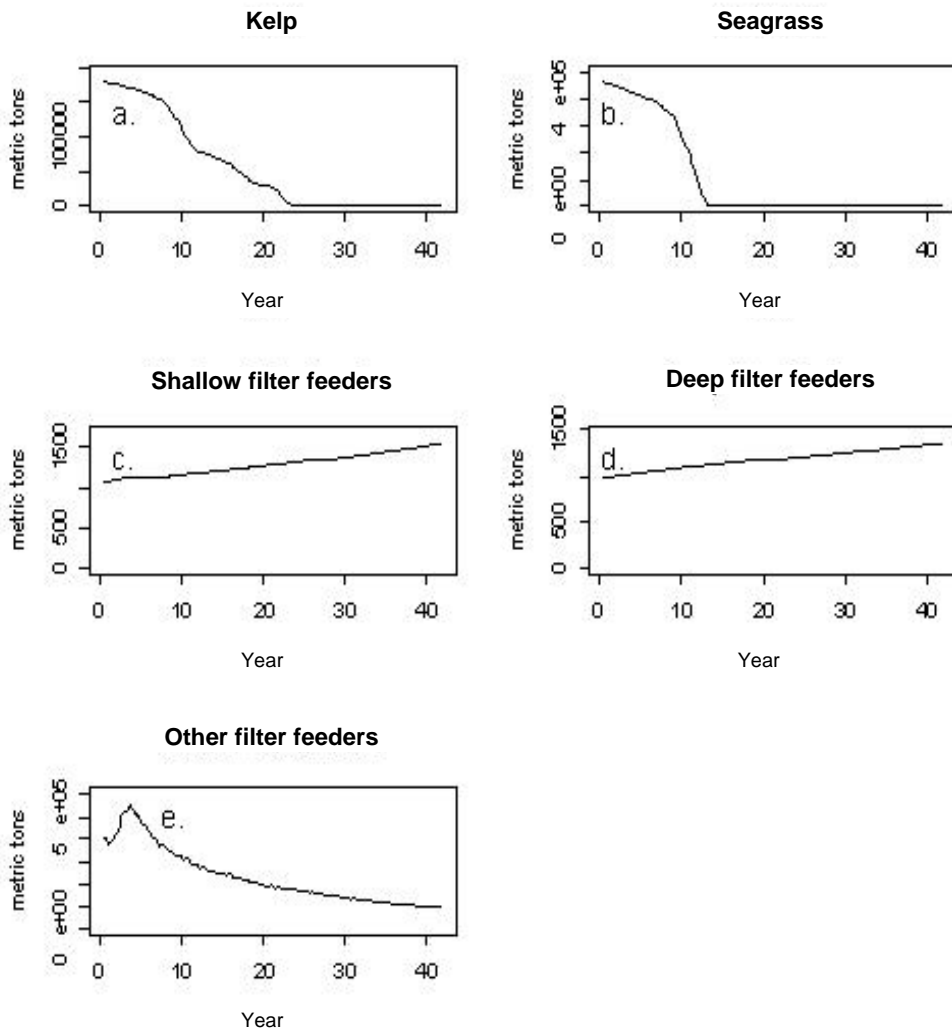


Figure 16. Abundance over the 42-year run for filter feeders, kelp and seagrass groups. Groups plotted in metric tons show the total abundance in the model region. The five groups plotted in mg N/m³ show the average concentration in the model region.

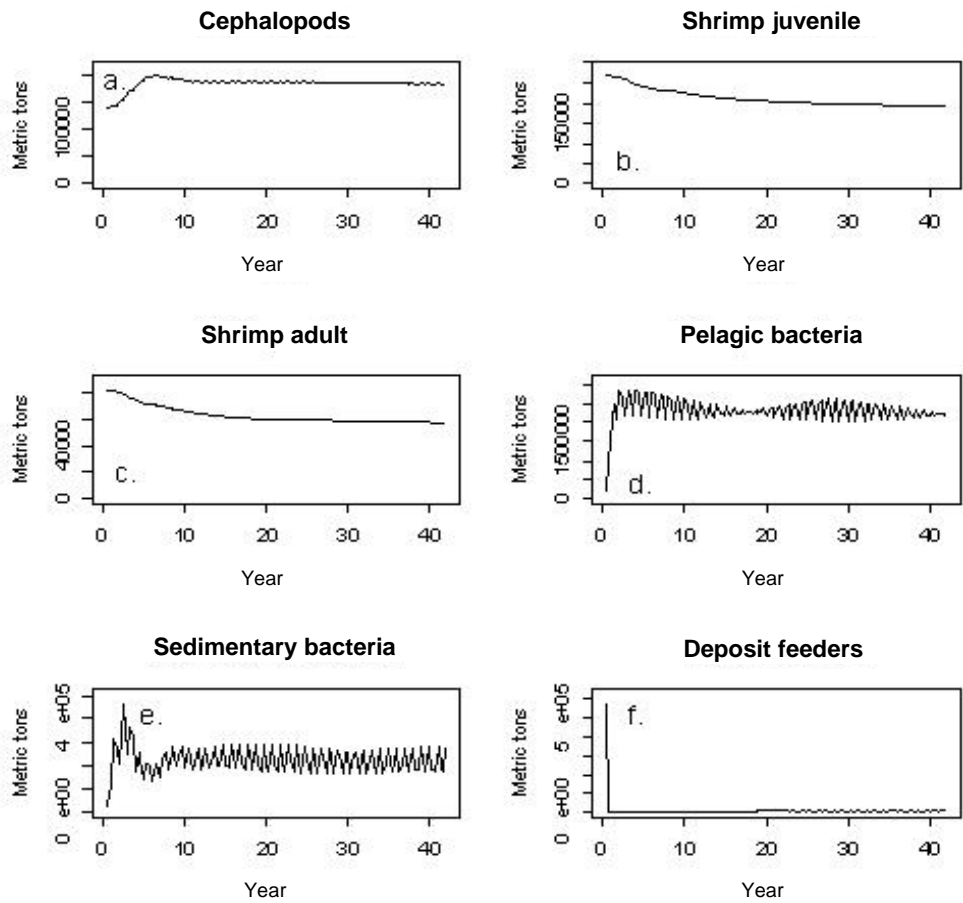


Figure 17. Abundance over the 42-year run for six invertebrate groups. Groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m³ show the average concentration in the model region.

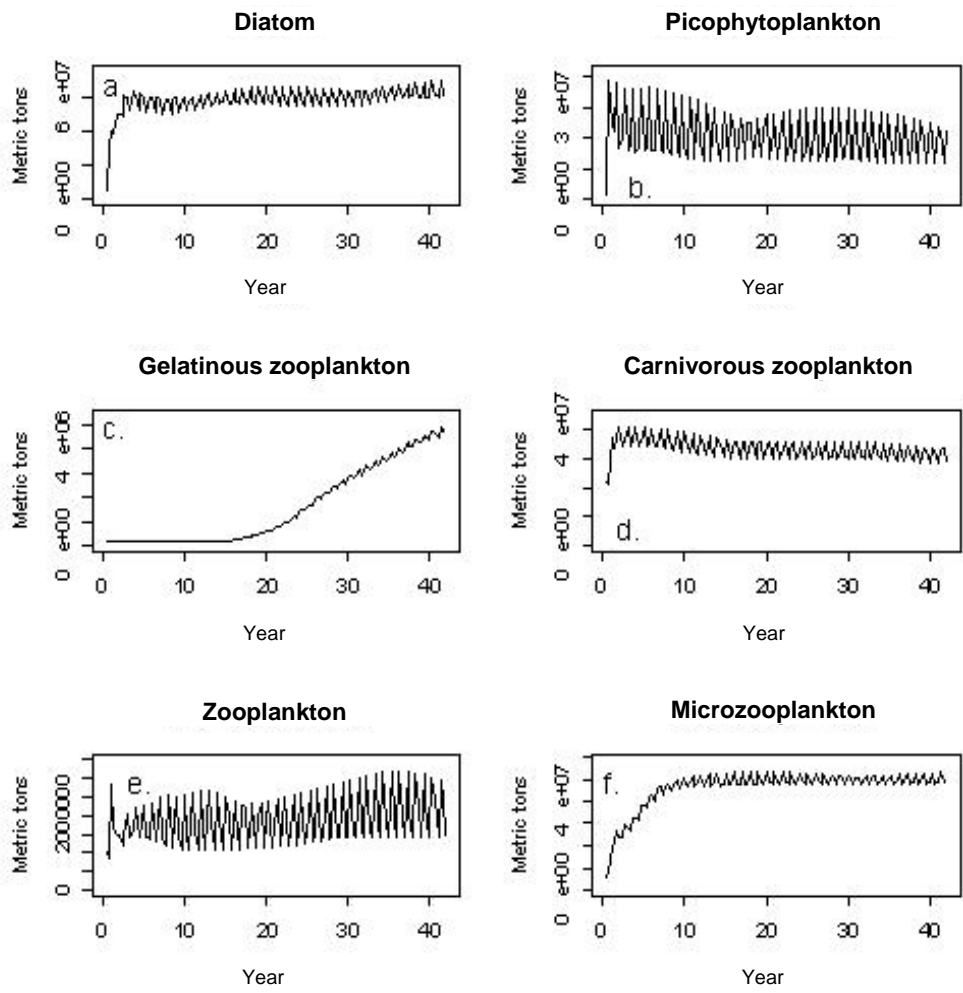


Figure 18. Abundance over the 42-year run for six plankton groups. Groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m³ show the average concentration in the model region.

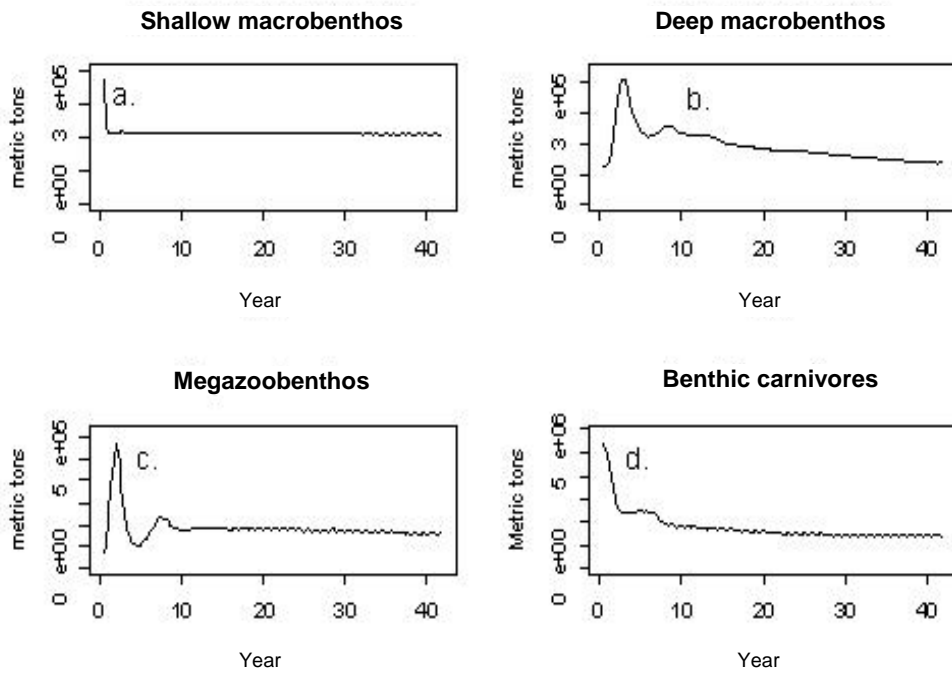


Figure 19. Abundance over the 42-year run for four benthic invertebrate groups. Groups plotted in metric tons show the total abundance in the model region. Groups plotted in mg N/m³ show the average concentration in the model region.

We compared predictions of unfished biomass (B_0) at the end of the 42-year simulation to estimates of unfished biomass available from stock assessments (Figure 20). We note that this “ B_0 ” value from assessments represents equilibrium biomass before fishing began, while the value from Atlantis is equilibrium abundance after a release from fishing; nonetheless, we would expect the two to be comparable. The models are also similar in that they currently assume fairly constant ocean condition through time. However, in 10 of 14 cases Atlantis predicts lower unfished biomass than single species models. In one case (transient orcas), the difference in abundance was four times, but typically the difference was 50% to 100%. These differences between Atlantis and single species models persisted, even though as part of the calibration process we attempted to bring Atlantis to the same equilibrium levels of abundance as predicted by single species assessments.

As noted above, this Atlantis model run includes an increase in the densities of primary producers to levels approximately four times higher than expected. If primary producer abundance were lower, Atlantis estimates of unfished vertebrate abundance would likely be lower, strengthening this trend of lower unfished abundance in Atlantis than in single species models.

In this unfished scenario, we expected seasonal abundance trends to clearly reflect the migrations specified in the input parameters. As expected, the model exhibited forced seasonal movement within the California Current as well as more extensive migrations that we imposed on migratory groups (Figure 10). For instance, hake exited the model in winter months, and returned in the spring (Figure 21). Salmon and albacore showed the correct seasonal pattern, but each showed periods of very low biomass for approximately 10 years.

Weight-at-age is dynamic within Atlantis, and is a useful check of whether parameters for consumption, growth, and reproductive costs are within a reasonable range. Weight-at-age has two components: reserve weight (muscle and fat) and structural weight (bones and hard parts). In Atlantis, reductions in reserve weight represent starvation due to insufficient maximum consumption rates, low prey abundance, low prey availability, or gape limitation. Structural weight will also decline if groups starve and fail to grow, but it is less sensitive to starvation than reserve weight. In this unfished scenario, weight-at-age of most groups stabilized over the 42 year run. No group suffered mortality directly due to starvation, but many groups exhibited lower than expected weights (Figures 22 through 26). This means through the course of the 42-year simulation, weight-at-age declined relative to our initial values, which derived from field studies. Rockfish and flatfish (Figures 22 and 23) generally only grew to about half the expected weights. Planktivores, tuna, deep vertical migrators, large demersal predators, and baleen whales all showed unreasonably low growth. Further calibration of diet, growth, and consumption parameters may resolve this.

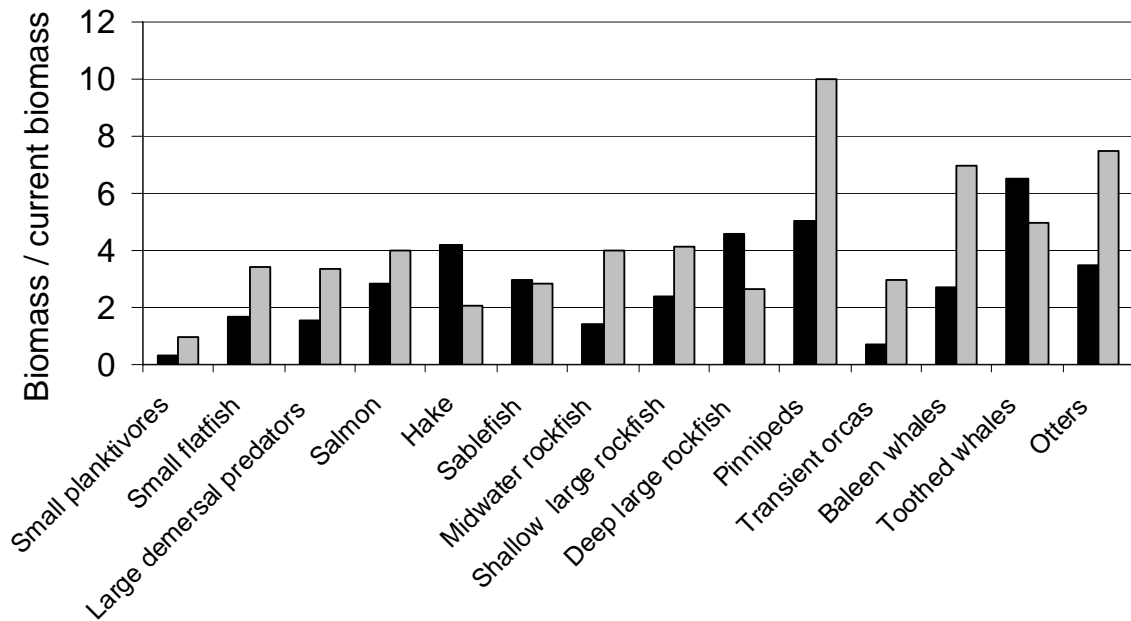


Figure 20. Unfished biomass relative to current biomass from Atlantis versus published assessments. Current biomass was used as the initial condition for Atlantis, and data sources are detailed in Appendix A. Black bars are the biomass predicted by Atlantis after 42 years without fishing. Gray bars are based on estimates of B_0 (virgin biomass) from the following assessments: small planktivores, Conser et al. 2003; small flatfish, Sampson and Wood 2001; large demersal predators, Cope et al. 2003, Jagielo et al. 2004; salmon, see FVB, Appendix A; hake, Helser et al. 2003; sablefish, Schirripa 2002; midwater rockfish, Hamel et al. 2003; shallow large rockfish, Ralston and Dick 2003 and Wallace et al. 2002; deep large rockfish, Piner and Methot 2001; pinnipeds, transient orcas, baleen whales, and toothed whales, Springer et al. 2003; otters, U.S. Fish and Wildlife Service 2003.

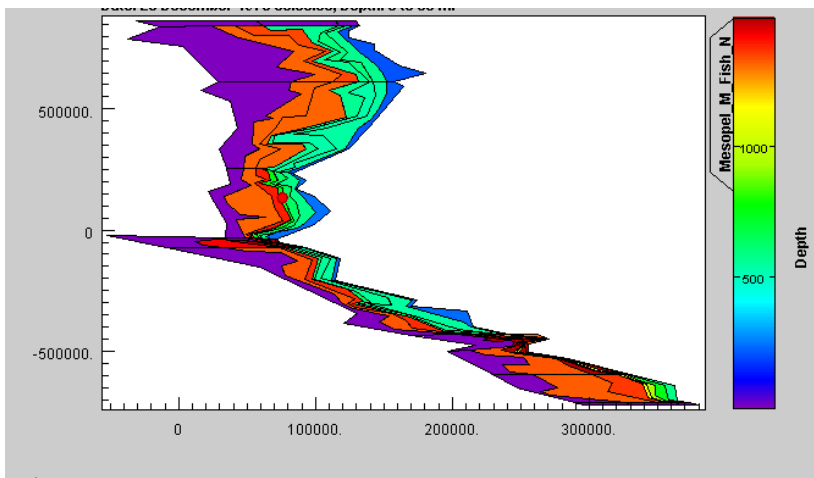
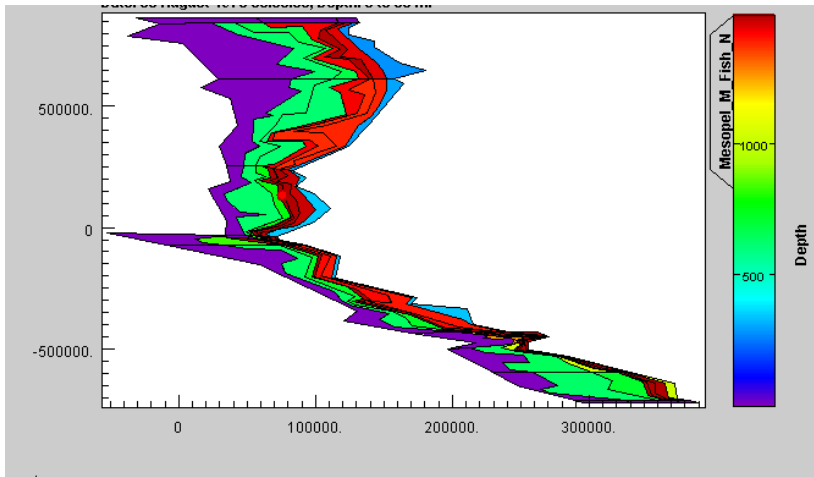
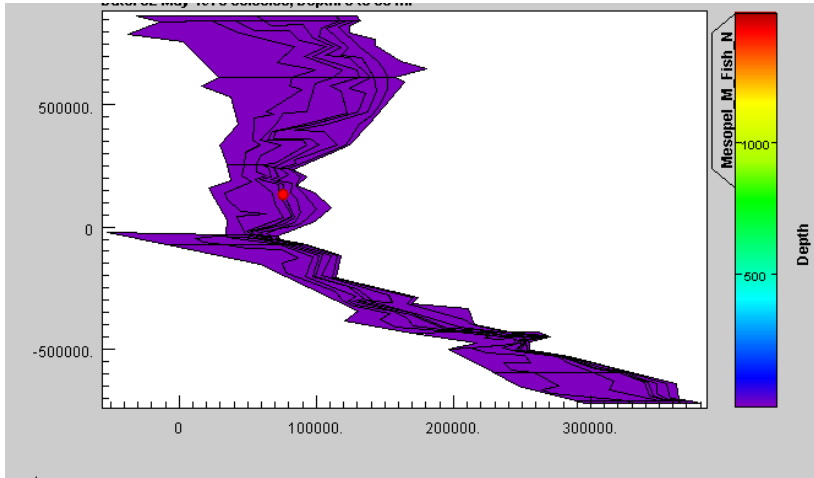


Figure 21. Seasonal distribution of hake biomass distribution displayed in winter, summer, and fall (top to bottom panels).

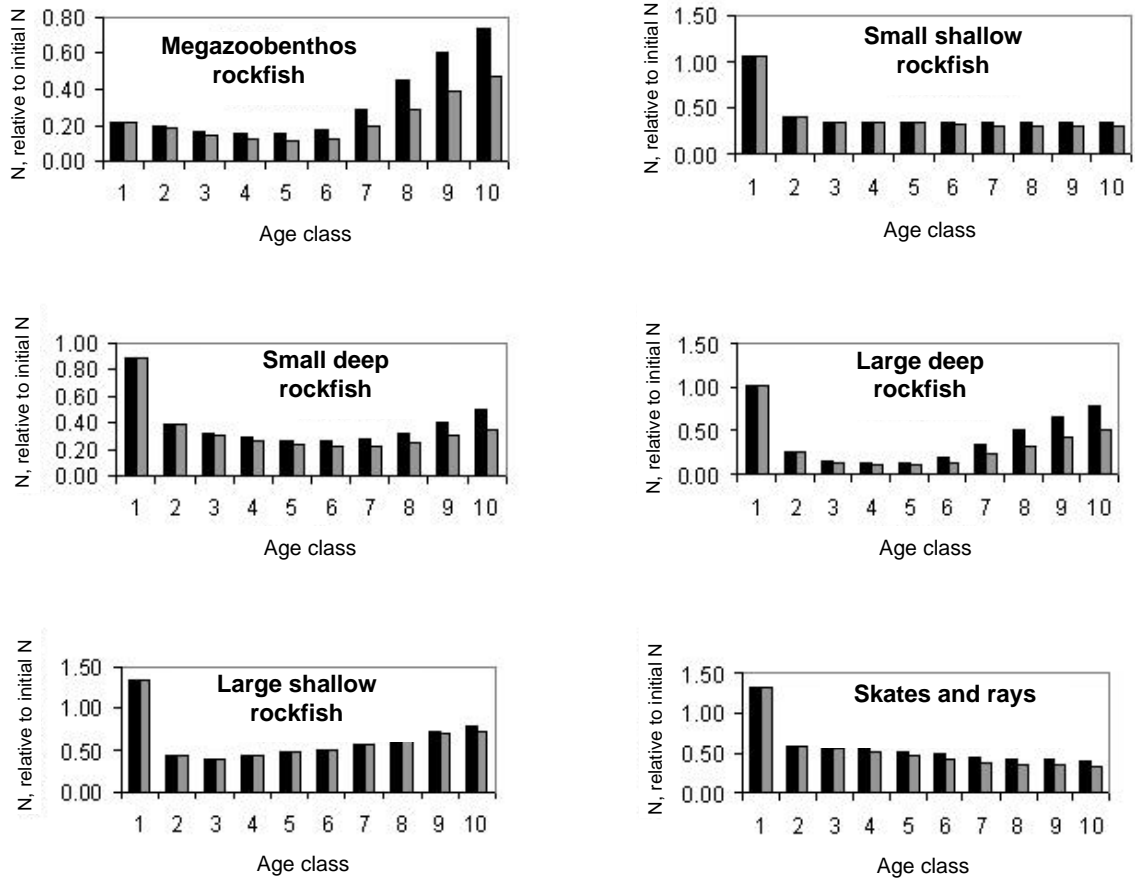


Figure 22. Change in reserve and structural nitrogen for rockfish and skates. Structural nitrogen (black bars) and reserve nitrogen (gray bars) for five rockfish groups and skates and rays, at the end of the 42-year unfished scenario relative to the initial values. Initial values derive from expected weight-at-age observed in field studies (from FishBase, see Table 3). Structural nitrogen represents bones and hard parts, and reserve nitrogen represents muscle and fat. All vertebrates contain 10 age classes. A decline in reserve nitrogen below a ratio of 0.8 is symptomatic of starvation, while ratios greater than 1.2 generally indicate excessive consumption.

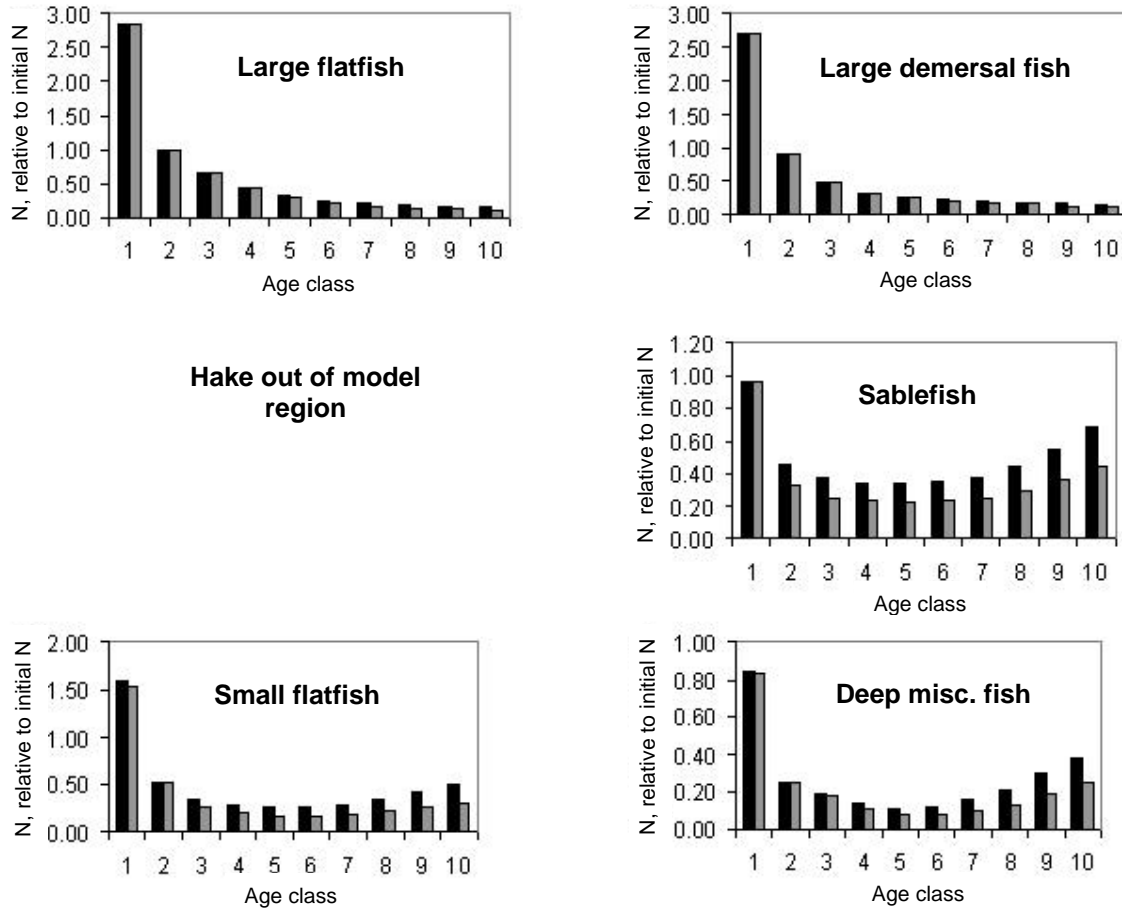


Figure 23. Change in reserve and structural nitrogen for other groundfish. Structural nitrogen (black bars) and reserve nitrogen (gray bars) for six groundfish groups, at the end of the 42-year unfished scenario relative to the initial values. Initial values derive from expected weight-at-age observed in field studies (from FishBase, see Table 3). Structural nitrogen represents bones and hard parts, and reserve nitrogen represents muscle and fat. All vertebrates contain 10 age classes. A decline in reserve nitrogen below a ratio of 0.8 is symptomatic of starvation, while ratios greater than 1.2 generally indicate excessive consumption. Hake were outside of the model, having migrated south of the model region, at the time point shown here.

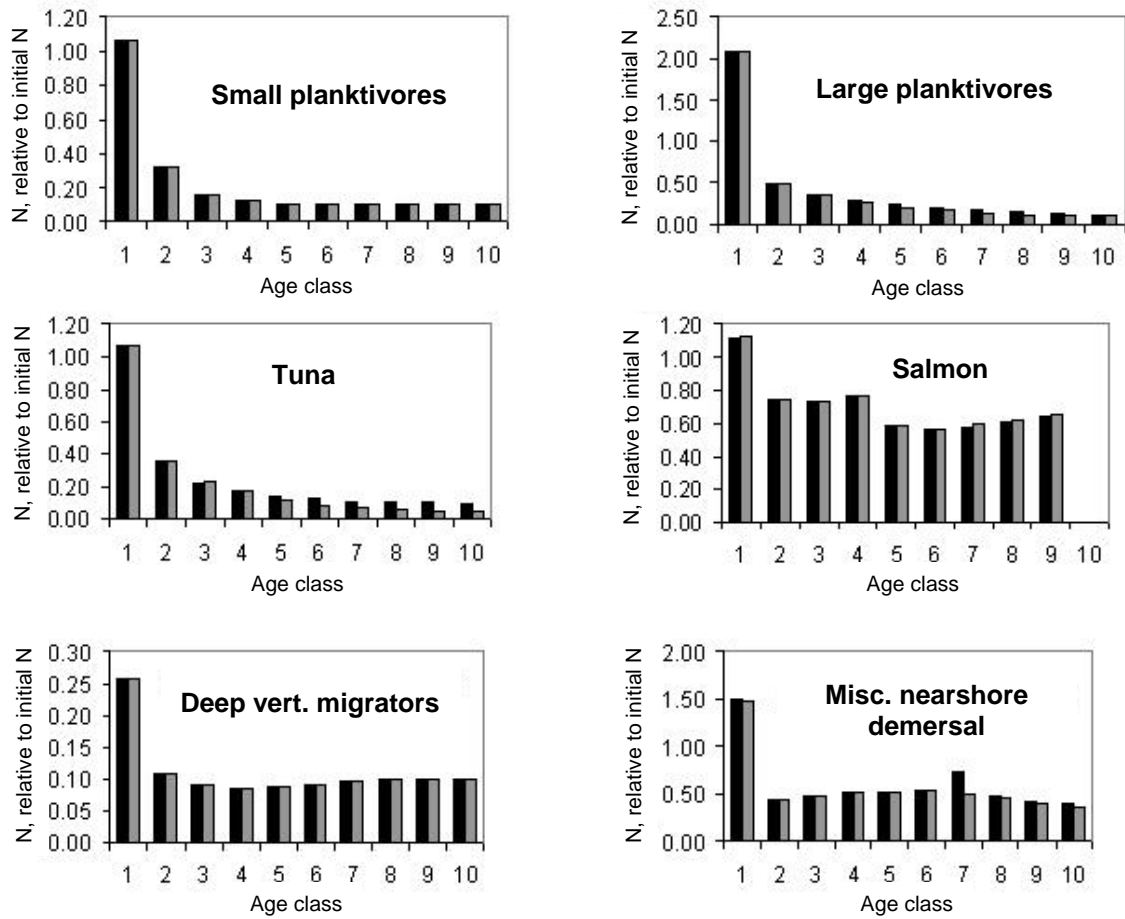


Figure 24. Change in reserve and structural nitrogen for pelagic groups. Structural nitrogen (black bars) and reserve nitrogen (gray bars) for pelagic groups, at the end of the 42-year unfished scenario relative to the initial values. Initial values derive from expected weight-at-age observed in field studies (from FishBase, see Table 3). Structural nitrogen represents bones and hard parts, and reserve nitrogen represents muscle and fat. All vertebrates contain 10 age classes. A decline in reserve nitrogen below a ratio of 0.8 is symptomatic of starvation, while ratios greater than 1.2 generally indicate excessive consumption.

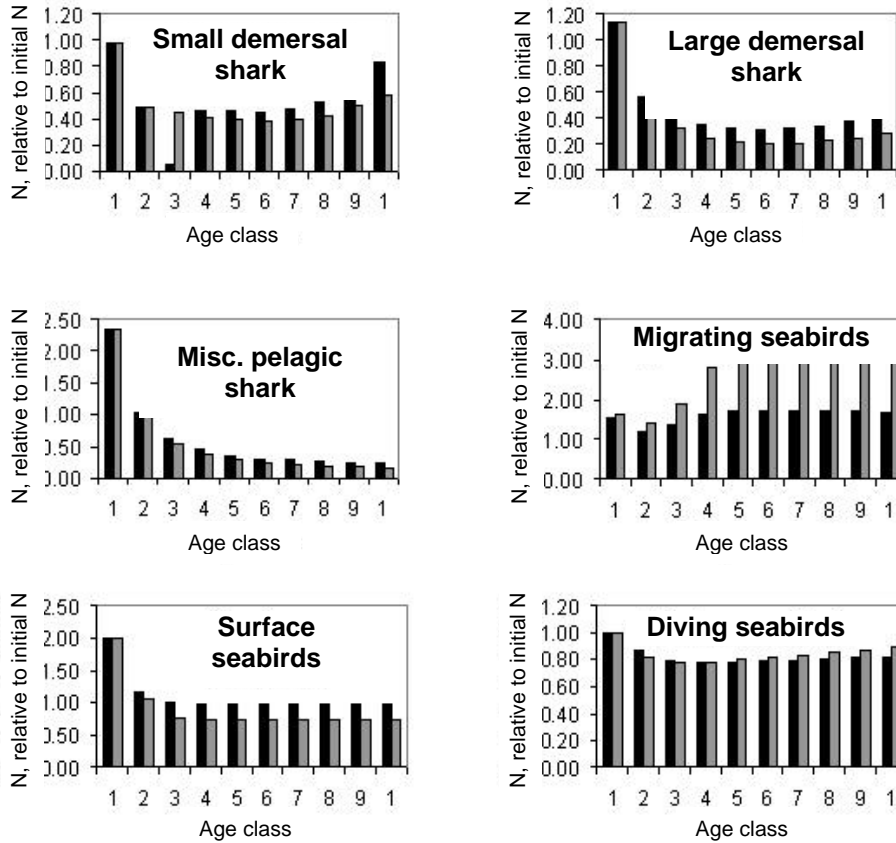


Figure 25. Structural nitrogen (black bars) and reserve nitrogen (gray bars) for shark and bird groups at the end of the 42-year unfished scenario relative to the initial values. Initial values derive from expected weight-at-age observed in field studies (from FishBase, see Table 3). Structural nitrogen represents bones and hard parts, and reserve nitrogen represents muscle and fat. All vertebrates contain 10 age classes. A decline in reserve nitrogen below a ratio of 0.8 is symptomatic of starvation, while ratios greater than 1.2 generally indicate excessive consumption.

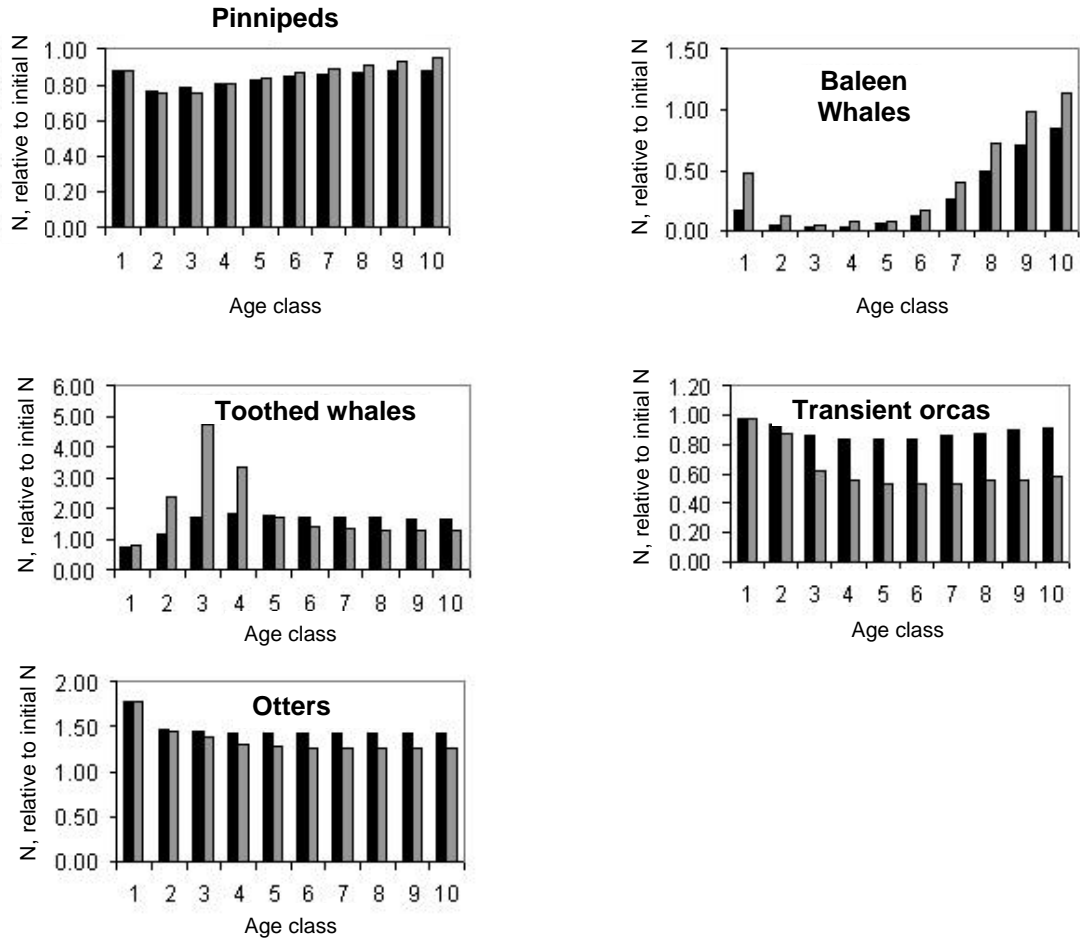


Figure 26. Structural nitrogen (black bars) and reserve nitrogen (gray bars) for marine mammal groups at the end of the 42-year unfished scenario relative to the initial values. Initial values derive from expected weight-at-age observed in field studies (from FishBase, see Table 3). Structural nitrogen represents bones and hard parts, and reserve nitrogen represents muscle and fat. All vertebrates contain 10 age classes. A decline in reserve nitrogen below a ratio of 0.8 is symptomatic of starvation, while ratios greater than 1.2 generally indicate excessive consumption.

Discussion

The full promise of this Atlantis model lies in its use for MSE, but parameterizing the ecology shown here forced a rethinking of many assumptions about the California Current ecosystem. For instance, large amounts of unexplained linear mortality on the large rockfish groups had to be invoked in order to keep their biomass near reasonable levels, until we realized that historically a large fraction of northern fur seals breed in Alaska waters but overwinter and feed in the California Current. Their diet in Oregon and Washington includes rockfish as a major prey item (Ream et al. 2005). Including these migratory fur seals in our model, with rockfish in their diets, allowed us to reduce the linear mortality term for large rockfish.

A second example of this type of learning through parameterization occurred as we tuned predator-prey availability parameters. Overall we found that the model came closest to matching expected unfished biomasses (Figure 27) when we used fairly low availability parameters. Substituting higher availability parameters from the southeast Australia Atlantis model led to extinction of many species. This could simply be a model parameterization artifact or a real difference regarding bottom habitat and refuges from predation. We also found that many of our initial vertebrate consumption rates were much too low, leading to insufficient growth (i.e., weight-at-age below estimates from field and laboratory aging analyses). This was addressed by switching from using consumption to biomass estimates from Ecopath models, to consumption rates predicted by von Bertalanffy growth rates and an assumed assimilation efficiency.

Finally, similar to other Atlantis modelers, we have struggled to parameterize the model in a way that keeps shrimp abundance above a small fraction of current abundance. We believe this lends some evidence to support the hypothesis of predator control of shrimp populations (Worm and Myers 2003). Here in our unfished scenario, hake, which are a major shrimp predator, increase in abundance by four times. We view model building with Atlantis as a useful way to generate hypotheses about how the ecosystem functions, and to synthesize data that allow us to look for evidence regarding existing hypotheses.

The results from the final parameterization of the unfished scenario shown here are generally consistent with the biological interactions predicted by Field (2004) and Field et al. (2006), who fit a spatially-aggregated Ecosim model to data from the California Current. Both models demonstrate that fishing mortality is the major driver of most finfish populations, with strong recovery in the unfished Atlantis model, comparable to the strong declines due to depletion in the Ecosim model with fishing. In both models, trophic interactions are a secondary effect after fishing, but are generally stronger for forage species. Both models saw strong effects of predation by hake on shrimp and by sablefish on small deep rockfish (thornyhead). In part the similarity between models is expected, because here we relied on many parameter estimates from the Ecosim model. However, the commonalities between the two models suggest that these results are at least not artifacts of structural assumptions in the models. Comparative analyses across models and across ecosystems are a promising area of future research.

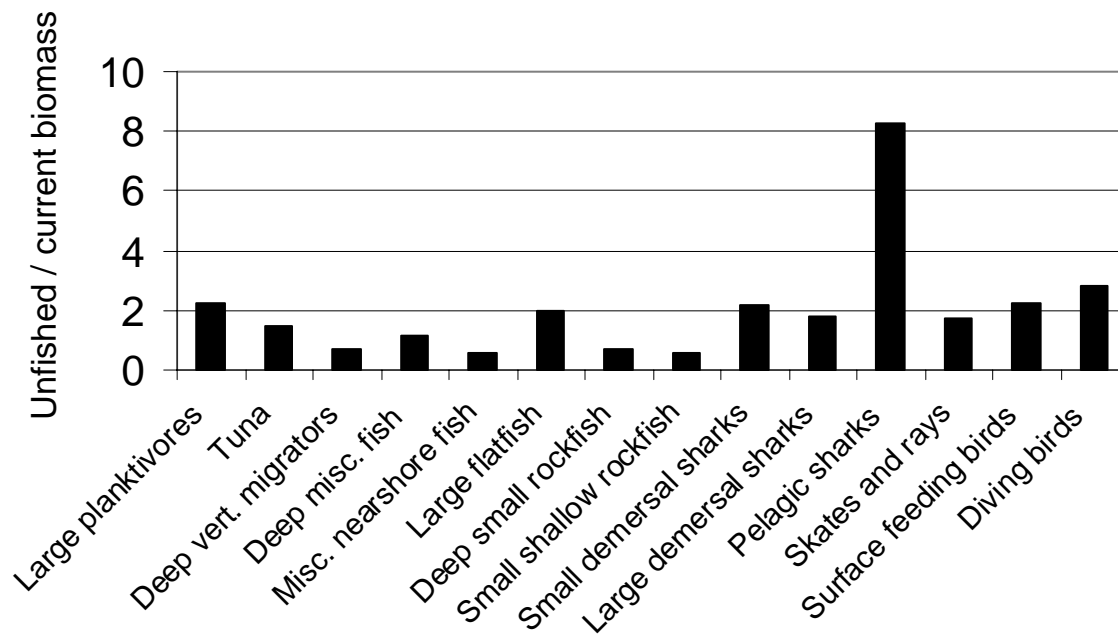


Figure 27. Biomass predicted by Atlantis after 40 years of no fishing, relative to current (≈ 2006) biomass. Current biomass was used as the initial condition for the start of the 42-year simulation. These species or functional groups are not assessed, so Atlantis estimates of unfished abundance are not compared to estimates of the assessments.

Unlike the Field et al. (2006) Ecosim model, the Atlantis model so far seems less sensitive to interannual fluctuations in climate. Field et al. (2006) found that forcing their model with top-down or bottom-up climate forcing improved model fits to data. The Atlantis model showed seasonal patterns of productivity, but no obvious interannual fluctuations. Including a longer time series of oceanographic forcing into Atlantis, including data prior to 1996, may capture some of the PDO climate signal that appears important in the Ecosim model. We expect this signal will be most easily detected in zooplankton, since in the unfished scenario they show the strongest response to seasonal changes in phytoplankton.

Ongoing work with the California Current Atlantis model will focus first on including historical fisheries catches, then on including fisheries fleet dynamics calibrated to match historical catches. Previous work with multispecies simulation models suggests model behavior must be constrained by calibrating the models so that population dynamics match trends in abundance observed in surveys or predicted by assessments (Cox et al. 2002).

Further calibration will strengthen comparisons such as that shown here between predictions of unfished biomass in Atlantis vs. single species models. Walters et al. (2005) showed that a series of ecosystem models predicted lower maximum sustainable yield than single species models. Fishing at rates predicted by single species models to give maximum yield would lead to overfishing in the ecosystem model. We hope to be able to use the California Current Atlantis model to make robust conclusions about reference points such as B_0 and maximum sustainable yield. Here we showed that for 10 of 14 functional groups, Atlantis

predicted less of a recovery of depleted stocks than did single species models. We expect that this pattern will hold true as we further develop this comparison, since the ecosystem model imposes realistic carrying capacities due to food limitation and predation that are not explicitly included in single species assessments.

The California Current Atlantis model is intended as a strategic MSE tool to identify tradeoffs between species, fleets, and management goals, and to identify effects of management policies. It is not intended for tactical management, for instance, setting annual quotas for target stocks. Instead we will use this Atlantis model to evaluate how management strategies, such as new ways of conducting stock assessments or limiting fishing effort, perform when faced with a realistic ecosystem that includes trophic effects and climate. Although the Atlantis model only qualitatively matches the ecosystem dynamics of the real world, like the real world it contains more ecological complexity than assessment or management models, and does not follow the same underlying equations. We can expect that management strategies that fail when applied in Atlantis will also fail in the real world.

Our work with this biological and oceanographic model has revealed several limitations in the model framework (Atlantis), the data, and our results to date. A few prominent limitations to the Atlantis framework include: 1) a lack of an “accounting” step before the model begins the dynamic simulation, so that the model must be run for minutes to hours before users identify gross misparameterizations that lead to extinction or excessive population growth; 2) the use of predator/prey interaction parameters only, rather than explicit input of diet data; 3) growth that can deviate radically from expected von Bertalanffy age-weight relationships, if consumption parameters are incorrect; and 4) the time-intensive process of parameter input and model calibration. Future programming efforts will address these issues. Data limitations include a lack of full spatiotemporal data for almost all functional groups; a lack of reliable biomass estimates for some groups, particularly invertebrates and benthos; and a lack of reliable diet data for many functional groups. Other difficulties with data are listed in Appendix A.

Key problems with the output include: 1) poor growth of planktivores, large demersal predators, tuna, deep vertical migrators, and baleen whales; 2) excessive recruitment leading to extremely rapid recovery of depleted groups such as large deep rockfish, and excessive intra-annual variation in the abundance of other groups such as small rockfish; 3) extinction of sea grass, shallow filter feeders, and deposit feeders; 4) accumulation of NH_3^+ and NO_3^- ; and 5) periods of very low abundance for salmon and tuna, two of the migratory species. We will attempt to resolve these behaviors as we further develop the California Current Model and calibrate it to historical data.

Despite the need for further calibration and the addition of fisheries information, we believe that the California Current model will be a useful tool for MSE for U.S. West Coast fisheries. The model synthesizes biotic and abiotic information from a variety of sources, and in the near future we will integrate this into the full MSE framework available in Atlantis. In this framework we can test harvest decisions, assessment techniques, and the utility of new and ongoing ocean monitoring programs. A similar model for southeast Australia has been used for more than five years, first to identify ecological indicators for fishery management, and now as a policy screening tool in the current restructuring of Australia’s southern federally managed fisheries. An additional advantage of the Atlantis modeling approach is that it can easily be

modified to nest fine-scale models within a coarser coast-wide model. We anticipate using this approach in central California to consider local ecological processes and management topics. Finally, on the level of basic ecological research, we have found that model outputs serve as hypotheses about the responses of species to changes in climate and management, and we expect that this will stimulate field research and collaboration.

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Appendix A: California Current Model Documentation

Benthic Habitat and Sediment Type

Habitat type and sediment classification are represented in Atlantis by proportional coverage within each spatial box. Sediment is classified as either soft or hard, and biogenic habitat as kelp, seagrass, or neither. This information is used in conjunction with functional group preference to regulate species movement within the model domain.

We derived habitat and sediment coverage from the groundfish Essential Fish Habitat Environmental Impact Statement (EFH EIS) data (NMFS 2004). These data are a compilation of survey data taken by several state, federal, and private organizations in Washington, Oregon, and California at different periods of time, and provide the most comprehensive habitat list available. We used Arcview GIS software (ESRI, Redlands, California) to calculate the coverage of each habitat and sediment type within each box.

Studies relating spatial coverage to biomass density enabled the conversion of the EFH EIS spatial coverage of kelp and seagrass data into biomass estimates, required by Atlantis. The estimates of biomass per unit area from beds of giant kelp (*Macrocystis integrifolia*) and bull kelp (*Nereocystis leutkeana*) from central California to Vancouver Island are summarized in Coon et al. (1981), Barns and Kalvass (1993), Sutherland et al. (1995), and Fox et al. (1999). Biomass density of seagrass was based on measurements of eel grass (*Zostera marina*) by Ruesink et al. (2006) in Willapa Bay, Washington. Biomasses of kelp and seagrass were converted to mg N per unit area using nitrogen content measurements.

Nutrients, Salinity, and Dissolved Oxygen

The ROMS model and Atlantis generate dynamic nutrient, salinity, and dissolved oxygen concentrations, but we also collected field observations of these quantities as initial conditions and for calibration purposes. Initial nutrient concentrations (dissolved inorganic nitrogen and silicate), salinity, and dissolved oxygen were largely derived from measurements at multiple depths collected on GLOBEC sampling cruises between 1997 and 2004 (Wetz et al. 2004); California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises from 2000 to 2004 (CalCOFI 2007); and cruises and mooring buoys in Monterey Bay, California (Bruland et al. 2001).

These efforts covered the region from the southerly boundary to lat 44°65'N, and in waters from coastal areas to our model boundary boxes. For regions outside of the area described above, we used data from Whitney and Freeland (1999), Hickey and Banas (2003), and the Line P long-term data collected off the British Columbia coast (Robert 2007). We focused on values from winter or early spring sampling periods because Atlantis takes initial

concentrations of nutrients and other solutes, assumed to occur on January 1 of the model year, then calculates subsequent fluxes of materials based on physical forcing, biological uptake, and recycling.

Iron data were considerably scarcer than data for other nutrients. Most dissolved iron data were taken from Chase et al. (2002), with additional data derived from Johnson et al. (1997), and Bruland et al. (2001). Sediment iron concentrations were assumed from Johnson et al. (1997).

We assumed that nutrient input from terrestrial sources, via river outflows, was negligible. This assumption may be faulty, particularly in coastal and shelf regions near major human population centers or in the northern portion of the model domain where river inputs are highest. For example, San Francisco Bay is a source of nitrate and silicate to coastal waters under some climate conditions (Wilkerson et al. 2002). The Columbia River is likely a major source of dissolved silicate, particulate organic carbon and particulate organic nitrogen (Hill and Wheeler 2002). Terrestrial sources of iron are also important, particularly in upwelling regions where iron is often a limiting nutrient (Bruland et al. 2001). Thus the assumption of negligible nutrient input from rivers may need to be amended during the tuning phase of model development.

Initial solute concentrations at depth were averaged or interpolated from empirical values in the same manner as described for chlorophyll a (see Phytoplankton subsection below).

Overview of Biological Parameters

Our parameter estimates closely follow those in Field (2004) for the 1990s California Current, with some additional references, particularly where our functional groups differed from his. Where possible we provide a comparison below between our parameter estimates and Field's (2004). Most of the differences and additional citations are necessitated by the capacity for representing spatial distributions within Atlantis, which was not possible in Field's 2004 Ecosim model. Life history and rate parameters are found in Table 3 for vertebrates, and in Table 4 for invertebrates.

Growth and Clearance Rates

Atlantis requires input of daily estimates of growth and clearance (consumption rates per individual) for each age class of all vertebrate groups. Growth rates were calculated from the von Bertalanffy growth curves (Table 3) for an archetypical species in each functional group; the archetypical species' parameters are the averages of the parameters for each species, weighted by their relative abundance (Table 2). Clearance rates were slightly more complicated. Where our functional groups overlapped with those of Field (2004), we attempted to convert his Ecopath Q/B (i.e., annual consumption/standing stock biomass) parameters to Atlantis clearance rates. However, we found that in most cases these Q/Bs led to lower growth than that expected from the von Bertalanffy and length-weight parameters.

Instead of using Ecopath Q/Bs, we calculated Atlantis clearance rates for juveniles by assuming a 10% conversion efficiency between consumption and growth (and no other metabolic

costs). Clearance rates of adult age classes equal those of the oldest juveniles, scaled by the ratio of size of the adult to the size of the oldest juvenile, raised to the three-fourths power. This captures the basic intuition that: 1) juveniles are converting most energy (or N) intake into growth, following some conversion efficiency, and 2) adult consumption rates (mg/day/individual) should generally be slightly higher than for juveniles, even though most of this energy is converted to reproduction, not growth. Respiration and consumption are generally related to biomass by the three-fourths power (Schmidt-Nielsen 1997). The resulting clearance rates generally yield better growth than converting Ecopath Q/Bs, likely due to the lack of age structure in the Field (2004) model.

Beverton Holt Recruitment Parameters

We used the standard form of the Beverton Holt recruitment model:

$$R = \alpha \times S / (\beta + S)$$

where α represents the maximum number of recruits produced (number of individuals), and β represents the spawning stock biomass at which recruitment is one-half maximum (measured in mg N). Recruitment R is the product of alpha times stock size S divided by the sum of beta plus stock size S . Here we use the ecological definition of recruits: fish that are approximately 60–180 days old and have settled out of the plankton and begun feeding. Atlantis does not explicitly model larvae or larval dispersal. Recruits are distributed evenly in all areas where juveniles can exist.

For most fish groups, estimates of unfished recruitment (α) were available for at least one species in the functional group. This was scaled up to an entire functional group using the proportion of each species in the 1998–2002 NMFS NWFSC slope survey (Builder Ramsey et al. 2002, Keller et al. 2005, Keller et al. 2006a, 2006b) and the 2003 NWFSC extended shelf-slope survey. This implies that we assume equal levels of depletion within a functional group. To derive β , we first calculated unfished spawner biomass in a way similar to unfished recruitment, scaling up from the level of an assessed species to the functional group. β was then equal to a proportion of this spawner biomass, where the proportion was calculated from stock recruit steepness (see Hilborn et al. 2003 for the conversion from steepness to β).

Steepness ranges from 0.2 to 1.0, where low values indicate a gradual increase in recruit abundance as spawning stock biomass increases (for instance, a constant 100 recruits per female spawner), and high values represent constant or “flat” recruitment across a very large range of spawning stock biomass. When possible, we used the values for steepness either estimated or assumed in stock assessment. When stock assessments assumed no stock-recruitment relationship, we used steepness of 0.9, that is, a flat relationship between spawners and recruits. When no assessments were available, we assumed steepness of 0.5 for groundfish, and 0.8 for pelagic fish, which frequently show a fairly flat stock recruit relationship. The use of fixed stock recruit parameters imposes a fairly strict density dependence on the model; in the future we may consider alternative stock-recruit relationships that rely less on uncertain estimates of steepness and unfished biomass and recruitment. Table 3 contains values for steepness, α , and β for all vertebrates.

For mammals and birds, we calculated α as the maximum number of offspring per adult, multiplied by an estimate of virgin adult abundance. We assumed mild compensation, equivalent to a steepness of 0.33, suggesting that at one-third historical abundance, mammals and birds could produce one-half of the maximum amount of offspring. Data on maximum number of offspring per adult were taken from Perrin et al. (2002) for mammals and Schreiber and Burger (2002) for birds. Estimates of historical levels of abundance are derived from the U.S. Fish and Wildlife Service (2003) and Springer et al. (2003) for marine mammals and Veit et al. (1996) and Oedekoven et al. (2001) for birds. We calculated β by scaling abundance to historical abundance, then multiplying by one-third. This implies that at one-third their historical biomass, mammals or birds could produce one-half their historical level of recruitment.

Migration

Atlantis identifies two types of migration: smaller seasonal migrations within the model domain and more extensive yearly migrations that take groups outside of the model boundary. Most groups display seasonal migration that shifts their biomass within the model area. Seasonal migration is quantified by allocating the total biomass of a group within each box by season, depending on that group's behavior.

Nine functional groups in the NCCE perform extensive migrations that take them outside of the model domain for part of every year. These groups are small planktivores, salmon, tuna, hake, migratory birds, pinnipeds, baleen whales, toothed whales, and dolphins. Out of this list, pinnipeds, salmon and baleen whales undergo two yearly migrations. Parameters for these extensive migrations for both juvenile and adult behavior are in Table 5.

Phytoplankton (PS, PL)

Biomass estimates for diatoms (PL) and microphytoplankton (PS) were largely derived from chlorophyll a concentrations measured throughout the model area at multiple depths on GLOBEC sampling cruises between 1997 and 2004 (Wetz et al. 2004), CalCOFI cruises from 2000 to 2004 (CalCOFI 2007), and cruises and mooring buoys in Monterey Bay. These efforts covered the region from the southerly boundary to lat 44°65'N, and in waters from coastal areas to our model boundary boxes. For regions outside of the area described above, we used Ocean Transect P data from Boyd and Harrison (1999). We focused on chlorophyll levels from winter or early spring sampling periods because Atlantis takes an initial phytoplankton biomass, assumed to occur on January 1 of the model year, and then calculates subsequent production and biomass based on factors such as ambient light, availability of nutrients, and grazer pressure. Ambient light is forced using a repeating 1 year time series, while nutrients and grazing pressure is dynamic within Atlantis.

Chlorophyll values were first averaged over the depth strata (0–50 m, 51–100 m, etc.) from which they were collected. They were then converted to standing stock phytoplankton estimates (in units of mg N m^{-3}). We further assumed 75% of the phytoplankton biomass was diatoms and 25% was picoplankton, as is thought to be characteristic of productive upwelling regions (e.g., Bruland et al. 2001 and references therein). Because coverage with empirical values only accounted for roughly 25% of all possible polygons and layers in our model area, we were forced to make considerable coarse-scale interpolations across regions and depths.

Generally, if a volume of water did not have a chlorophyll estimate, averages were taken of the nearest neighbor estimates to the north and south at the same depth stratum.

Zooplankton (ZL, ZM, ZS, ZG, PWN)

Zooplankton groups include large carnivorous zooplankton (euphausiids, ZL), mesozooplankton (copepods, ZM), microzooplankton (ZS), gelatinous zooplankton (ZG), and crangon and mysid shrimp (PWN) (Table 4). For all zooplankton groups in our model, relative abundance varies with distance from shore, following surveys 5–165 km off Brookings, Oregon (Lauri 1967). Estimates of absolute abundance of large carnivorous zooplankton (euphausiids) and shrimp, and how these varied with depth, are derived from sampling along the Newport line off Oregon from 1960 to 1968 (Percy 1970, Percy 1972). We averaged day and night values for use in the model.

Estimates of absolute abundance of gelatinous zooplankton and mesozooplankton between 0 and 200 m depth are also from Percy (1972). As a starting point, we assume that gelatinous zooplankton and mesozooplankton were not present beneath this depth. Densities of mesozooplankton along the Newport transect range from 1.92 to 18 mg C/m³ (Peterson and Miller 1977, Peterson et al. 2002, Peterson and Keister 2003). We chose 1.92 mg C/m³, or 0.33 mg N/m³ as our starting estimate for mesozooplankton, and 0.02 mg N/m³ as our starting estimate for gelatinous zooplankton.

Initial abundance estimates of zooplankton do not vary latitudinally, since the vast majority of zooplankton data available were from Oregon, the central portion of our model area.

For all zooplankton groups, mg C/m³ was converted to mg N/m³ following Table 11 in Parsons et al. (1984). We could not find estimates of microzooplankton abundance off the U.S. West Coast, so we used ZS values from Fulton (2001).

Cephalopods (CEP, BMS)

The cephalopods in our system are split into two functional groups: Octopi (BMS) and all other cephalopod species (CEP). Despite the lack of data on both of these subgroups, we felt it necessary to split the cephalopod family by general life history parameters in order to more appropriately represent their respective behaviors and roles within the ecosystem.

The “all other cephalopod” functional group is generally represented by market squid (*Loligo opalescens*), the most common and heavily harvested squid off the Pacific Coast. We used an estimate of 1.954 mt/km² from Field (2004). We assumed that 75% of the biomass of this semelparous species was in the juvenile group, and 25% in the adult group, equal to 0.0264 mg N/m³ and 0.0088 mg N/m³ respectively. Field’s estimates are from top-down balancing of his 1990s Ecopath model and include octopus, which we model as a separate group.

Benthic Invertebrates (BC, BML, BFF, BMD, BG)

Benthic infauna and epifauna in the model are grouped into carnivorous infauna such as polychaetes (BC), megazoobenthos such as crustaceans (BML), other benthic filter feeders such as mollusks (BFF), deep macro-zoobenthos such as echinoderms but excluding sea urchins

(BMD), and benthic grazers (BG, primarily sea urchins). Due to limited data, initial biomass density estimates in the model vary with depth but not with latitude.

Starting biomass assigned to these model groups between depths of 0–200 m are from the work of Lie (1969). Lie (1969) sampled off the coast of Washington in the summer of 1967 in three regions: 13–65 m depth, 104–329 m, and 50–155 m.

Biomass estimates for these benthic groups between 200 and 2,400 m are from Carey (1972). Carey sampled benthic infauna and macroepifauna from 1962 to 1965 along the Newport transect line, in depths from 30 to 200 m. We made the crude assumption that abundance beyond 200 m was similar to Carey's estimates at 200 m.

Both Lie (1969) and Carey (1972) report echinoderm biomass without differentiating between sea urchins and other types of echinoderms. To parse their estimates of echinoderm abundance into these two groups, we used estimates of relative abundance from Alton's (1972) sampling in northern Oregon near the mouth of the Columbia River. Alton found that urchin abundance, as a proportion of total echinoderm abundance, increased from 10% at 100–150 m depth to 90% at 200–250 m, and then declined to zero as depth increased to 750–850 m.

Our megazoobenthos group primarily consists of Dungeness crabs (*Cancer magister*) and tanner crabs (*Chionoecetes bairdi*). Abundance of these two groups follows Field (2004). His estimate of 41,000 metric tons (mt) of Dungeness crab is based on landings, assuming that 75% of adult males are caught, a 50:50 sex ratio, and an equal biomass of juveniles and adults. Adding Field's top-down Ecopath estimate of 0.79 mt/km² of tanner crabs yields a total of 0.12 mg DW/m².

Clearance (ingestion) rates and maximum growth rates are from Field (2004), assuming that maximum clearance rate is $1.2 \cdot Q/B$ (average consumption per biomass) in Ecopath. Table 4 lists the final clearance and growth parameters after calibration.

Biomass estimates for octopus (BMS), shallow benthic filter feeders (BFS), and anemones (BFD) are not currently available, and we used reference values from the S.E. Australia Atlantis model as a starting point for these groups.

Small Planktivorous Fish (FPS)

The small planktivorous fish group consists primarily of sardines (*Sardinops sagax*), anchovy (*Engraulis mordax*), saury (*Cololabis saira*), and herring (*Clupea harengus*). We used an estimate of 1,000,090 mt of sardines for the entire U.S. West Coast, from Conser et al. (2003). Richardson (1981) estimated Oregon anchovy abundance ranged from 100,000 mt to 1 million mt in 1975–1976, and Stauffer and Charter (1982) estimated California anchovy populations to be 1.5 million mt in 1979. We assumed an abundance of 2.5 million mt of anchovy for our model region. Smith et al. (1970) estimated that saury abundance was 0.37 mt/km² off California, and 0.27 mt/km² off Oregon. We used 0.31 mt/km² as an approximation for the entire coast. The California Fish and Game Commission (2004) estimated the biomass of the San Francisco Bay spawning stock of herring to be 45,000 mt, which we used as our estimate of herring abundance since we lacked additional information on herring. Shad (*Alosa*

sapidissima), eulachon (*Thaleichthys pacificus*), some herring stocks, and a few other important forage fish are not included in these estimates, and we therefore chose estimates of biomass on the high end of the ranges reported for sardines and anchovies.

Our total estimate of 3.84 million mt of small planktivores is an average of 41 mt/km², higher than Field's estimate of 27 mt/km² (26 tons/km² of "forage fish" and 1 ton of sardines/km²). Life history parameters were taken from Gunderson (1997), Butler et al. (1993), Hargreaves et al. (1994), Love (1996), and FishBase (Froese and Pauly 2005). Diet was derived from Love (1996). Beverton Holt parameters are based upon the assumption that stock and recruitment are currently at unfished levels, and steepness is 0.8 (Table 3). A northern stock of anchovies, which comprise roughly 60% of this functional group, gather offshore of the Columbia River in the summer to spawn, and this is reflected in the seasonal migration parameters.

Large Planktivorous Fish (FPL)

This group consists primarily of jack mackerel (*Trachurus symmetricus*) and also Pacific mackerel (*Scomber japonicus*). We used a biomass estimate of 81,000 mt of Pacific mackerel from a 2003 stock assessment (Hill and Crone 2004). MacCall and Stauffer (1983) estimated 640,000 to 1.3 million mt of jack mackerel in the Cal COFI sampling area; we used 900,000 mt as a starting point for the biomass of this species, yielding a sum of 171,000 mt for both species. Life history and diet parameters are based on jack mackerel from MacCall and Stauffer (1983), Love (1996), and FishBase (Froese and Pauly 2005). Beverton Holt parameters are based upon our assumption that stock and recruitment are currently at unfished levels, and steepness is 0.8 (Table 3). While this group does not exhibit extensive migrations, older adults do shift northwards in the summer, and this is reflected in our seasonal distribution parameters.

Shallow Piscivorous Fish (FDE)

The shallow piscivorous fish group is dominated by croaker (*Genyonemus lineatus*) and sculpin (Cottidae). Life history parameters are weighted by species' relative abundance in the NMFS trawl survey and are from FishBase (Froese and Pauly 2005). Our biomass estimate of 60,181 mt was derived from Field's benthic fish estimate (259,420 mt) minus the biomass of our deep miscellaneous fish group (179,207 mt) and estimated ratfish (*Hydrolagus colliei*) population (20,032 mt). This group does not exhibit proportional seasonal migrations in the model since it only lives within the nearshore boxes (0–50 m isobath). Beverton Holt parameters assume a steepness of 0.5 (Table 3), and that stock and recruitment are at historical levels.

Deep Vertical Migrators (FBP)

This group includes lanternfish and lampfish (Myctophidae), Pacific viperfish (*Chauliodus macouni*), and other mesopelagic species that exhibit diel vertical migrations from the deep slope to the midwater and near surface. We estimated biomass from several relevant studies (Pearcy and Laurs 1966, Beamish et al. 1999, Savinykh 1999, Field 2004).

Life history parameters, including von Bertalanffy growth parameters, length-weight conversions, natural mortality, age at maturity, maximum age, and diet were taken from

FishBase (Froese and Pauly 2005). We assumed that the 1998–2003 NMFS trawl surveys accurately sampled the community composition, and weighted the functional group’s life history parameters accordingly. The resulting functional-group parameters are therefore based mainly on those of myctophids, longfin dragonfish (*Tactostoma macropus*), and Pacific viperfish. Beverton Holt parameters assume a steepness of 0.5 (Table 3), and that current levels of stock and recruitment are equal to historical levels. This functional group is not known to exhibit seasonal migrations.

Deep Demersal Fish (FDD)

This group includes hagfish, eelpouts, grenadiers, and other similar fish, but is dominated by Pacific grenadier (*Coryphaenoides acrolepis*) and giant grenadier (*Albatrossia pectoralis*). Biomass estimates are from the 1998–2003 NMFS trawl survey data. However, camera sled surveys suggest the trawl surveys severely undersample hagfish, so the hagfish component of the deep demersal group was adjusted based on the observed ratio of hagfish to eelpouts reported by Wakefield (Wakefield 1991). This functional group’s life history parameters are weighted based on relative biomass of the species within the group. Life history parameters including diet, maximum age and length, movement, and habitat preferences were derived from Merrett and Haedrich (1997). Other parameters, including von Bertalanffy growth parameters, length-weight conversions and natural mortality, were taken from FishBase (Froese and Pauly 2005). Beverton Holt parameters assume a steepness of 0.5 (Table 3), and that current levels of stock and recruitment are equal to historical levels. Spatial distribution of this group is based on the NMFS trawl survey data and does not vary seasonally.

Rockfish (FDB, FDC, FDO, SHR, FDS)

Rockfish populations were divided into five groups by size and depth location: small shallow, large shallow, small deep, large deep, and midwater. Most of these species are not assessed, and therefore assessments can not be used to estimate biomass per functional group. Our estimates of rockfish biomass generally rely on 1998–2003 NMFS triennial trawl survey data corrected for differences in catchability. Where assessments were available, we compare their species level predictions to our estimates of biomass for the functional group. To date, we have incorporated assessment data from 2003; in the future we will incorporate additional information from the 2005 round of groundfish assessments.

The small deep rockfish group includes longspine thornyheads (*Sebastolobus altivelis*), sharpchin (*Sebastes zacentrus*), splitnose (*S. diploproa*), and aurora rockfish (*S. aurora*). Biomass estimates of small deep rockfish were estimated from trawl survey data, assuming catchability (Q) of 0.65. This is the average of catchabilities estimated by Rogers et al. (1996) for splitnose and sharpchin rockfish. Life history parameters and diet are from Love et al. (2002), FishBase (Froese and Pauly 2005), and Cailliet et al. (2000) and were weighted by the relative biomass of each species in the group. Our biomass estimate of 338,000 mt is higher than the approximate 255,000 mt predicted by extrapolating Field’s (2004) biomasses to our model region. This comparison assumes that our deep small rockfish group would incorporate 20% of Field’s juvenile rockfish group, 50% of his juvenile thornyhead group, 100% of his longspine thornyhead group, and 50% of his slope rockfish group. No assessments are available for deep

small rockfish. Beverton Holt parameters assume a steepness of 0.5 (Table 3), and that current levels of stock and recruitment are equal to half the unfished level.

The large deep rockfish group includes shortspine thornyhead (*Sebastolobus alascanus*) and darkblotched rockfish (*Sebastes crameri*). Biomass of large deep rockfish was estimated from NMFS 1998–2003 trawl survey data, assuming catchability (Q) of 0.50. This is a general estimate of catchability suggested by Rogers et al. (1996). Our biomass estimate is therefore 124,000 mt. In comparison, extrapolating Field's estimate of 1.678 mt/km² to our model area gives 159,000 mt. This comparison assumes that our deep large rockfish group includes 20% of Field's juvenile rockfish, 50% of juvenile thornyhead, 100% of shortspine thornyhead, and 50% of slope rockfish. Of the species in this functional group, only shortspine thornyhead and darkblotched rockfish have been assessed; with 30,000–62,000 mt of shortspine thornyhead (Piner and Methot 2001), and 7,300 mt of age 1+ darkblotched (Piner and Methot 2001, Rogers 2003). These estimates are low relative to the 124,000 mt, considering the fact that these two species account for 95% of the biomass of deep large rockfish caught by the 1998–2003 NMFS trawl survey.

Life history parameters for this group were weighted by the relative biomass of each species in the group, and come from Love et al. (2002), FishBase (Froese and Pauly 2005), Cailliet et al (2000), and Wilkins et al. (1998). Beverton Holt parameters are based on scaling up from the unfished stock and recruitment estimates for shortspine thornyhead, which make up 72% of this group's biomass in the 1998–2003 NMFS trawl survey data. We assume a steepness of 0.8 (Table 3), intermediate between the assessment values of 0.5 for darkblotched rockfish (Piner and Methot 2001), and no density dependence assumed in the shortspine thornyhead assessment (Rogers 2003).

We estimated midwater rockfish biomass to be 408,000 mt, using the NMFS trawl survey data and assuming a catchability of 0.18 (Millar and Methot 2002). This is higher than the 325,000 mt estimated by summing the biomasses of canary (*S. pinniger*), bocaccio (*S. paucispinis*), yellowtail (*S. flavidus*), and Pacific ocean perch (*S. alutus*) in Field (2004) and extrapolating to our model area. Assessments are available for bocaccio, 2,914 mt (MacCall 2003), canary rockfish, 6,500 mt (Methot and Piner 2001), widow rockfish (*S. entomelas*), 62,000 mt (Williams et al. 2000), yellowtail rockfish, 63,388 mt (Lai et al. 2003), and Pacific ocean perch, 23,073 mt (Hamel et al. 2003). These assessed species account for 59% of midwater rockfish biomass in the 1998–2003 NMFS trawl survey.

The functional group's life history parameters are based on the parameters of the assessed stocks, and are weighted by their relative abundance. Life history parameters are from Pacific Fishery Management Council (PFMC) Groundfish Fisheries Assessment (1999), Hamel et al. (2003), MacCall (2003), Wilkins et al. (1998), and Methot and Piner (2001). Beverton Holt parameters are based on scaling up from the unfished stock and recruitment of Pacific ocean perch (16% of this functional group's biomass in the NMFS trawl survey data), and a steepness of 0.5 (Table 3). This is intermediate between bocaccio assessments (MacCall 2003) which assume no stock-recruit relationship, canary rockfish steepness of 0.289 (Methot and Piner 2001), and Pacific ocean perch steepness of 0.32 (Hamel et al. 2003).

Biomass of small nearshore rockfish such as stripetail (*S. saxicola*), shortbelly (*S. jordani*), and greenstriped (*S. elongatus*) was estimated to be 48,000 mt based on the 1998–2003 NMFS trawl survey, assuming a catchability of 0.5 (Rogers et al. 1996). Life history parameters are from Love et al. (2002), PFMC Groundfish Fisheries Assessment (1999), FishBase (Froese and Pauly 2005) and Cailliet et al. (2000), and are weighted by biomass in the trawl survey. Beverton Holt parameters assume a steepness of 0.5 (Table 3) and that current stock and biomass are at 50% of historical levels.

The large nearshore rockfish group includes redstriped (*S. proriger*), yelloweye (*S. ruberrimus*), and black rockfish (*S. melanops*), among others. Biomass was estimated to be 62,000 mt from the 1998–2003 NMFS trawl survey, assuming catchability of 0.2 (based on catchability for yelloweye, (Rogers et al. 1996). Ralston and Dick (2003) estimated 11,200 mt of age 2+ black rockfish, and Wallace et al. (2002) estimated there to be 255 mt of yelloweye rockfish. Both functional groups of shallow rockfish total 108,000 mt, compared to 100,000 mt if we extrapolate black rockfish plus shelf rockfish from Field (2004) to our model area.

Life history parameters derive from Cailliet et al (2000), the black rockfish assessment (Ralston and Dick 2003), the cowcod (*S. levis*) assessment (Butler et al. 2003), PFMC Groundfish Fisheries Assessment (1999), Barker (1979), Gowan (1983), Rosenthal et al. (1982), and Workman et al. (1998). Beverton Holt parameters are based on scaling up the unfished stock and biomass estimated for yelloweye rockfish, and a steepness of 0.5 (Table 3). This is intermediate between a steepness of 0.429 for yelloweye rockfish (Rogers et al. 1996) and 0.65 for black rockfish (Ralston and Dick 2003).

Rockfish do not have forced seasonal migrations in the model. Their spatial distribution is based on the 1998–2003 NMFS trawl survey.

Flatfish (FDF)

Biomasses of flatfish such as English sole (*Parophrys vetulus*), rex sole (*Glyptocephalus zachirus*), and Dover sole (*Microstomus pacificus*) were estimated from 1998 to 2003 NMFS trawl survey data, assuming catchability (Q) of 0.50. This is intermediate between a catchability of 0.79 found for Dover sole (Sampson and Wood 2001) and 0.35 for English sole (Field 2004). The resulting biomass of 745,000 mt is close to Field's estimate of 721,000 mt, and the differences are likely caused by using slightly different years of NMFS trawl survey data. Sampson and Wood (2001) estimated age 5+ Dover sole biomass to be 115,000 mt. Life history parameters and diet are from Cailliet et al. (2000), Love (1996), and FishBase (Froese and Pauly 2005). The values were weighted by the relative biomass of each species in the NMFS trawl survey. Beverton Holt parameters are based on scaling up unfished stock and recruitment of Dover sole, which are 72% of the functional group's biomass, based on NMFS trawl data. We assume a steepness of 0.9 because Sampson and Wood (2001) assume no density dependence. The functional group does not have forced seasonal migrations in the model.

Hake (FMM)

The Pacific hake (*Merluccius productus*) group also includes tomcod (*Microgadus proximus*), Pacific cod (*Gadus macrocephalus*), and walleye pollock (*Theragra chalcogramma*),

but the functional group is parameterized as Pacific hake because of their numerical dominance and importance to the fishery. Biomass estimates of 2.7 million mt are from the Helser et al. (2003) stock assessment.

Life history parameters are from Helser et al. (2003) and Bailey et al. (1982). Beverton Holt parameters are based on estimates of unfished stock and recruitment from the assessment. We used a steepness of 0.9 because Helser et al. (2003) assume no density dependence (Table 3). Seasonal migration patterns were also derived from Bailey et al. (1982). Hake migrations are prescribed so that they are south of the system during the winter, come in close to shore in the spring, spread out over the shelf/slope break during the summer, and move away towards the outer shelf in the fall.

Sablefish (FMN)

Sablefish (*Anoplopoma fimbria*) biomass estimates of 118,000 mt are from Schirripa (2002). Length-weight parameters are from Sigler et al. (2003), lifespan is from Love (1996), natural mortality is from Hilborn et al. (2001), and von Bertalanffy parameters are from FishBase (Froese and Pauly 2005). Sablefish do not migrate seasonally (Love 1996). As a starting point, we distributed them in all boxes between 150 and 1,200 m depth. Beverton Holt parameters are based on estimates of unfished stock and recruitment from the assessment. We used a steepness of 0.9 because Schirripa (2002) assumes no density dependence (Table 3).

Large Piscivorous Flatfish (FVD)

This group includes California halibut (*Paralichthys californicus*), Pacific halibut (*Hippoglossus stenolepis*), arrowtooth flounder (*Atheresthes stomias*), and petrale sole (*Eopsetta jordani*). From Field (2004) we estimated that there were 1.24 mt/km² of arrowtooth, petrale, and California halibut. This was estimated by adding 50% of the juvenile flatfish abundance to the arrowtooth, halibut and petrale sole biomass estimates. We added an additional 3,600 mt of Pacific halibut following the assessment for IPHC area 2A (Clark and Hare 2004). Life history parameters and diets are from Cailliet et al (2000), Love (1996), and FishBase (Froese and Pauly 2005). Stock recruit parameters are not available for arrowtooth, the dominant component of this group. We therefore assume a steepness of 0.5 (Table 3), and current stock and recruitment at historical levels. We do not force seasonal migrations for this species, but their spatial distribution was taken from 1998–2003 NMFS trawl survey data.

Large Demersal Predators (FVS)

Large demersal predators are parameterized primarily as lingcod (*Ophiodon elongatus*) and cabezon (*Scorpaenichthys marmoratus*). This group's biomass is estimated as two times the female lingcod biomass (11,000 mt) reported in Jagielo et al. (2004), plus 830 mt of cabezon (Cope et al. 2003). Life history parameters and diet for lingcod are used for this group, derived from Love (1996) and Jagielo et al. (2004). We base Beverton Holt parameters on scaling up estimates of historical stock and recruitment for lingcod to the entire functional group. We assume a steepness of 0.9 because the assessment assumes no density dependence (Table 3). Lingcod and cabezon spatial distributions were derived from the 1998–2003 NMFS trawl survey data.

Salmon (FVB)

Due to the varied and complex life histories of the salmonid species in the California Current system, we were unable to fully represent their unique dynamics. As a compromise, we focused our attention on two of the most prevalent species, Chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*). To estimate the biomass of our salmon group, we replicated Field's (2004) methodology by taking the total coastal commercial and recreational trolling catch of Chinook and coho in 2004 (Weitkamp et al. 1995, Myers et al. 1998, PFMC 2005) of 1,148,800 individual salmon. This figure, multiplied by an average weight of a mature Chinook (0.0081 mt, Groot and Margolis 1991), gave us a total in metric tons of fish caught on coast. We did not differentiate between wild and hatchery fish. Following Field (2004), we assume this number represented 50% of the salmon in the system (i.e., 50% escapement) and further that 50% of the total population that swims through our system may be present in the system. This brought us to a total biomass of 37,221 mt. This figure, averaged over the area of our system, equals 0.4 mt/km². This average closely matches Field's (2004) estimate of 0.418 mt/km². We patterned salmon migration off fall run Chinook salmon, due to their prevalence in the system. Beverton Holt stock recruit parameters assume a steepness of 0.5 and that the stock is at 25% of historical levels (Table 3). Migration follows Myers et al. (1998) and Healey (1983), and the remainder of the salmon life history parameters were derived from Groot and Margolis (1991).

Albacore (FVT)

Albacore tuna (*Thunnus alalunga*) biomass estimates are from Field (2004), who estimated 0.014 tons/km² as an annual average, assuming albacore only spent summer months (one-fourth of the year) within the California Current. We multiplied his estimate by four, since we can explicitly represent the migration of albacore into our region during summer. Life history parameters are from FishBase (Froese and Pauly 2005), except for natural mortality, which was taken from PFMC (2003). Diets are from Love (1996). Beverton Holt parameters assume that stock size and recruitment are at half of unfished levels, and a steepness of 0.8 (Table 3).

Skates and Rays (SSK)

Skate and ray biomass is estimated from the 1998–2003 NMFS trawl survey. In the absence of stock assessments for skates and rays in our system, we assume a catchability of 1. The life history parameters are weighted by relative biomass in the trawl, which is dominated by Bering skate (*Bathyraja interrupta*), rougtail skate (*B. trachura*), and longnose skate (*Raja rhina*). Life history parameters are from Zeiner and Wolf (1993), Cailliet et al. (2000), Love (1996), and FishBase (Froese and Pauly 2005). Our estimate of 54,000 mt is higher than Field's prediction of 39,000 mt (0.04 mt/km² times 93,559 km² in our model area). We based Beverton Holt parameters on an assumption that stock size and recruitment are at two-thirds unfished levels, and that steepness is 0.5 (Table 3).

Small Demersal Sharks (SHB)

The small demersal shark group is primarily spiny dogfish (*Squalus acanthias*) and spotted ratfish (*Hydrolagus colliei*). Small demersal shark biomass was taken directly from the 1998–2003 NMFS trawl survey, and the assumed catchability was 1.0. Life history parameters were weighted by species biomass, which is dominated by dogfish. Our estimate of 118,000 mt is slightly higher than the 94,000 mt (1 ton/km² times 93,559 km²) estimated by Field (2004); however, Field (2004) also noted during some years in the 1990s, slope surveys suggested abundances of > 2 tons/km². Life history parameters are from Love (1996), Cailliet et al (2000), and FishBase (Froese and Pauly 2005). Not enough is known about dogfish migration patterns to effectively represent them in this model (Love 1996). Beverton Holt parameters assume that stock size and recruitment are at unfished levels, and a steepness of 0.5 (Table 3).

Demersal Sharks (SHD)

Biomass estimates of demersal sharks—sixgill (*Hexanchus griseus*), sevengill (*Notorynchus cepedianus*), and sleeper sharks (*Somniosus pacificus*)—are not available from the literature. We assumed that one-fifth of Field's (2004) mass-balance estimate of shark biomass was demersal shark. Life history parameters are from FishBase (Froese and Pauly 2005) and are those of sevengill sharks, since life history parameters were not available for the other species. Beverton Holt parameters assume that stock size and recruitment are at unfished levels, and a steepness of 0.5 (Table 3).

Pelagic Sharks (SHP)

Biomass estimates of pelagic sharks (primarily soupfin, *Galeorhinus galeus*, and thresher, *Alopias vulpinus*) are not available. We assumed that four-fifths of Field's (2004) mass-balance estimate of shark biomass was pelagic shark. Life history parameters are those of thresher and soupfin sharks (thresher shark length parameters were not used because of the extremely long tail), taken from PFMC (2003), Love (1996), and FishBase (Froese and Pauly 2005). Beverton Holt parameters assume stock size and recruitment are at one-fourth unfished levels, and a steepness of 0.5 (Table 3). The model does not assume consistent seasonal migrations in our region.

Migrating Birds (FVO)

The primary component of the migratory bird group is the sooty shearwater (*Puffinus griseus*), which makes up roughly 90% of the biomass of seabirds that make large (>1,000 km) aerial migrations into and out of the California Current ecosystem. Lesser components are the black-footed albatross (*Phoebastria nigripes*), Laysan albatross (*P. immutabilis*), northern fulmar (*Fulmaris glacialis*), and black-legged kittiwake (*Rissa tridactyla*). Population estimates for these species come from seasonal at sea and nesting colony counts in the 1970s and 1980s, as compiled by Parrish and Logerwell (2001). Population sizes were then converted to biomass estimates using average weight data compiled by Schreiber and Burger (2002), and a P/B ratio of 0.1 was derived from Field (2004). All general life history parameters (age at maturity, maximum age, clutch size, natural mortality rate; see Table 3) were taken from Schreiber and Burger (2002), and were weighted according to the abundance of the constituent species.

Shearwaters feed in a different manner than many other seabirds. They surface feed and can perform pursuit dives averaging 39 m and sometimes approaching 70 m (Weimerskirch and Sagar 1996). Thus their diets are considerably more diverse than the surface feeding or diving bird trophospecies. Beverton Holt parameters assume a steepness of 0.34, and that the populations have been reduced to 10% of their historical level (Veit et al. 1996).

The migratory pattern for shearwaters is to enter the model region on approximately February 15 of each year, generally coming in from the south or west into the offshore regions of the California Current. They typically remain around shelf break regions of the system and forage until November 1, when they will return to their southern hemisphere breeding and nesting habitats (Briggs and Chu 1986). Importantly, shearwaters do not necessarily come to the northeast Pacific during their northerly migration; in recent years, the bulk of the shearwater biomass has migrated to the northwest Pacific, possibly in relation to oceanic productivity declines in the California Current (Spear and Ainley 1999). Thus the population estimates of Parrish and Logerwell (2001) might best be viewed as maximum values, and sizable decreases may occur that owe to changes in migration behavior (e.g., northerly migrations to the western Pacific rather than to the California Current) rather than massive population die-offs (Spear and Ainley 1999).

Surface-Feeding Birds (SB)

The surface feeding bird group is comprised of gulls (*Larus* spp.), phalaropes (*Phalaropus* spp.), storm petrels (particularly Leach's storm petrel [*Oceanodroma leucorhoa*] and the fork-tailed storm petrel [*O. furcata*]), brown pelicans (*Pelecanus occidentalis*), and Caspian terns (*Sterna caspia*). More than 80% of this group by biomass are gulls. Biomass estimates come from seasonal at sea and nesting colony counts in the 1970s and 1980s, compiled by Parrish and Logerwell (2001), and average weight data, compiled by Schreiber and Burger (2002). All general life history parameters (age at maturity, maximum age, clutch size, natural mortality rate) were taken from Schreiber and Burger (2002), and were weighted according to the abundance of the constituent species (Table 3). Beverton Holt parameters assume a steepness of 0.34 and that the populations are currently at historical levels. Most of this trophospecies feeds in coastal and shelf waters, although some gulls and most of the storm petrels make use of slope waters. With the exception of pelicans, which move south in cooler months, this group is considered nonmigratory; therefore, the functional group as a whole does not migrate in the model.

Diving Birds (SP)

Diving birds are a diverse group that includes common murres (*Uria aalge*), rhinoceros auklets (*Cerorhinca monocerata*), Cassin's auklets (*Ptychoramphus aleuticus*), tufted puffins (*Fratercula cirrhata*), pigeon guillemots (*Cepphus columba*), Brandt's cormorants (*Phalacrocorax penicillatus*), double-crested cormorants (*P. auritus*), ancient murrelets (*Synthliboramphus antiquum*), and marbled murrelets (*Brachyramphus marmoratus*). Common murres make up about 60% of this group by biomass, with auklets ($\approx 20\%$) and cormorants (16%) contributing sizable portions as well. Biomass estimates come from seasonal at sea and nesting colony counts in the 1970s and 1980s, compiled by Parrish and Logerwell (2001) and by Perry and McKinnell (2005), and average weight data, compiled by Schreiber and Burger (2002). All

general life history parameters (age at maturity, maximum age, clutch size, natural mortality rate) were taken from Schreiber and Burger (2002), and were weighted according to the abundance of the constituent species (Table 3). Beverton Holt parameters assume a steepness of 0.34 and that the populations are currently at historical levels.

This trophospecies is typically found in coastal waters and over the shelf. We assume they are essentially nonmigratory, although this is unclear because of difficulties in seasonal censuses of these birds, many of which dig nesting burrows in breeding seasons and then disperse at sea for other parts of the year (Parrish and Logerwell 2001). The difficulties in enumerating these species are highlighted by differences in species counts by Parrish and Logerwell (2001) and Perry and McKinnell (2005); we have generally followed the counts of Parrish and Logerwell because they are more thoroughly documented, but have included PICES counts for species not counted by Parrish and Logerwell (pigeon guillemots, Cassin's auklets, and murrelets).

Pinnipeds (PIN)

The pinniped group includes northern elephant seals (*Mirounga angustirostris*), harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), and northern fur seals (*Callorhinus ursinus*). Population sizes are based on counts from recent NOAA stock assessments (Angliss and Lodge 2004, Carretta and Forney 2004) and supporting studies (Jeffries et al. 2003, Lowry and Carretta 2003, Ream et al. 2005). Population biomasses were assumed using average individual body masses (Trites and Pauly 1998) and were also weighted by P/B ratios from Field (2004).

Body masses were weighted by sex because adult pinnipeds are sexually dimorphic (males larger than females, Trites and Pauly 1998) and sex ratios are often heavily skewed toward females (Perrin and Thewissen 2002). Pinniped diets and many life history parameters were drawn mainly from Perrin and Thewissen (2002), with additional information on longevity, maximum length and length-weight relationships from Trites and Pauly (1998), and growth rates of Steller sea lions from Winship et al. (2001) (Table 3). Beverton Holt parameters assume the populations are at 10% of historical levels (Springer et al. 2003), and a steepness of 0.34, which implies that at one-third historical levels the stock could produce one-half the historical maximum number of pups.

A major component of the pinniped trophospecies is the northern elephant seal, owing to its relatively large estimated population size (>100,000) and very large individual biomass (male/female weighted average = 344 kg). The seasonal migration of the functional group is therefore based primarily on elephant seal movements. Male northern elephant seals undergo two migrations each year between the model domain and the North Pacific, whereas females migrate no further north than roughly lat 45°N (Carretta et al. 2005). The northerly migrations are for feeding. Elephant seals pup on offshore islands in the model domain during the winter months, then move north to feed. They return to the model domain to molt in the spring and summer and then return to the feeding grounds in the late summer and fall.

Additionally, the vast majority of the northern fur seal biomass in the model area consists of females and immature males that emigrate from Alaska waters and overwinter over shelf

waters of the NCCE from approximately February through mid-May; they then migrate north to Alaska waters for the summer months (Ream et al. 2005). The other major components of the pinniped biomass, California sea lions and harbor seals, do not migrate seasonally.

Transient Orcas (REP)

Transient orcas (*Orcinus orca*) are those killer whales that feed primarily on marine mammals, occasionally supplementing their diets with seabirds, fish, and invertebrates. The population estimate of approximately 120 animals is based on counts from recent NOAA marine mammal stock assessments (Black et al. 1997, Angliss and Lodge 2004, Carretta et al. 2005). Population biomass was assumed using growth rates (Noren unpubl. data) and length-weight relationships from Trites and Pauly (1998). Other life history data included natural mortality rates from Heppell et al. (1999) and longevity and maximum size data from Trites and Pauly (1998). Transient orca diet information came from Ford et al. (1998), Perrin and Thewissen (2002), and unpublished anecdotal reports. Beverton Holt parameters assume the population is at one-third of historical levels (Springer et al. 2003), and a steepness of 0.34. We devoted a full functional group to this small population because they are of critical conservation concern.

Baleen Whales (WHB)

Baleen whales include gray whales (*Eschrichtius robustus*), humpback whales (*Megaptera novaeangliae*), blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), sei whales (*B. borealis*), and minke whales (*B. acutorostrata*). Population sizes are based on counts from recent NOAA marine mammal stock assessments (Angliss and Lodge 2004, Carretta et al. 2005) and supporting literature (Hobbs and Rush 1999, Barlow and Taylor 2001, Barlow 2003). Population biomasses were assumed using average individual body masses (Trites and Pauly 1998). Natural mortality rate estimates were available for humpback whales (Mizroch et al. 2004) and sei whales (Perrin and Thewissen 2002); von Bertalanffy k estimates were available for gray whales (Rice and Wolman 1971), fin whales (Sampson 1990), and minke whales (Olsen and Sunde 2002); and longevity information and length-weight relationships came from Trites and Pauly (1998). Baleen whale diet information was derived mainly from Perrin and Thewissen (2002), with additional data in Dunham and Duffus (2002) and Tershy (1992) (Table 3). Beverton Holt parameters assume that the populations are at one-seventh of historical levels (Springer et al. 2003), and a steepness of 0.34.

Because of their relatively large population (more than 26,000, Hobbs and Rush 1999, Angliss and Lodge 2004), gray whales represent more than 61% of the baleen whale biomass pool. This is important because gray whales have diets distinct from the rest of this functional group. Whereas other baleen whales filter feed on pelagic invertebrates and small fishes, gray whales prefer to feed on benthic invertebrates, which they scoop from the sediments (Dunham and Duffus 2002). Gray whales also undergo very different migrations than the other baleen whales. They calve south in Mexican coastal waters (south of the model domain) in winter and then migrate up the coast in the late winter through spring, ultimately bound for feeding grounds in the Bering and Chukchi seas. In the fall, they migrate south again, through the model domain and back to their calving grounds (Carretta et al. 2005).

The other baleen whales also exhibit seasonal migrations. Humpback whales winter off Central America before moving as far north as British Columbia in the summer and fall; blue and fin whales typically occur no further north than California and Oregon during the summer months and are out of the model domain in cooler months; and minke whales occur throughout the model domain at all times of the year (Angliss and Lodge 2004, Carretta et al. 2005). We based this functional group's seasonal movement parameters on gray whales, since they account for the majority of the biomass.

Toothed Whales (WHT)

Toothed whales are comprised of larger-bodied toothed whales (except for transient orcas, which have distinct diets). The toothed whales include both the coastal resident and offshore populations of orcas ($n \approx 80$ and 400, respectively), sperm whales (*Physeter macrocephalus*), pygmy sperm whales (*Kogia breviceps*), Cuvier's beaked whale (*Ziphius cavirostris*), Baird's beaked whale (*Berardius bairdii*), and mesoplodont beaked whales (*Mesoplodon* spp.). Population sizes are based on counts from recent NOAA marine mammal stock assessments (Carretta et al. 2005) and supporting literature (Barlow 1997, Black et al. 1997, Barlow 2003). Population biomasses were assumed using average individual body masses (Trites and Pauly 1998) and were also weighted by P/B ratios because sperm whales are much larger than the other whales in this group. However, Field (2004) did not report a P/B value for sperm whales or larger beaked whales, so we assigned sperm whales the same P/B value Field assigned to orcas (0.02) and the remaining large toothed whales the same P/B value that Field assigned to dolphins and porpoises (0.07).

Growth rate and mortality rate estimates for sperm whales came from Evans and Hindell (2004); growth rates for orcas came from Noren (unpubl. data); natural mortality rates for orcas were derived from Heppell et al. (1999); and length-weight relationships, longevity, and maximum size for many species came from Trites and Pauly (1998) (Table 3). Diets for large toothed whales were taken from Perrin and Thewissen (2002). Beverton Holt parameters assume the populations are at one-fifth of historical levels (Springer 2003), and a steepness of 0.34.

Sperm whales are relatively large and abundant, and thus comprise the bulk of this functional group. This is important because sperm whales have a distinct diet from other whales in this group, utilizing large cephalopods to a greater extent (Perrin and Thewissen 2002). Sperm whales, along with the offshore orcas, are in deeper waters of the model region in all seasons (Carretta et al. 2005). Little is known about the distributions of the beaked whales and pygmy sperm whale, which comprise roughly 29% of this trophospecies. They are believed to occur in offshore areas in the summer and migrate out of the model domain in the remaining months (Carretta et al. 2005).

Sea Otters (WDG)

There are two sea otter (*Enhydra lutris*) population centers in the model region, one in central and northern California waters and one in Washington and British Columbia waters. The California population accounts for about 85% of the roughly 2,750 individuals in the U.S. portion of the study region, according to the last stock assessment conducted in 1995 (see Appendix 5 of Carretta et al. 2005), but more than 1,500 are believed to live off of Vancouver

Island (Watson et al. 1997). Individual sea otter biomass for the model region was difficult to find in the literature, so we assumed the same length-to-weight relationship as observed in pinnipeds (Trites and Pauly 1998) and assigned a von Bertalanffy k similar to that of harbor porpoises, which grow to roughly the same length in the same number of years. An estimate of sea otter natural mortality (as an Ecopath P/B parameter) was given in Okey and Pauly (1999). Sea otter diets were summarized in Van Blaricom and Estes (1988) and Perrin and Thewissen (2002). Beverton Holt parameters assume the population is at 13% of historical levels (USFWS 2003) and a steepness of 0.34. Sea otters are nonmigratory.

Appendix B: Predator-Prey Parameters

This appendix, consisting of tables B-1 through B-12, details the values for the predator-prey (variable a) parameters, as represented in Equation 10. This parameter specifies the availability of each prey to each predator. The proportion of each prey item in the diet is then treated as an emergent property that dynamically responds to changes in predator and prey abundance. In the current parameterization, these availability parameters are converted to a Hollings type II functional response, with gape limitations such that predators can only consume prey below a size threshold. Tables B-1 through B-6 contain the values for the predator-prey (variable a) parameter in the calibrated model, and Tables B-7 through B-12 show their relative change from the original uncalibrated values.

Table B-1. Consumption parameters (variable a in Equation 10) in the calibrated model for predation on groups including birds (FVO) and fish (all other groups). A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
j → j	FPL	Large planktivores	0.05	0.1	0	0.3	0.1	0.1	0	0.01	0.01	0.05	0.02
a → j	FPL	Large planktivores	0	0.1	0	0	0	0	0	0	0	0.05	0
j → a	FPL	Large planktivores	0.01	0.1	0	0.05	0.01	0.01	0	0.1	0.07	0.05	0.01
a → a	FPL	Large planktivores	0	0.1	0	0	0	0	0	0	0	0.01	0
j → j	FPS	Small planktivores	0.1	0.00002	0	0.3	0.05	0.1	0	0.1	0.1	0.0005	0.02
a → j	FPS	Small planktivores	0	0	0	0	0	0	0	0	0	0	0
j → a	FPS	Small planktivores	0.00003	0.00003	0	0.1	0.00002	0.1	0	0.0001	0.1	0.00005	0.02
a → a	FPS	Small planktivores	0	0	0	0	0	0	0	0	0	0	0
j → j	FVD	Large flatfish	0	0	0	0.0002	0	0	0	0.002	0.1	0.0001	0.1
a → j	FVD	Large flatfish	0	0	0	0	0	0	0	0	0	0.0001	0.6
j → a	FVD	Large flatfish	0.0001	0.0005	0	0.0002	0.0001	0	0	0.002	0.05	0.0001	0.08
a → a	FVD	Large flatfish	0.0005	0.0005	0	0	0	0	0	0	0.3	0.0001	0
j → j	FVS	Large demersal predators	0.01	0.01	0	0.05	0	0	0	0.1	0.1	0.1	0.02
a → j	FVS	Large demersal predators	0	0.01	0	0	0	0	0	0	0	0.0005	0.2
j → a	FVS	Large demersal predators	0.0002	0.001	0	0.05	0.001	0	0	0.1	0.1	0.1	0.12
a → a	FVS	Large demersal predators	0.0005	0.001	0	0	0	0	0	0.1	0	0.0005	0
j → j	FVT	Large pelagic predators	0.1	0.1	0	0	0.1	0.1	0	0.2	0	0.1	0
a → j	FVT	Large pelagic predators	0.1	0.1	0	0	0	0.05	0	0.2	0	0.1	0
j → a	FVT	Large pelagic predators	0.1	0.1	0	0	0.1	0.1	0	0.2	0	0.1	0
a → a	FVT	Large pelagic predators	0.1	0.1	0	0	0	0.1	0	0.1	0	0.1	0
j → j	FVO	Shearwaters	0.0001	0.001	0	0	0.0001	0.05	0	0.01	0	0.001	0
a → j	FVO	Shearwaters	0	0.001	0	0	0	0	0	0	0	0.0001	0
j → a	FVO	Shearwaters	0.0001	0.005	0	0	0.0001	0.05	0	0.01	0	0.002	0
a → a	FVO	Shearwaters	0	0.005	0	0	0	0	0	0	0	0.0003	0
j → j	FVB	Salmon	0.001	0.01	0	0	0.002	0.1	0	0.01	0	0.05	0
a → j	FVB	Salmon	0	0.01	0	0	0	0	0	0	0	0.01	0
j → a	FVB	Salmon	0	0.1	0	0	0	0	0	0	0	0	0
a → a	FVB	Salmon	0	0.1	0	0	0	0	0	0	0	0	0
j → j	FMM	Hake	0.0001	0.0001	0	0.3	0.000003	0.001	0	0.0001	0.1	0.01	0.02
a → j	FMM	Hake	0	0.00001	0	0	0	0	0	0	0	0.0005	0.2
j → a	FMM	Hake	0.0001	0.0001	0	0.001	0.000003	0.001	0	0.0001	0.1	0.01	0.05

Table B-1 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for predation on groups including birds (FVO) and fish (all other groups). A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
a → a	FMM	Hake	0	0.00001	0	0	0	0	0	0	0	0.0005	0
j → j	FMN	Sablefish	0.0001	0.001	0	0.005	0	0	0	0.01	0.05	0.001	0.01
a → j	FMN	Sablefish	0	0.001	0	0	0	0	0	0	0	0.0001	0.2
j → a	FMN	Sablefish	0.0001	0.001	0	0.005	0	0	0	0.01	0.05	0.01	0.01
a → a	FMN	Sablefish	0.0003	0.001	0	0	0	0	0	0.005	0.05	0.0001	0
j → j	FBP	Deep vertical migrators	0.1	0.001	0	0	0	0.2	0	0.1	0	0.001	0
a → j	FBP	Deep vertical migrators	0	0	0	0	0	0	0	0	0	0	0
j → a	FBP	Deep vertical migrators	0.1	0.002	0	0	0.002	0.15	0	0.001	0.1	0.001	0.02
a → a	FBP	Deep vertical migrators	0	0.002	0	0	0	0	0	0	0	0.001	0
j → j	FDD	Deep miscellaneous fish	0	0	0	0	0	0	0	0.005	0.05	0.0001	0.03
a → j	FDD	Deep miscellaneous fish	0	0	0	0	0	0	0	0	0	0.000005	0.05
j → a	FDD	Deep miscellaneous fish	0	0	0	0.001	0	0	0	0.005	0.05	0.0001	0.03
a → a	FDD	Deep miscellaneous fish	0	0	0	0	0	0	0	0	0	0.000005	0
j → j	FDS	Midwater rockfish	0.00001	0.001	0	0.001	0.001	0	0	0.001	0.1	0.001	0.001
a → j	FDS	Midwater rockfish	0	0.001	0	0	0	0	0	0	0	0.00003	0.2
j → a	FDS	Midwater rockfish	0.00001	0.0001	0	0.001	0.00001	0	0	0.0001	0.1	0.001	0.001
a → a	FDS	Midwater rockfish	0.00001	0.0001	0	0	0	0	0	0.0001	0.6	0.00003	0
j → j	FDB	Small shallow rockfish	0.001	0.001	0	0	0	0	0	0.01	0	0.001	0
a → j	FDB	Small shallow rockfish	0	0.001	0	0	0	0	0	0	0	0.001	0
j → a	FDB	Small shallow rockfish	0.001	0.001	0	0.01	0.001	0	0	0.01	0	0.001	0
a → a	FDB	Small shallow rockfish	0	0.001	0	0	0	0	0	0	0	0.001	0
j → j	FDC	Deep small rockfish	0	0.001	0	0	0	0	0	0.01	0.1	0.1	0.02
a → j	FDC	Deep small rockfish	0	0.001	0	0	0	0	0	0	0	0.001	0.2
j → a	FDC	Deep small rockfish	0.0005	0.001	0	0	0	0	0	0.01	0.1	0.1	0.02
a → a	FDC	Deep small rockfish	0	0	0	0	0	0	0	0	0	0.0005	0
j → j	FDO	Deep large rockfish	0	0.001	0	0	0	0	0	0.01	0.1	0.02	0.02
a → j	FDO	Deep large rockfish	0	0.001	0	0	0	0	0	0	0	0.0005	0.2
j → a	FDO	Deep large rockfish	0.0005	0.001	0	0.01	0	0.02	0	0.01	0.1	0.02	0.05
a → a	FDO	Deep large rockfish	0	0	0	0	0	0	0	0.01	0.01	0.001	0
j → j	FDE	Miscellaneous nearshore	0	0	0	0.3	0	0	0	0.1	0	0.0003	0
a → j	FDE	Miscellaneous nearshore	0	0	0	0	0	0	0	0	0	0.02	0
j → a	FDE	Miscellaneous nearshore	0.0003	0.001	0	0.001	0.001	0	0	0.01	0	0.002	0

Table B-1 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for predation on groups including birds (FVO) and fish (all other groups). A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
a → a	FDE	Miscellaneous nearshore	0	0	0	0	0	0	0	0	0	0.0005	0
j → j	FDF	Small flatfish	0	0.001	0	0.01	0.0001	0	0	0.01	0.1	0.01	0.1
a → j	FDF	Small flatfish	0	0	0	0	0	0	0	0	0	0.0001	0.2
j → a	FDF	Small flatfish	0	0.001	0	0.01	0.0001	0	0	0.01	0.1	0.01	0.2
a → a	FDF	Small flatfish	0	0.001	0	0	0	0	0	0	0	0.0001	0
j → j	SHD	Large demersal sharks	0	0	0	0.5	0	0	0	0.1	0.2	0.03	0.1
a → j	SHD	Large demersal sharks	0	0	0	0.01	0	0	0	0.2	0.6	0.01	0.8
j → a	SHD	Large demersal sharks	0	0	0	0.2	0	0	0	0.1	0.2	0.1	0.1
a → a	SHD	Large demersal sharks	0	0	0	0.01	0	0	0	0.2	0.6	0.01	0.8
j → j	SHP	Misc. pelagic sharks	0.001	0.001	0	0.0001	0.002	0.02	0	0.01	0.1	0.0002	0.02
a → j	SHP	Misc. pelagic sharks	0.1	0.01	0	0.001	0	0.2	0	0.001	0.6	0.002	0.8
j → a	SHP	Misc. pelagic sharks	0.0005	0.001	0	0.0001	0.002	0.02	0	0.01	0.05	0.0003	0.02
a → a	SHP	Misc. pelagic sharks	0.02	0.01	0	0.001	0.00005	0.2	0	0.001	0.6	0.002	0.8
j → j	SHB	Small demersal sharks	0	0.01	0	0.01	0	0.05	0	0.01	0.1	0.01	0.1
a → j	SHB	Small demersal sharks	0	0.01	0	0	0	0.1	0	0	0	0.01	0.2
j → a	SHB	Small demersal sharks	0	0.01	0	0.01	0	0.05	0	0.01	0.1	0.01	0.1
a → a	SHB	Small demersal sharks	0	0.01	0	0	0	0.1	0	0	0.6	0.001	0.2
j → j	SHR	Shallow large rockfish	0.005	0.01	0	0.01	0.001	0	0	0.01	0.1	0.01	0
a → j	SHR	Shallow large rockfish	0	0.01	0	0	0	0	0	0	0	0.001	0
j → a	SHR	Shallow large rockfish	0.005	0.01	0	0.01	0.001	0	0	0.01	0.1	0.01	0
a → a	SHR	Shallow large rockfish	0	0.01	0	0	0	0	0	0	0	0.001	0
j → j	SSK	Skates and rays	0	0	0	0.01	0	0	0	0.01	0.1	0.01	0.05
a → j	SSK	Skates and rays	0	0	0	0	0	0	0	0	0	0.001	0.2
j → a	SSK	Skates and rays	0	0	0	0.01	0	0	0	0.01	0.1	0.01	0.05
a → a	SSK	Skates and rays	0	0	0	0	0	0	0	0	0	0.001	0.2
j → j	SB	Surface seabirds	0.1	0.1	0	0	0.05	0.1	0	0.1	0	0.05	0
a → j	SB	Surface seabirds	0	0.1	0	0	0	0	0	0	0	0.01	0
j → a	SB	Surface seabirds	0.1	0.1	0	0	0.05	0.1	0	0.1	0	0.05	0
a → a	SB	Surface seabirds	0	0.01	0	0	0	0	0	0	0	0.01	0
j → j	SP	Diving seabirds	0.03	0.1	0	0	0.05	0.1	0	0.1	0	0.005	0
a → j	SP	Diving seabirds	0	0.01	0	0	0	0	0	0	0	0.01	0

Table B-1 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for predation on groups including birds (FVO) and fish (all other groups). A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
j → a	SP	Diving seabirds	0.03	0.1	0	0	0.05	0.1	0	0.1	0	0.005	0
a → a	SP	Diving seabirds	0	0.01	0	0	0	0	0	0	0	0.01	0
j → j	REP	Transient orcas	0	0	0	0	0	0	0	0	0	0	0
a → j	REP	Transient orcas	0	0	0	0	0	0	0	0	0	0	0
j → a	REP	Transient orcas	0	0	0	0	0	0	0	0	0	0	0
a → a	REP	Transient orcas	0	0	0	0	0	0	0	0	0	0	0
j → j	PIN	Pinnipeds	0.005	0.0005	0	0.0001	0.0005	0.005	0	0.005	0.1	0.0005	0.5
a → j	PIN	Pinnipeds	0.01	0.01	0	0.001	0.00002	0	0	0.001	0.6	0.003	0.8
j → a	PIN	Pinnipeds	0.005	0.0005	0	0.0001	0.0005	0.005	0	0.005	0.1	0.0005	0.5
a → a	PIN	Pinnipeds	0.01	0.01	0	0.001	0.00002	0.05	0	0.003	0.6	0.003	0.8
j → j	WHB	Baleen whales	0	0	0	0	0	0	0	0	0	0	0
a → j	WHB	Baleen whales	0	0	0	0	0	0	0	0	0	0	0
j → a	WHB	Baleen whales	0	0	0	0	0	0	0	0	0	0	0
a → a	WHB	Baleen whales	0	0	0	0	0	0	0	0	0	0	0
j → j	WHT	Toothed whales	0.0005	0.001	0	0.001	0.0001	0.002	0	0.01	0.1	0.05	0.3
a → j	WHT	Toothed whales	0.001	0.001	0	0.001	0.00002	0.02	0	0.01	0.6	0.001	0.6
j → a	WHT	Toothed whales	0.001	0.01	0	0.001	0.0001	0.002	0	0.01	0.1	0.05	0.3
a → a	WHT	Toothed whales	0.001	0.001	0	0.001	0.00002	0.02	0	0.01	0.6	0.001	0.6
j → j	WDG	Otters	0	0	0	0	0	0	0	0	0	0	0
a → j	WDG	Otters	0	0	0	0	0	0	0	0	0	0	0
j → a	WDG	Otters	0	0	0	0	0	0	0	0	0	0	0
a → a	WDG	Otters	0	0	0	0	0	0	0	0	0	0	0
	ZG	Gelatinous zooplankton	0.0001	0.0001	0	0	0.00001	0.02	0	0.0001	0	0.0000	0
	ZL	Large zooplankton	0	0	0	0	0	0	0	0	0	0	0
	ZM	Mesozooplankton	0	0	0	0	0	0	0	0	0	0	0
	ZS	Microzooplankton	0	0	0	0	0	0	0	0	0	0	0
	BD	Deposit feeders	0	0	0	0	0	0	0	0	0	0	0
	BO	Meiobenthos	0	0	0	0	0	0	0	0	0	0	0
	BC	Carnivorous infauna	0	0	0	0	0	0	0	0	0	0	0
	BFS	Shallow benthic filter	0	0	0	0	0	0	0	0	0	0	0
	BFF	Other benthic filter feeders	0	0	0	0	0	0	0	0	0	0	0
	BFD	Deep benthic filter feeders	0	0	0	0	0	0	0	0	0	0	0

Table B-1 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for predation on groups including birds (FVO) and fish (all other groups). A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
	BMS	Shallow macro-zoobenthos	0	0	0	0.1	0	0	0	0	0	0.0000	0.02
	BML	Mega-zoobenthos	0	0	0	0.002	0	0	0	0.0001	0.0008	0.0000	0.005
	BMD	Deep macro-zoobenthos	0	0	0	0	0	0	0	0	0	0	0
	BG	Benthic grazers	0	0	0	0	0	0	0	0	0	0	0
	CEP	Cephalopods	0.001	0.005	0	0.01	0.005	0.1	0	0.01	0.1	0.0005	0.1
	PWN	Shrimp	0	0	0	0	0	0	0	0	0	0	0
	PWN	Shrimp	0	0	0	0	0	0	0	0	0	0	0

* In the stages column, j → j signifies juvenile predation on juveniles, a → j signifies adult predation on juveniles, j → a signifies juvenile predation on adults, and a → a signifies adult predation on adults.

Table B-2. Consumption parameters (variable a in Equation 10) in the calibrated model for additional prey including fish and sharks. Prey groups are listed by column. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDf	SHB	SHD	SHP	SHR	SSK
j → j	FPL	Large planktivores	0.1	0.1	0.05	0	0	0	0	0	0	0.1	0
a → j	FPL	Large planktivores	0	0	0	0	0	0	0	0	0	0	0
j → a	FPL	Large planktivores	0.03	0.05	0.01	0	0	0	0	0	0	0.01	0
a → a	FPL	Large planktivores	0.015	0	0	0	0	0	0	0	0	0	0
j → j	FPS	Small planktivores	0.0001	0.05	0.05	0	0	0	0	0	0	0.1	0
a → j	FPS	Small planktivores	0	0	0	0	0	0	0	0	0	0	0
j → a	FPS	Small planktivores	0.00005	0.1	0.0001	0	0	0	0	0	0	0.1	0
a → a	FPS	Small planktivores	0	0	0	0	0	0	0	0	0	0	0
j → j	FVD	Large flatfish	0.00015	0.0002	0.0006	0.001	0.0005	0.2	0	0	0	0.005	0.0001
a → j	FVD	Large flatfish	0.001	0	0.0002	0.001	0	0.3	0	0	0	0	0
j → a	FVD	Large flatfish	0.00015	0.0002	0.00006	0.001	0.0001	0.01	0.0001	0	0	0.005	0.0001
a → a	FVD	Large flatfish	0.001	0	0.0002	0.001	0	0.3	0.1	0	0	0	0.1
j → j	FVS	Large demersal predators	0.1	0.05	0.05	0.01	0.1	0.1	0	0	0	0.1	0.03
a → j	FVS	Large demersal predators	0.1	0	0.05	0.1	0	0.3	0	0	0	0	0
j → a	FVS	Large demersal predators	0.1	0.01	0.01	0.01	0.005	0.1	0.00005	0	0	0.01	0.03
a → a	FVS	Large demersal predators	0.1	0	0.01	0.01	0	0.1	0.01	0	0	0	0.03
j → j	FVT	Large pelagic predators	0.005	0.01	0.001	0	0	0	0	0	0	0.1	0
a → j	FVT	Large pelagic predators	0.1	0	0.1	0	0	0	0	0	0	0	0
j → a	FVT	Large pelagic predators	0.1	0.1	0.1	0	0	0	0	0	0	0.1	0
a → a	FVT	Large pelagic predators	0.3	0	0.1	0	0	0	0	0	0	0	0
j → j	FVO	Shearwaters	0	0.01	0.001	0	0	0	0	0	0	0.001	0
a → j	FVO	Shearwaters	0	0	0	0	0	0	0	0	0	0	0
j → a	FVO	Shearwaters	0	0.1	0.001	0	0	0	0	0	0	0.001	0
a → a	FVO	Shearwaters	0	0	0	0	0	0	0	0	0	0	0
j → j	FVB	Salmon	0.1	0.01	0.005	0	0	0	0	0	0	0.01	0
a → j	FVB	Salmon	0.15	0	0	0	0	0	0	0	0	0	0
j → a	FVB	Salmon	0.1	0	0	0	0	0	0	0	0	0	0
a → a	FVB	Salmon	0.15	0	0	0	0	0	0	0	0	0	0
j → j	FMM	Hake	0.002	0.01	0.00005	0.001	0.1	0.1	0	0	0	0.2	0

Table B-2 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for additional prey including fish and sharks. Prey groups are listed by column. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDf	SHB	SHD	SHP	SHR	SSK
a → j	FMM	Hake	0.002	0	0.05	0.01	0	0.3	0	0	0	0	0
j → a	FMM	Hake	0.001	0.0001	0.00005	0.0001	0.001	0.003	0	0	0	0.0001	0.01
a → a	FMM	Hake	0.002	0	0	0.0001	0	0.3	0	0	0	0	0
j → j	FMN	Sablefish	0	0.002	0.001	0.015	0.0002	0.1	0	0	0	0.001	0
a → j	FMN	Sablefish	0.01	0	0.003	0.003	0	0.3	0	0	0	0	0
j → a	FMN	Sablefish	0	0.002	0.001	0.015	0.0002	0.005	0.00003	0	0	0.001	0.005
a → a	FMN	Sablefish	0.01	0.002	0	0.003	0.00001	0.005	0.0005	0	0	0	0.005
j → j	FBP	Deep vertical migrators	0	0	0	0	0	0	0	0	0	0	0
a → j	FBP	Deep vertical migrators	0	0	0	0	0	0	0	0	0	0	0
j → a	FBP	Deep vertical migrators	0	0.01	0.05	0.1	0.1	0.1	0	0	0	0.1	0
a → a	FBP	Deep vertical migrators	0	0	0	0	0	0	0	0	0	0	0
j → j	FDD	Deep miscellaneous fish	0	0	0	0.01	0.00001	0.01	0	0	0	0	0.001
a → j	FDD	Deep miscellaneous fish	0	0	0	0.001	0	0.06	0	0	0	0	0
j → a	FDD	Deep miscellaneous fish	0	0.001	0	0.01	0.00001	0.06	0.000005	0	0	0	0.001
a → a	FDD	Deep miscellaneous fish	0	0	0	0.001	0	0.06	0.0001	0	0	0	0
j → j	FDS	Midwater rockfish	0.001	0.01	0.001	0.01	0.001	0.1	0	0	0	0.0001	0
a → j	FDS	Midwater rockfish	0.01	0	0.001	0.001	0	0.3	0	0	0	0	0
j → a	FDS	Midwater rockfish	0.001	0.0002	0.0001	0.01	0.001	0.1	0	0	0	0.0001	0
a → a	FDS	Midwater rockfish	0.01	0.5	0.0001	0.001	0	0.3	0	0	0	0	0
j → j	FDB	Small shallow rockfish	0.1	0.1	0.01	0	0	0.1	0	0	0	0	0
a → j	FDB	Small shallow rockfish	0.15	0	0	0	0	0.3	0	0	0	0	0
j → a	FDB	Small shallow rockfish	0.1	0.1	0.01	0	0	0.1	0	0	0	0.1	0
a → a	FDB	Small shallow rockfish	0.15	0	0	0	0	0.3	0	0	0	0	0
j → j	FDC	Deep small rockfish	0	0.1	0	0.02	0.3	0.1	0	0	0	0	0
a → j	FDC	Deep small rockfish	0	0	0	0	0	0.3	0	0	0	0	0
j → a	FDC	Deep small rockfish	0	0	0	0.02	0.1	0.1	0	0	0	0	0
a → a	FDC	Deep small rockfish	0	0	0	0	0	0.3	0	0	0	0	0
j → j	FDO	Deep large rockfish	0	0.1	0	0.02	0.1	0.1	0	0	0	0	0

Table B-2 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for additional prey including fish and sharks. Prey groups are listed by column. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDf	SHB	SHD	SHP	SHR	SSK
a → j	FDO	Deep large rockfish	0	0	0	0.1	0	0.3	0	0	0	0	0
j → a	FDO	Deep large rockfish	0.04	0.002	0.005	0.02	0.001	0	0.0003	0	0	0.01	0
a → a	FDO	Deep large rockfish	0	0.002	0	0.001	0	0.3	0.1	0	0	0	0.1
j → j	FDE	Misc. nearshore	0.05	0.01	0.05	0	0	0.1	0	0	0	0	0
a → j	FDE	Misc. nearshore	0	0	0	0	0	0	0	0	0	0	0
j → a	FDE	Misc. nearshore	0.0002	0.01	0.001	0	0	0.1	0	0	0	0	0.0002
a → a	FDE	Misc. nearshore	0.001	0	0.05	0	0	0.3	0	0	0	0	0
j → j	FDf	Small flatfish	0.01	0.01	0.001	0.01	0.001	0.1	0	0	0	0	0
a → j	FDf	Small flatfish	0.1	0	0	0	0	0	0	0	0	0	0
j → a	FDf	Small flatfish	0.1	0.001	0.001	0.01	0.001	0.001	0	0	0	0	0
a → a	FDf	Small flatfish	0.01	0	0	0	0	0	0	0	0	0	0
j → j	SHD	Large demersal sharks	0.1	0	0	0	0	0.2	0.01	0.05	0	0	0.3
a → j	SHD	Large demersal sharks	0.01	0	0	0	0	0.2	0.1	0	0	0	0.3
j → a	SHD	Large demersal sharks	0.1	0	0	0	0	0.2	0.01	0.05	0	0	0.3
a → a	SHD	Large demersal sharks	0.01	0	0	0	0	0.2	0.1	0	0	0	0.3
j → j	SHP	Misc. pelagic sharks	0.0001	0.0002	0.00005	0.005	0.005	0	0.01	0.05	0	0.005	0
a → j	SHP	Misc. pelagic sharks	0.001	0.001	0.001	0.005	0.001	0	0.1	0.05	0	0.0005	0
j → a	SHP	Misc. pelagic sharks	0.05	0.0002	0.00005	0.005	0.005	0	0.01	0.1	0.4	0.005	0.0001
a → a	SHP	Misc. pelagic sharks	0.0005	0.001	0.001	0.005	0.002	0	0.1	0.1	0.1	0.0005	0
j → j	SHB	Small demersal sharks	0.02	0.02	0.0005	0.02	0.01	0.1	0.003	0	0	0.01	0
a → j	SHB	Small demersal sharks	0.07	0	0	0	0	0.3	0	0	0	0	0
j → a	SHB	Small demersal sharks	0.05	0.01	0.003	0.02	0.01	0.001	0.003	0	0	0.01	0.02
a → a	SHB	Small demersal sharks	0.01	0	0	0	0	0.1	0.05	0	0	0	0
j → j	SHR	Shallow large rockfish	0.01	0.01	0.003	0.01	0.1	0.1	0	0	0	0	0
a → j	SHR	Shallow large rockfish	0.01	0	0.05	0	0	0.1	0	0	0	0	0
j → a	SHR	Shallow large rockfish	0.01	0.01	0.005	0.01	0.01	0.1	0	0	0	0	0
a → a	SHR	Shallow large rockfish	0.04	0	0.005	0	0	0.1	0	0	0	0	0
j → j	SSK	Skates and rays	0.01	0.01	0.001	0.02	0.01	0.1	0	0	0	0.01	0.02
a → j	SSK	Skates and rays	0.02	0	0	0	0	0.1	0	0	0	0	0
j → a	SSK	Skates and rays	0.03	0.01	0.001	0.02	0.02	0.01	0	0	0	0.01	0.02

Table B-2 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for additional prey including fish and sharks. Prey groups are listed by column. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDf	SHB	SHD	SHP	SHR	SSK
a → a	SSK	Skates and rays	0.02	0	0	0	0	0.1	0	0	0	0	0.05
j → j	SB	Surface seabirds	0	0.01	0.02	0	0	0	0	0	0	0.1	0
a → j	SB	Surface seabirds	0	0	0	0	0	0	0	0	0	0	0
j → a	SB	Surface seabirds	0	0.01	0.02	0	0	0	0	0	0	0.01	0
a → a	SB	Surface seabirds	0	0	0	0	0	0	0	0	0	0	0
j → j	SP	Diving seabirds	0.1	0.01	0.005	0.02	0.1	0	0	0	0	0.01	0
a → j	SP	Diving seabirds	0.3	0	0	0	0	0	0	0	0	0	0
j → a	SP	Diving seabirds	0.1	0.01	0.005	0.02	0.1	0	0	0	0	0.01	0
a → a	SP	Diving seabirds	0.3	0	0	0	0	0	0	0	0	0	0
j → j	REP	Transient orcas	0	0	0	0	0	0	0	0	0	0	0
a → j	REP	Transient orcas	0	0	0	0	0	0	0	0	0	0	0
j → a	REP	Transient orcas	0	0	0	0	0	0	0	0	0	0	0
a → a	REP	Transient orcas	0	0	0	0	0	0	0	0	0	0	0
j → j	PIN	Pinnipeds	0.1	0.0005	0.0001	0.005	0.003	0.01	0.001	0	0	0.003	0.0005
a → j	PIN	Pinnipeds	0.0005	0.001	0.001	0.005	0.001	0.01	0.01	0	0	0.0005	0.0005
j → a	PIN	Pinnipeds	0.1	0.0005	0.0001	0.005	0.003	0.01	0.001	0	0	0.003	0.0005
a → a	PIN	Pinnipeds	0.0005	0.001	0.0001	0.005	0.001	0.06	0.01	0	0	0.0005	0.0005
j → j	WHB	Baleen whales	0	0	0	0	0	0	0	0	0	0	0
a → j	WHB	Baleen whales	0	0	0	0	0	0	0	0	0	0	0
j → a	WHB	Baleen whales	0	0	0	0	0	0	0	0	0	0	0
a → a	WHB	Baleen whales	0	0	0	0	0	0	0	0	0	0	0
j → j	WHT	Toothed whales	0.055	0.0005	0.0001	0.001	0.001	0.001	0.001	0.1	0	0.003	0.001
a → j	WHT	Toothed whales	0.001	0.001	0.0001	0.001	0.001	0.006	0.001	0.1	0	0.0001	0.001
j → a	WHT	Toothed whales	0.055	0.0005	0.0001	0.001	0.003	0.001	0.001	0.1	0	0.003	0.001
a → a	WHT	Toothed whales	0.001	0.001	0.0003	0.001	0.001	0.006	0.001	0.1	0	0.0001	0.001
j → j	WDG	Otters	0.055	0	0.05	0	0	0.5	0	0	0	0.1	0
a → j	WDG	Otters	0.1	0	0.05	0	0	0.6	0	0	0	0	0
j → a	WDG	Otters	0.055	0	0.05	0	0	0.5	0	0	0	0.1	0
a → a	WDG	Otters	0.1	0	0.05	0	0	0.6	0	0	0	0.1	0
	ZG	Gelatinous zooplankton	0.00001	0.01	0.00001	0.0001	0.0005	0	0	0	0	0.0001	0

Table B-2 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for additional prey including fish and sharks. Prey groups are listed by column. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDf	SHB	SHD	SHP	SHR	SSK
	ZL	Large zooplankton	0	0	0	0	0	0	0	0	0	0	0
	ZM	Mesozooplankton	0	0	0	0	0	0	0	0	0	0	0
	ZS	Microzooplankton	0	0	0	0	0	0	0	0	0	0	0
	BD	Deposit feeders	0	0	0	0	0	0	0	0	0	0	0
	BO	Meiobenthos	0	0	0	0	0	0	0	0	0	0	0
	BC	Carnivorous infauna	0	0	0	0	0	0	0	0	0	0	0
	BFS	Shall. Benthic filter feeders	0	0	0	0	0	0	0	0	0	0	0
	BFF	Other benthic filter feeders	0	0	0	0	0	0	0	0	0	0	0
	BFD	Deep benthic filter feeders	0	0	0	0	0	0	0	0	0	0	0
	BMS	Shall. macro-zoobenthos	0.02	0.01	0.005	0.01	0.1	0.1	0.01	0	0	0.001	0.1
	BML	Mega-zoobenthos	0.0001	0.0001	0.00005	0.0001	0.0001	0.0001	0	0	0	0.0001	0
	BMD	Deep macro-zoobenthos	0	0	0	0	0	0	0	0	0	0	0
	BG	Benthic grazers	0	0	0	0	0	0	0	0	0	0	0
	CEP	Cephalopods	0.001	0.01	0.0005	0.001	0.1	0	0	0	0	0	0
	PWN	Shrimp	0	0	0	0	0	0	0	0	0	0	0
	PWN	Shrimp	0	0	0	0	0	0	0	0	0	0	0

* In the stages column, $j \rightarrow j$ signifies juvenile predation on juveniles, $a \rightarrow j$ signifies adult predation on juveniles, $j \rightarrow a$ signifies juvenile predation on adults, and $a \rightarrow a$ signifies adult predation on adults.

Table B-3. Consumption parameters (variable a in Equation 10) in the calibrated model for seabird and mammal prey. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group						
	Code	Group	SB	SP	PIN	REP	WHB	WHT	WDG
j → j	FPL	Large planktivores	0	0	0	0	0	0	0
a → j	FPL	Large planktivores	0	0	0	0	0	0	0
j → a	FPL	Large planktivores	0	0	0	0	0	0	0
a → a	FPL	Large planktivores	0	0	0	0	0	0	0
j → j	FPS	Small planktivores	0	0	0	0	0	0	0
a → j	FPS	Small planktivores	0	0	0	0	0	0	0
j → a	FPS	Small planktivores	0	0	0	0	0	0	0
a → a	FPS	Small planktivores	0	0	0	0	0	0	0
j → j	FVD	Large flatfish	0	0	0	0	0	0	0
a → j	FVD	Large flatfish	0	0	0	0	0	0	0
j → a	FVD	Large flatfish	0	0	0	0	0	0	0
a → a	FVD	Large flatfish	0	0	0	0	0	0	0
j → j	FVS	Large demersal predators	0	0	0	0	0	0	0
a → j	FVS	Large demersal predators	0	0	0	0	0	0	0
j → a	FVS	Large demersal predators	0	0	0	0	0	0	0
a → a	FVS	Large demersal predators	0	0	0	0	0	0	0
j → j	FVT	Large pelagic predators	0	0	0	0	0	0	0
a → j	FVT	Large pelagic predators	0	0	0	0	0	0	0
j → a	FVT	Large pelagic predators	0	0	0	0	0	0	0
a → a	FVT	Large pelagic predators	0	0	0	0	0	0	0
j → j	FVO	Shearwaters	0	0	0	0	0	0	0
a → j	FVO	Shearwaters	0	0	0	0	0	0	0
j → a	FVO	Shearwaters	0	0	0	0	0	0	0
a → a	FVO	Shearwaters	0	0	0	0	0	0	0
j → j	FVB	Salmon	0	0	0	0	0	0	0
a → j	FVB	Salmon	0	0	0	0	0	0	0
j → a	FVB	Salmon	0	0	0	0	0	0	0
a → a	FVB	Salmon	0	0	0	0	0	0	0
j → j	FMM	Hake	0	0	0	0	0	0	0
a → j	FMM	Hake	0	0	0	0	0	0	0
j → a	FMM	Hake	0	0	0	0	0	0	0
a → a	FMM	Hake	0	0	0	0	0	0	0
j → j	FMN	Sablefish	0	0	0	0	0	0	0
a → j	FMN	Sablefish	0	0	0	0	0	0	0
j → a	FMN	Sablefish	0	0	0	0	0	0	0
a → a	FMN	Sablefish	0	0	0	0	0	0	0
j → j	FBP	Deep vertical migrators	0	0	0	0	0	0	0
a → j	FBP	Deep vertical migrators	0	0	0	0	0	0	0
j → a	FBP	Deep vertical migrators	0	0	0	0	0	0	0
a → a	FBP	Deep vertical migrators	0	0	0	0	0	0	0
j → j	FDD	Deep miscellaneous fish	0	0	0	0	0	0	0
a → j	FDD	Deep miscellaneous fish	0	0	0	0	0	0	0
j → a	FDD	Deep miscellaneous fish	0	0	0	0	0	0	0
a → a	FDD	Deep miscellaneous fish	0	0	0	0	0	0	0
j → j	FDS	Midwater rockfish	0	0	0	0	0	0	0
a → j	FDS	Midwater rockfish	0	0	0	0	0	0	0

Table B-3 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for seabird and mammal prey. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group						
	Code	Group	SB	SP	PIN	REP	WHB	WHT	WDG
j → a	FDS	Midwater rockfish	0	0	0	0	0	0	0
a → a	FDS	Midwater rockfish	0	0	0	0	0	0	0
j → j	FDB	Small shallow rockfish	0	0	0	0	0	0	0
a → j	FDB	Small shallow rockfish	0	0	0	0	0	0	0
j → a	FDB	Small shallow rockfish	0	0	0	0	0	0	0
a → a	FDB	Small shallow rockfish	0	0	0	0	0	0	0
j → j	FDC	Deep small rockfish	0	0	0	0	0	0	0
a → j	FDC	Deep small rockfish	0	0	0	0	0	0	0
j → a	FDC	Deep small rockfish	0	0	0	0	0	0	0
a → a	FDC	Deep small rockfish	0	0	0	0	0	0	0
j → j	FDO	Deep large rockfish	0	0	0	0	0	0	0
a → j	FDO	Deep large rockfish	0	0	0	0	0	0	0
j → a	FDO	Deep large rockfish	0.3	0.3	0.1	0	0	0	0.1
a → a	FDO	Deep large rockfish	0	0	0	0	0	0	0
j → j	FDE	Miscellaneous nearshore	0	0	0	0	0	0	0
a → j	FDE	Miscellaneous nearshore	0	0	0	0	0	0	0
j → a	FDE	Miscellaneous nearshore	0	0	0	0	0	0	0
a → a	FDE	Miscellaneous nearshore	0	0	0	0	0	0	0
j → j	FDf	Small flatfish	0	0	0	0	0	0	0
a → j	FDf	Small flatfish	0	0	0	0	0	0	0
j → a	FDf	Small flatfish	0	0	0	0	0	0	0
a → a	FDf	Small flatfish	0	0	0	0	0	0	0
j → j	SHD	Large demersal sharks	0	0	0	0	0	0	0
a → j	SHD	Large demersal sharks	0	0	0	0	0	0	0
j → a	SHD	Large demersal sharks	0	0	0	0	0	0	0
a → a	SHD	Large demersal sharks	0	0	0	0	0	0	0
j → j	SHP	Misc. pelagic sharks	0.1	0.3	0.3	0	0	0	0.4
a → j	SHP	Misc. pelagic sharks	0.5	0.5	0.3	0	0	0	0.4
j → a	SHP	Misc. pelagic sharks	0.1	0.3	0.25	0.1	0	0.1	0.4
a → a	SHP	Misc. pelagic sharks	0.4	0.5	0.3	0.1	0.2	0.1	0.4
j → j	SHB	Small demersal sharks	0	0	0	0	0	0	0
a → j	SHB	Small demersal sharks	0	0	0	0	0	0	0
j → a	SHB	Small demersal sharks	0	0	0	0	0	0	0
a → a	SHB	Small demersal sharks	0	0	0	0	0	0	0
j → j	SHR	Shallow large rockfish	0	0	0	0	0	0	0
a → j	SHR	Shallow large rockfish	0	0	0	0	0	0	0
j → a	SHR	Shallow large rockfish	0	0	0	0	0	0	0
a → a	SHR	Shallow large rockfish	0	0	0	0	0	0	0
j → j	SSK	Skates and rays	0	0	0	0	0	0	0
a → j	SSK	Skates and rays	0	0	0	0	0	0	0
j → a	SSK	Skates and rays	0	0	0	0	0	0	0
a → a	SSK	Skates and rays	0	0	0	0	0	0	0
j → j	SB	Surface seabirds	0	0	0	0	0	0	0
a → j	SB	Surface seabirds	0	0	0	0	0	0	0
j → a	SB	Surface seabirds	0	0	0	0	0	0	0
a → a	SB	Surface seabirds	0	0	0	0	0	0	0
j → j	SP	Diving seabirds	0	0	0	0	0	0	0
a → j	SP	Diving seabirds	0	0	0	0	0	0	0

Table B-3 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for seabird and mammal prey. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group						
	Code	Group	SB	SP	PIN	REP	WHB	WHT	WDG
j → a	SP	Diving seabirds	0	0	0	0	0	0	0
a → a	SP	Diving seabirds	0	0	0	0	0	0	0
j → j	REP	Transient orcas	0.1	0.3	0.3	0	0.002	0.1	0.6
a → j	REP	Transient orcas	0.4	0.5	0.3	0	0.2	0.1	0.6
j → a	REP	Transient orcas	0.1	0.3	0.3	0	0.002	0.1	0.6
a → a	REP	Transient orcas	0.4	0.5	0.3	0	0.2	0.1	0.6
j → j	PIN	Pinnipeds	0	0	0	0	0	0	0
a → j	PIN	Pinnipeds	0	0	0	0	0	0	0
j → a	PIN	Pinnipeds	0	0	0	0	0	0	0
a → a	PIN	Pinnipeds	0	0	0	0	0	0	0
j → j	WHB	Baleen whales	0	0	0	0	0	0	0
a → j	WHB	Baleen whales	0	0	0	0	0	0	0
j → a	WHB	Baleen whales	0	0	0	0	0	0	0
a → a	WHB	Baleen whales	0	0	0	0	0	0	0
j → j	WHT	Toothed whales	0	0	0	0	0	0	0
a → j	WHT	Toothed whales	0	0	0	0	0	0	0
j → a	WHT	Toothed whales	0	0	0	0	0	0	0
a → a	WHT	Toothed whales	0	0	0	0	0	0	0
j → j	WDG	Otters	0	0	0	0	0	0	0
a → j	WDG	Otters	0	0	0	0	0	0	0
j → a	WDG	Otters	0	0	0	0	0	0	0
a → a	WDG	Otters	0	0	0	0	0	0	0
	ZG	Gelatinous zooplankton	0	0	0	0	0	0	0
	ZL	Large zooplankton	0	0	0	0	0	0	0
	ZM	Mesozooplankton	0	0	0	0	0	0	0
	ZS	Microzooplankton	0	0	0	0	0	0	0
	BD	Deposit feeders	0	0	0	0	0	0	0
	BO	Meiobenthos	0	0	0	0	0	0	0
	BC	Carnivorous infauna	0	0	0	0	0	0	0
	BFS	Shallow benthic filter feeders	0	0	0	0	0	0	0
	BFF	Other benthic filter feeders	0	0	0	0	0	0	0
	BFD	Deep benthic filter feeders	0	0	0	0	0	0	0
	BMS	Shallow macro-zoobenthos	0	0	0	0	0	0	0
	BML	Mega-zoobenthos	0	0	0	0	0	0	0
	BMD	Deep macro-zoobenthos	0	0	0	0	0	0	0
	BG	Benthic grazers	0	0	0	0	0	0	0
	CEP	Cephalopods	0	0	0	0	0	0	0
	PWN	Shrimp	0	0	0	0	0	0	0
	PWN	Shrimp	0	0	0	0	0	0	0

* In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

Table B-4. Consumption parameters (variable a in Equation 10) of benthic prey in the calibrated model. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
j → j	FPL	Large planktivores	0	0	0	0	0	0	0	0.01	0
a → j	FPL	Large planktivores	0	0	0	0	0	0	0	0.01	0
j → a	FPL	Large planktivores	0	0	0	0	0	0	0.1	0.01	0
a → a	FPL	Large planktivores	0	0	0	0	0	0	0.1	0.01	0
j → j	FPS	Small planktivores	0	0	0	0	0	0	0	0.1	0
a → j	FPS	Small planktivores	0	0	0	0	0	0	0	0.1	0
j → a	FPS	Small planktivores	0	0	0	0	0	0	0	0.1	0
a → a	FPS	Small planktivores	0	0	0	0	0	0	0	0.1	0
j → j	FVD	Large flatfish	0	0.02	0.1	0	0.1	0.05	0.1	0.1	0.1
a → j	FVD	Large flatfish	0	0.02	0.1	0	0.1	0.05	0.1	0.1	0.1
j → a	FVD	Large flatfish	0	0.02	0.1	0	0.1	0.05	0.1	0.1	0.1
a → a	FVD	Large flatfish	0	0.02	0.1	0	0.1	0.05	0.1	0.1	0.1
j → j	FVS	Large demersal predators	0	0.1	0.1	0	0.1	0.05	0.1	0.1	0.1
a → j	FVS	Large demersal predators	0	0.1	0.1	0	0.1	0.05	0.1	0.1	0.1
j → a	FVS	Large demersal predators	0	0.1	0.1	0	0.1	0.05	0.1	0.1	0.1
a → a	FVS	Large demersal predators	0	0.1	0.1	0	0.1	0.05	0.1	0.1	0.1
j → j	FVT	Large pelagic predators	0	0	0	0	0	0	0	0.01	0
a → j	FVT	Large pelagic predators	0	0	0	0	0	0	0	0.01	0
j → a	FVT	Large pelagic predators	0	0	0	0	0	0	0	0.01	0
a → a	FVT	Large pelagic predators	0	0	0	0	0	0	0	0.01	0
j → j	FVO	Shearwaters	0	0	0	0	0	0	0	0	0
a → j	FVO	Shearwaters	0	0	0	0	0	0	0	0	0
j → a	FVO	Shearwaters	0	0	0	0	0	0	0	0	0
a → a	FVO	Shearwaters	0	0	0	0	0	0	0	0	0
j → j	FVB	Salmon	0	0	0	0	0	0	0	0.1	0
a → j	FVB	Salmon	0	0	0	0	0	0	0	0.1	0
j → a	FVB	Salmon	0	0	0	0	0	0	0	0	0
a → a	FVB	Salmon	0	0	0	0	0	0	0	0	0
j → j	FMM	Hake	0	0	0	0	0	0.05	0.1	0.1	0
a → j	FMM	Hake	0	0	0	0	0	0.05	0.1	0.1	0.1
j → a	FMM	Hake	0	0	0	0	0	0.05	0.1	0.1	0.1

Table B-4 continued. Consumption parameters (variable a in Equation 10) of benthic prey in the calibrated model. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
a → a	FMM	Hake	0	0	0	0	0	0.05	0.1	0.1	0.1
j → j	FMN	Sablefish	0	0.02	0.15	0.01	0.05	0.05	0.1	0.1	0.1
a → j	FMN	Sablefish	0	0.02	0.15	0.01	0.05	0.05	0.1	0.1	0.1
j → a	FMN	Sablefish	0	0.02	0.15	0.01	0.05	0.05	0.1	0.1	0.1
a → a	FMN	Sablefish	0	0.02	0.15	0.01	0.05	0.05	0.1	0.1	0.1
j → j	FBP	Deep vertical migrators	0	0	0	0	0	0	0	0.01	0
a → j	FBP	Deep vertical migrators	0	0	0	0	0	0	0	0.01	0
j → a	FBP	Deep vertical migrators	0	0	0	0	0	0	0	0.01	0
a → a	FBP	Deep vertical migrators	0	0	0	0	0	0	0	0.01	0
j → j	FDD	Deep miscellaneous fish	0	0.01	0.15	0.01	0.05	0.05	0.1	0.1	0.1
a → j	FDD	Deep miscellaneous fish	0	0.01	0.15	0.01	0.05	0.05	0.1	0.1	0.1
j → a	FDD	Deep miscellaneous fish	0	0.01	0.15	0.01	0.05	0.05	0.1	0.1	0.1
a → a	FDD	Deep miscellaneous fish	0	0.01	0.15	0.01	0.05	0.05	0.1	0.1	0.1
j → j	FDS	Midwater rockfish	0	0.01	0	0	0	0.05	0.1	0.1	0.1
a → j	FDS	Midwater rockfish	0	0.01	0	0	0	0.05	0.1	0.1	0.1
j → a	FDS	Midwater rockfish	0	0.01	0	0	0	0.05	0.1	0.1	0.1
a → a	FDS	Midwater rockfish	0	0.01	0	0	0	0.05	0.1	0.1	0.1
j → j	FDB	Small shallow rockfish	0	0.1	0	0	0.1	0.4	0.1	0.1	0.1
a → j	FDB	Small shallow rockfish	0	0.1	0	0	0.1	0.4	0.1	0.1	0.1
j → a	FDB	Small shallow rockfish	0	0.1	0	0	0.1	0.4	0.1	0.1	0.1
a → a	FDB	Small shallow rockfish	0	0.1	0	0	0.1	0.4	0.1	0.1	0.1
j → j	FDC	Deep small rockfish	0	0.1	0.05	0	0	0.4	0.1	0.1	0.1
a → j	FDC	Deep small rockfish	0	0.1	0.05	0	0	0.4	0.1	0.1	0.1
j → a	FDC	Deep small rockfish	0	0.1	0.05	0	0	0.4	0.1	0.1	0.1
a → a	FDC	Deep small rockfish	0	0.1	0.05	0	0	0.4	0.1	0.1	0.1
j → j	FDO	Deep large rockfish	0	0.02	0.05	0	0	0.05	0.1	0.1	0.1
a → j	FDO	Deep large rockfish	0	0.02	0.05	0	0	0.05	0.1	0.1	0.1
j → a	FDO	Deep large rockfish	0	0	0	0	0	0.05	0.1	0	0
a → a	FDO	Deep large rockfish	0	0.02	0.05	0	0	0.05	0.1	0.1	0.1
j → j	FDE	Miscellaneous nearshore	0	0.005	0	0	0.08	0.02	0.1	0.05	0
a → j	FDE	Miscellaneous nearshore	0	0.005	0	0	0.08	0.02	0.1	0.05	0

Table B-4 continued. Consumption parameters (variable a in Equation 10) of benthic prey in the calibrated model. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
j → a	FDE	Miscellaneous nearshore	0	0.005	0	0	0.08	0.02	0.1	0.05	0
a → a	FDE	Miscellaneous nearshore	0	0.005	0	0	0.08	0.02	0.1	0.05	0
j → j	FDF	Small flatfish	0	0.03	0.05	0.01	0.1	0.02	0.1	0.1	0.1
a → j	FDF	Small flatfish	0	0.03	0.05	0.01	0.1	0.02	0.1	0.1	0.1
j → a	FDF	Small flatfish	0	0.03	0.05	0.01	0.1	0.02	0.1	0.1	0.1
a → a	FDF	Small flatfish	0	0.03	0.05	0.01	0.1	0.02	0.1	0.1	0.1
j → j	SHD	Large demersal sharks	0	0.02	0.15	0.1	0.1	0.02	0.1	0.1	0.1
a → j	SHD	Large demersal sharks	0	0.02	0.15	0.1	0.1	0.02	0.1	0.1	0.1
j → a	SHD	Large demersal sharks	0	0.02	0.15	0.1	0.1	0.02	0.1	0.1	0.1
a → a	SHD	Large demersal sharks	0	0.02	0.15	0.1	0.1	0.02	0.1	0.1	0.1
j → j	SHP	Miscellaneous pelagic sharks	0	0	0	0	0	0.1	0.1	0	0
a → j	SHP	Miscellaneous pelagic sharks	0	0	0	0	0	0.1	0.1	0	0
j → a	SHP	Miscellaneous pelagic sharks	0	0	0	0	0	0.1	0.1	0	0
a → a	SHP	Miscellaneous pelagic sharks	0	0	0	0	0	0.1	0.1	0	0
j → j	SHB	Small demersal sharks	0	0.1	0.1	0.05	0	0.1	0.1	0.1	0.1
a → j	SHB	Small demersal sharks	0	0.1	0.1	0.05	0	0.1	0.1	0.1	0.1
j → a	SHB	Small demersal sharks	0	0.1	0.1	0.05	0	0.1	0.1	0.1	0.1
a → a	SHB	Small demersal sharks	0	0.1	0.1	0.05	0	0.1	0.1	0.1	0.1
j → j	SHR	Shallow large rockfish	0	0.005	0	0	0	0.02	0.1	0.05	0
a → j	SHR	Shallow large rockfish	0	0.005	0	0	0	0.02	0.1	0.05	0
j → a	SHR	Shallow large rockfish	0	0.005	0	0	0	0.02	0.1	0.05	0
a → a	SHR	Shallow large rockfish	0	0.005	0	0	0	0.02	0.1	0.05	0
j → j	SSK	Skates and rays	0	0.1	0.1	0.05	0.1	0.2	0.1	0.1	0.1
a → j	SSK	Skates and rays	0	0.1	0.1	0.05	0.1	0.2	0.1	0.1	0.1
j → a	SSK	Skates and rays	0	0.1	0.1	0.05	0.1	0.2	0.1	0.1	0.1
a → a	SSK	Skates and rays	0	0.1	0.1	0.05	0.1	0.2	0.1	0.1	0.1
j → j	SB	Surface seabirds	0	0.1	0	0	0	0	0	0	0
a → j	SB	Surface seabirds	0	0.1	0	0	0	0	0	0	0
j → a	SB	Surface seabirds	0	0.1	0	0	0	0	0	0	0
a → a	SB	Surface seabirds	0	0.1	0	0	0	0	0	0	0
j → j	SP	Diving seabirds	0	0.005	0	0	0	0.02	0	0.05	0

Table B-4 continued. Consumption parameters (variable a in Equation 10) of benthic prey in the calibrated model. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
a → j	SP	Diving seabirds	0	0.005	0	0	0	0.02	0	0.05	0
j → a	SP	Diving seabirds	0	0.005	0	0	0	0.02	0	0.05	0
a → a	SP	Diving seabirds	0	0.005	0	0	0	0.02	0	0.05	0
j → j	REP	Transient orcas	0	0	0	0	0	0	0	0	0
a → j	REP	Transient orcas	0	0	0	0	0	0	0	0	0
j → a	REP	Transient orcas	0	0	0	0	0	0	0	0	0
a → a	REP	Transient orcas	0	0	0	0	0	0	0	0	0
j → j	PIN	Pinnipeds	0	0.05	0	0	0.1	0.1	0.1	0	0
a → j	PIN	Pinnipeds	0	0.5	0	0	0.1	0.1	0.1	0	0
j → a	PIN	Pinnipeds	0	0.05	0	0	0.1	0.1	0.1	0	0
a → a	PIN	Pinnipeds	0	0.5	0	0	0.1	0.1	0.1	0	0
j → j	WHB	Baleen whales	0	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1
a → j	WHB	Baleen whales	0	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1
j → a	WHB	Baleen whales	0	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1
a → a	WHB	Baleen whales	0	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1
j → j	WHT	Toothed whales	0	0.001	0.1	0	0	0.002	0.1	0	0
a → j	WHT	Toothed whales	0	0.001	0.1	0	0	0.002	0.1	0	0
j → a	WHT	Toothed whales	0	0.001	0.1	0	0	0.002	0.1	0	0
a → a	WHT	Toothed whales	0	0.001	0.1	0	0	0.002	0.1	0	0
j → j	WDG	Otters	0	0.1	0	0.5	0.1	0.2	0.1	0.1	0.1
a → j	WDG	Otters	0	0.1	0	0.5	0.1	0.2	0.1	0.1	0.1
j → a	WDG	Otters	0	0.1	0	0.5	0.1	0.2	0.1	0.1	0.1
a → a	WDG	Otters	0	0.1	0	0.5	0.1	0.2	0.1	0.1	0.1
	ZG	Gelatinous zooplankton	0	0	0	0	0	0	0	0.01	0
	ZL	Large zooplankton	0	0	0	0	0	0	0	0.01	0
	ZM	Mesozooplankton	0	0	0	0	0	0	0	0	0
	ZS	Microzooplankton	0	0	0	0	0	0	0	0	0
	BD	Deposit feeders	0	0	0	0	0	0	0	0.1	0
	BO	Meiobenthos	0	0	0	0	0	0	0	0	0
	BC	Carnivorous infauna	0	0	0	0	0	0	0	0.01	0
	BFS	Shallow benthic filter feeders	0	0	0	0	0	0	0	0	0

Table B-4 continued. Consumption parameters (variable a in Equation 10) of benthic prey in the calibrated model. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
	BFF	Other benthic filter feeders	0	0	0	0	0	0	0	0	0
	BFD	Deep benthic filter feeders	0	0	0	0	0	0.001	0	0.01	0.1
	BMS	Shallow macro-zoobenthos	0	0.001	0	0	0.001	0.003	0.1	0.05	0
	BML	Mega-zoobenthos	0	3E-05	0	0.000	0	0.0001	0	0.01	0.1
	BMD	Deep macro-zoobenthos	0	0.0002	0	0.001	0.001	0.001	0	0.01	0
	BG	Benthic grazers	0	0	0	0	0	0	0	0	0
	CEP	Cephalopods	0	0	0	0	0	0	0	0.01	0
	PWN	Shrimp	0	0	0	0	0	0	0	0.01	0
	PWN	Shrimp	0	0	0	0	0	0	0	0.01	0

^a In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

^b BFS = shallow benthic filter feeders.

^c BFF = other benthic filter feeders.

^d BFD = deep benthic filter feeders.

^e BG = benthic grazers.

^f BMD = deep macro-zoobenthos.

^g BML = mega-zoobenthos.

^h BMS = shallow macro-zoobenthos.

ⁱ BD = deposit feeders.

^j BC = carnivorous infauna.

Table B-5. Consumption parameters (variable a in Equation 10) in the calibrated model for prey including plankton, shrimp, and squid. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWNjuv ^g	CEP ^h
j → j	FPL	Large planktivores	0.1	0.2	0.01	0.0000	0	0.00001	0
a → j	FPL	Large planktivores	0.1	0.2	0.01	0.0000	0	0.00001	0
j → a	FPL	Large planktivores	0.0001	0.01	0.03	0	0	0.00001	0
a → a	FPL	Large planktivores	0.0001	0.01	0.03	0	0	0.00001	0
j → j	FPS	Small planktivores	0.00004	0.0002	0.0002	0.0000	0	0.0001	0
a → j	FPS	Small planktivores	0.00004	0.0002	0.0002	0.0000	0	0.0001	0
j → a	FPS	Small planktivores	0.0002	0.0002	0.0002	0	0	0.0001	0
a → a	FPS	Small planktivores	0.00004	0.0002	0.0002	0	0	0.0001	0
j → j	FVD	Large flatfish	0	0.01	0	0	0.005	0.01	0.03
a → j	FVD	Large flatfish	0	0.01	0	0	0.005	0.01	0.03
j → a	FVD	Large flatfish	0	0.01	0	0	0.005	0.01	0.03
a → a	FVD	Large flatfish	0	0.01	0	0	0.005	0.01	0.03
j → j	FVS	Large demersal predators	0	0.05	0.005	0	0.008	0.01	0.05
a → j	FVS	Large demersal predators	0	0.05	0.005	0	0.008	0.01	0.05
j → a	FVS	Large demersal predators	0	0.01	0	0	0.008	0.01	0.05
a → a	FVS	Large demersal predators	0	0.01	0	0	0.008	0.01	0.05
j → j	FVT	Large pelagic predators	0.0005	0.01	0.05	0	0	0.2	0.2
a → j	FVT	Large pelagic predators	0.0005	0.075	0.05	0	0	0.1	0.1
j → a	FVT	Large pelagic predators	0.0005	0.075	0	0	0	0.1	0.1
a → a	FVT	Large pelagic predators	0.0005	0.075	0	0	0	0.1	0.1
j → j	FVO	Shearwaters	0.001	0.001	0	0	0	0.001	0
a → j	FVO	Shearwaters	0.001	0.001	0	0	0	0.001	0
j → a	FVO	Shearwaters	0.001	0.001	0	0	0	0.001	0
a → a	FVO	Shearwaters	0.001	0.001	0	0	0	0.001	0
j → j	FVB	Salmon	0.003	0.01	0.01	0	0	0.01	0.01
a → j	FVB	Salmon	0.004	0.01	0.01	0	0	0.01	0.01
j → a	FVB	Salmon	0	0	0	0	0	0	0
a → a	FVB	Salmon	0	0	0	0	0	0	0
j → j	FMM	Hake	0.000003	0.00001	0.00001	0	0.00001	0.00001	0.001
a → j	FMM	Hake	0.000003	0.00001	0.00001	0	0.00001	0.00001	0.001
j → a	FMM	Hake	0.000003	0.00001	0	0	0.00001	0.00001	0.001
a → a	FMM	Hake	0.000003	0.00001	0	0	0.00001	0.00001	0.001

Table B-5 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for prey including plankton, shrimp, and squid. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWNjuv ^g	CEP ^h
j → j	FMN	Sablefish	0.0003	0.0001	0.001	0	0.001	0.001	0.01
a → j	FMN	Sablefish	0.0003	0.0001	0.001	0	0.001	0.001	0.01
j → a	FMN	Sablefish	0.0003	0.0001	0	0	0.001	0.001	0.01
a → a	FMN	Sablefish	0.0005	0.0001	0	0	0.001	0.001	0.01
j → j	FBP	Deep vertical migrators	0.0005	0.001	0.0005	0.002	0	0.001	0
a → j	FBP	Deep vertical migrators	0.0005	0.001	0.0005	0.002	0	0.001	0
j → a	FBP	Deep vertical migrators	0.0005	0.001	0.0005	0	0	0.001	0
a → a	FBP	Deep vertical migrators	0.0005	0.001	0.0005	0	0	0.001	0
j → j	FDD	Deep misc. fish	0	0.01	0	0	0.007	0.01	0
a → j	FDD	Deep misc. fish	0	0.01	0	0	0.007	0.01	0
j → a	FDD	Deep misc. fish	0	0.01	0	0	0.007	0.01	0
a → a	FDD	Deep misc. fish	0	0.01	0	0	0.007	0.01	0
j → j	FDS	Midwater rockfish	0.00001	0.00001	0.0001	0	0.00001	0.00001	0.005
a → j	FDS	Midwater rockfish	0.00001	0.00001	0.0001	0	0.00001	0.00001	0.005
j → a	FDS	Midwater rockfish	0.00001	0.00001	0	0	0.00001	0.00001	0.005
a → a	FDS	Midwater rockfish	0.00001	0.00001	0	0	0.00001	0.00001	0.005
j → j	FDB	Small shallow rockfish	0.001	0.001	0.001	0	0.001	0.001	0
a → j	FDB	Small shallow rockfish	0.001	0.001	0.001	0	0.001	0.001	0
j → a	FDB	Small shallow rockfish	0.001	0.001	0.001	0	0.001	0.001	0
a → a	FDB	Small shallow rockfish	0.001	0.001	0.001	0	0.001	0.001	0
j → j	FDC	Deep small rockfish	0.0005	0.001	0.001	0	0.001	0.001	0
a → j	FDC	Deep small rockfish	0.0005	0.001	0.001	0	0.001	0.001	0
j → a	FDC	Deep small rockfish	0.0005	0.001	0.001	0	0.001	0.001	0
a → a	FDC	Deep small rockfish	0.0005	0.001	0.001	0	0.001	0.001	0
j → j	FDO	Deep large rockfish	0.0001	0.001	0.001	0	0.001	0.001	0.001
a → j	FDO	Deep large rockfish	0.0003	0.001	0.001	0	0.001	0.001	0.001
j → a	FDO	Deep large rockfish	0	0	0	0	0	0.001	0.001
a → a	FDO	Deep large rockfish	0.0005	0.001	0	0	0.001	0.001	0.001
j → j	FDE	Misc. nearshore	0.0005	0.1	0.05	0	0.01	0.1	0
a → j	FDE	Misc. nearshore	0.0005	0.1	0.05	0	0.01	0.1	0
j → a	FDE	Misc. nearshore	0.0005	0.1	0.05	0	0.01	0.1	0

Table B-5 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for prey including plankton, shrimp, and squid.
 A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWNjuv ^g	CEP ^h
a → a	FDE	Misc. nearshore	0.0005	0.1	0.05	0	0.01	0.1	0
j → j	FDF	Small flatfish	0.0001	0.001	0	0	0.001	0.001	0
a → j	FDF	Small flatfish	0.0001	0.001	0	0	0.001	0.001	0
j → a	FDF	Small flatfish	0.0001	0.001	0	0	0.001	0.001	0
a → a	FDF	Small flatfish	0.0001	0.001	0	0	0.001	0.001	0
j → j	SHD	Large demersal sharks	0	0	0	0	0.1	0.1	0.1
a → j	SHD	Large demersal sharks	0	0	0	0	0.1	0.1	0.1
j → a	SHD	Large demersal sharks	0	0	0	0	0.1	0.1	0.1
a → a	SHD	Large demersal sharks	0	0	0	0	0.1	0.1	0.1
j → j	SHP	Misc. pelagic sharks	0	0	0	0	0	0.1	0.1
a → j	SHP	Misc. pelagic sharks	0	0	0	0	0	0.1	0.1
j → a	SHP	Misc. pelagic sharks	0	0	0	0	0	0.1	0.1
a → a	SHP	Misc. pelagic sharks	0	0	0	0	0	0.1	0.1
j → j	SHB	Small demersal sharks	0.001	0.01	0	0	0.005	0.01	0
a → j	SHB	Small demersal sharks	0.001	0.01	0	0	0.005	0.01	0
j → a	SHB	Small demersal sharks	0.001	0.01	0	0	0.005	0.01	0
a → a	SHB	Small demersal sharks	0.001	0.01	0	0	0.005	0.01	0
j → j	SHR	Shallow large rockfish	0.0005	0.01	0.001	0	0.005	0.01	0.05
a → j	SHR	Shallow large rockfish	0.0005	0.01	0.001	0	0.005	0.01	0.05
j → a	SHR	Shallow large rockfish	0.0005	0.01	0	0	0.005	0.01	0.05
a → a	SHR	Shallow large rockfish	0.0005	0.01	0	0	0.005	0.01	0.05
j → j	SSK	Skates and rays	0	0	0	0	0.01	0	0
a → j	SSK	Skates and rays	0	0	0	0	0.01	0	0
j → a	SSK	Skates and rays	0	0	0	0	0.01	0	0
a → a	SSK	Skates and rays	0	0	0	0	0.01	0	0
j → j	SB	Surface seabirds	0.05	0.1	0	0	0	0.1	0
a → j	SB	Surface seabirds	0.05	0.1	0	0	0	0.1	0
j → a	SB	Surface seabirds	0.05	0.1	0	0	0	0.1	0
a → a	SB	Surface seabirds	0.05	0.1	0	0	0	0.1	0
j → j	SP	Diving seabirds	0.0005	0.1	0.01	0	0.1	0.1	0
a → j	SP	Diving seabirds	0.0005	0.1	0.01	0	0.1	0.1	0

Table B-5 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for prey including plankton, shrimp, and squid. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWNjuv ^g	CEP ^h
j → a	SP	Diving seabirds	0.0005	0.1	0.01	0	0.1	0.1	0
a → a	SP	Diving seabirds	0.0005	0.1	0.01	0	0.1	0.1	0
j → j	REP	Transient orcas	0	0	0	0	0	0	0
a → j	REP	Transient orcas	0	0	0	0	0	0	0
j → a	REP	Transient orcas	0	0	0	0	0	0	0
a → a	REP	Transient orcas	0	0	0	0	0	0	0
j → j	PIN	Pinnipeds	0	0.01	0	0	0.01	0.01	0.01
a → j	PIN	Pinnipeds	0	0.01	0	0	0.01	0.01	0.01
j → a	PIN	Pinnipeds	0	0.01	0	0	0.01	0.01	0.01
a → a	PIN	Pinnipeds	0	0.01	0	0	0.01	0.01	0.01
j → j	WHB	Baleen whales	0.000005	0.1	0.00002	0	0.00001	0.0001	0
a → j	WHB	Baleen whales	0.000005	0.1	0.00002	0	0.00001	0.0001	0
j → a	WHB	Baleen whales	0.000005	0.01	0.00002	0	0.00001	0.0001	0
a → a	WHB	Baleen whales	0.000005	0.01	0.00002	0	0.00001	0.0001	0
j → j	WHT	Toothed whales	0	0.001	0	0	0	0.001	0.015
a → j	WHT	Toothed whales	0	0.001	0	0	0	0.001	0.015
j → a	WHT	Toothed whales	0	0.001	0	0	0	0.001	0.015
a → a	WHT	Toothed whales	0	0.001	0	0	0	0.001	0.015
j → j	WDG	Otters	0	0.1	0	0	0.1	0.1	0.1
a → j	WDG	Otters	0	0.1	0	0	0.1	0.1	0.1
j → a	WDG	Otters	0	0.1	0	0	0.1	0.1	0.1
a → a	WDG	Otters	0	0.1	0	0	0.1	0.1	0.1
	ZG	Gelatinous zooplankton	0.00005	0.0008	0.001	0.0002	0	0.01	0
	ZL	Large zooplankton	0.0002	0.0008	0.001	0.0002	0	0	0
	ZM	Mesozooplankton	0	0	0.00008	0.0001	0	0	0
	ZS	Microzooplankton	0	0	0	0.0002	0	0	0
	BD	Deposit feeders	0	0	0.001	0.0002	0	0	0
	BO	Meiobenthos	0	0	0	0.00001	0	0	0
	BC	Carnivorous infauna	0	0	0	0	0	0	0
	BFS	Shall. benthic filter feeders	0	0	0.001	0.002	0	0	0
	BFF	Other benthic filter feeders	0	0	0.008	0.0001	0	0	0

Table B-5 continued. Consumption parameters (variable a in Equation 10) in the calibrated model for prey including plankton, shrimp, and squid. A value of 0 indicates cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWNjuv ^g	CEP ^h
	BFD	Deep benthic filter feeders	0	0.001	0.001	0.002	0.01	0	0
	BMS	Shallow macro-zoobenthos	0	0	0	0	0.001	0.001	0
	BML	Mega-zoobenthos	0	0	0.001	0	0.001	0	0
	BMD	Deep macro-zoobenthos	0	0	0	0	0.01	0	0
	BG	Benthic grazers	0	0	0	0	0	0	0
	CEP	Cephalopods	0.001	0.001	0.005	0	0	0.01	0
	PWN	Shrimp	0	0	0	0	0.00001	0	0
	PWN	Shrimp	0	0	0	0	0.00001	0	0

^a In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

^b ZG = gelatinous zooplankton.

^c ZL = large zooplankton.

^d ZM = mesozooplankton.

^e ZS = microzooplankton.

^f PWN = shrimp.

^g PWNjuv = juvenile shrimp.

^h CEP = cephalopods.

Table B-6. Parameters in the calibrated model for consumption (variable a in Equation 10) of macroalgae, seagrass, bacteria, meiobenthos, detritus, and carrion. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										Lg. phyto-plankt.	Sm. phyto-plankt.	
			Macro algae	Sea grass	Pelagic bacteria	Sed. bacteria	Meio-benthos	Labile detritus	Refr. detritus	Carrion	Labile detritus in sed.	Refract. detritus in sed.			Carrion in sed.
	Code	Group	MA	SG	PB	BB	BO	DL	DR	DC	DLsed	DRsed	DCsed	PL	PS
j → j	FPL	Lg. planktivores	0	0	0.1	0	0	0.0001	0	0	0	0	0	0.0001	0
a → j	FPL	Lg. planktivores	0	0	0.1	0	0	0.0001	0	0	0	0	0	0.0001	0
j → a	FPL	Lg. planktivores	0	0	0.1	0	0	0.0001	0	0	0	0	0	0	0
a → a	FPL	Lg. planktivores	0	0	0.1	0	0	0.0001	0	0	0	0	0	0	0
j → j	FPS	Sm. Planktivores	0	0	0.1	0	0	0.0001	0	0	0	0	0	0.0002	0
a → j	FPS	Sm. Planktivores	0	0	0.1	0	0	0.0001	0	0	0	0	0	0.0002	0
j → a	FPS	Sm. Planktivores	0	0	0.1	0	0	0.0001	0	0	0	0	0	0	0
a → a	FPS	Sm. Planktivores	0	0	0.1	0	0	0.0001	0	0	0	0	0	0	0
j → j	FVD	Lg. flatfish	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0
a → j	FVD	Large flatfish	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0
j → a	FVD	Large flatfish	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → a	FVD	Large flatfish	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → j	FVS	Large demersal predators	0	0	0.1	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0
a → j	FVS	Large demersal predators	0	0	0.1	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0
j → a	FVS	Large demersal predators	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → a	FVS	Large demersal predators	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → j	FVT	Lg. pelagic pred.	0	0	0.01	0	0	0.01	0	0	0	0	0	0	0
a → j	FVT	Lg. pelagic pred.	0	0	0.01	0	0	0.01	0	0	0	0	0	0	0
j → a	FVT	Lg. pelagic pred.	0	0	0	0	0	0	0	0	0	0	0	0	0
a → a	FVT	Lg. pelagic pred.	0	0	0	0	0	0	0	0	0	0	0	0	0
j → j	FVO	Shearwaters	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → j	FVO	Shearwaters	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → a	FVO	Shearwaters	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → a	FVO	Shearwaters	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → j	FVB	Salmon	0	0	0.1	0	0	0.01	0	0	0	0	0	0	0
a → j	FVB	Salmon	0	0	0.1	0	0	0.01	0	0	0	0	0	0	0

Table B-6 continued. Parameters in the calibrated model for consumption (variable *a* in Equation 10) of macroalgae, seagrass, bacteria, meiobenthos, detritus, and carrion. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										Large phyto-plankt.	Small phyto-plankt.
			Macro algae	Sea grass	Pelagic bacteria	Sed. bacteria	Meio-benthos	Labile detritus	Refr. detritus	Carrion	Labile detritus in sed.	Refract. detritus in sed.		
Code	Group	MA	SG	PB	BB	BO	DL	DR	DC	DLsed	DRsed	DCsed	PL	PS
j → a	FVB	Salmon	0	0	0	0	0	0	0	0	0	0	0	0
a → a	FVB	Salmon	0	0	0	0	0	0	0	0	0	0	0	0
j → j	FMM	Hake	0	0	0	0	0.01	0.0001	0	0	0	0	0	0
a → j	FMM	Hake	0	0	0	0	0.01	0.0001	0	0	0	0	0	0
j → a	FMM	Hake	0	0	0	0	0	0.0001	0	0	0	0	0	0
a → a	FMM	Hake	0	0	0	0	0	0.0001	0	0	0	0	0	0
j → j	FMN	Sablefish	0	0	0	0	0.01	0.0001	0	0.01	0.01	0	0.01	0
a → j	FMN	Sablefish	0	0	0	0	0.01	0.0001	0	0.01	0.01	0	0.01	0
j → a	FMN	Sablefish	0	0	0	0	0	0.0001	0	0.01	0	0	0	0
a → a	FMN	Sablefish	0	0	0	0	0	0.0001	0	0.01	0	0	0	0
j → j	FBP	Deep vertical Migrators	0	0	0.1	0	0	0.0001	0.01	0.01	0	0	0	0
a → j	FBP	Deep vertical Migrators	0	0	0.1	0	0	0.0001	0.01	0.01	0	0	0	0
j → a	FBP	Deep vertical Migrators	0	0	0.1	0	0	0.0001	0.01	0.01	0	0	0	0
a → a	FBP	Deep vertical Migrators	0	0	0.1	0	0	0.0001	0.01	0.01	0	0	0	0
j → j	FDD	Deep misc. fish	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0
a → j	FDD	Deep misc. fish	0	0	0	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0
j → a	FDD	Deep misc. fish	0	0	0	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0
a → a	FDD	Deep misc. fish	0	0	0	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0
j → j	FDS	Midwater rockfish	0	0	0.1	0	0	0.0001	0	0.01	0.01	0	0.01	0
a → j	FDS	Midwater rockfish	0	0	0.1	0	0	0.0001	0	0.01	0.01	0	0.01	0
j → a	FDS	Midwater rockfish	0	0	0	0	0	0	0	0.01	0	0	0	0
a → a	FDS	Midwater rockfish	0	0	0	0	0	0	0	0.01	0	0	0	0
j → j	FDB	Small shallow rockfish	0	0	0.01	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0

Table B-6 continued. Parameters in the calibrated model for consumption (variable a in Equation 10) of macroalgae, seagrass, bacteria, meiobenthos, detritus, and carrion. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										Large phytoplankt.	Small phytoplankt.	
			Macro algae	Sea grass	Pelagic bacteria	Sed. bacteria	Meio-benthos	Labile detritus	Refr. detritus	Carrion	Labile detritus in sed.	Refract. detritus in sed.			Carrion in sed.
Code	Group	MA	SG	PB	BB	BO	DL	DR	DC	DLsed	DRsed	DCsed	PL	PS	
a → j	FDB	Small shallow rockfish	0	0	0.1	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
j → a	FDB	Small shallow rockfish	0	0	0.1	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
a → a	FDB	Small shallow rockfish	0	0	0.1	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
j → j	FDC	Deep small Rockfish	0	0	0.01	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
a → j	FDC	Deep small Rockfish	0	0	0.01	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
j → a	FDC	Deep small Rockfish	0	0	0.01	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
a → a	FDC	Deep small Rockfish	0	0	0.01	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
j → j	FDO	Deep lg. rockfish	0	0	0.01	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
a → j	FDO	Deep lg. rockfish	0	0	0.01	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
j → a	FDO	Deep lg. rockfish	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → a	FDO	Deep lg. rockfish	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → j	FDE	Misc. nearshore	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0
a → j	FDE	Misc. nearshore	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0
j → a	FDE	Misc. nearshore	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0
a → a	FDE	Misc. nearshore	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0
j → j	FDF	Small flatfish	0	0	0	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
a → j	FDF	Small flatfish	0	0	0	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
j → a	FDF	Small flatfish	0	0	0	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
a → a	FDF	Small flatfish	0	0	0	0.01	0.01	0.0001	0	0.01	0.01	0	0.01	0	0
j → j	SHD	Lg. dem. sharks	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0
a → j	SHD	Lg. dem. sharks	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0
j → a	SHD	Lg. dem. sharks	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0
a → a	SHD	Lg. dem. sharks	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0
j → j	SHP	Misc. pelagic sharks	0	0	0	0	0	0	0	0.01	0	0	0	0	0

Table B-6 continued. Parameters in the calibrated model for consumption (variable a in Equation 10) of macroalgae, seagrass, bacteria, meiobenthos, detritus, and carrion. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										Large phytoplankt.	Small phytoplankt.
			Macro algae	Sea grass	Pelagic bacteria	Sed. bacteria	Meio-benthos	Labile detritus	Refr. detritus	Carrion	Labile detritus in sed.	Refract. detritus in sed.		
Code	Group	MA	SG	PB	BB	BO	DL	DR	DC	DLsed	DRsed	DCsed	PL	PS
a → j	SHP	Misc. pelagic sharks	0	0	0	0	0	0	0	0.01	0	0	0	0
j → a	SHP	Misc. pelagic sharks	0	0	0	0	0	0	0	0.01	0	0	0	0
a → a	SHP	Misc. pelagic sharks	0	0	0	0	0	0	0	0.01	0	0	0	0
j → j	SHB	Small demersal sharks	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0
a → j	SHB	Small demersal sharks	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0
j → a	SHB	Small demersal sharks	0	0	0	0	0	0	0	0.01	0.01	0	0.01	0
a → a	SHB	Small demersal sharks	0	0	0	0	0	0	0	0.01	0.01	0	0.01	0
j → j	SHR	Shallow large Rockfish	0	0	0.1	0.01	0	0.01	0	0.01	0.01	0	0.01	0
a → j	SHR	Shallow large Rockfish	0	0	0.1	0.01	0	0.01	0	0.01	0.01	0	0.01	0
j → a	SHR	Shallow large Rockfish	0	0	0	0	0	0	0	0.01	0	0	0	0
a → a	SHR	Shallow large Rockfish	0	0	0	0	0	0	0	0.01	0	0	0	0
j → j	SSK	Skates and rays	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0
a → j	SSK	Skates and rays	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0
j → a	SSK	Skates and rays	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0
a → a	SSK	Skates and rays	0	0	0	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0
j → j	SB	Surface seabirds	0	0	0	0	0	0	0	0.01	0	0	0	0
a → j	SB	Surface seabirds	0	0	0	0	0.01	0	0	0.01	0	0	0	0
j → a	SB	Surface seabirds	0	0	0	0	0	0	0	0.01	0	0	0	0
a → a	SB	Surface seabirds	0	0	0	0	0	0	0	0.01	0	0	0	0
j → j	SP	Diving seabirds	0	0.001	0	0.01	0.01	0	0	0.01	0.01	0	0.01	0
a → j	SP	Diving seabirds	0	0.001	0	0.01	0.01	0	0	0.01	0.01	0	0.01	0

Table B-6 continued. Parameters in the calibrated model for consumption (variable *a* in Equation 10) of macroalgae, seagrass, bacteria, meiobenthos, detritus, and carrion. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										Large phytoplankt.	Small phytoplankt.	
			Macro algae	Sea grass	Pelagic bacteria	Sed. bacteria	Meio-benthos	Labile detritus	Refr. detritus	Carrion	Labile detritus in sed.	Refract. detritus in sed.			Carrion in sed.
	Code	Group	MA	SG	PB	BB	BO	DL	DR	DC	DLsed	DRsed	DCsed	PL	PS
j → a	SP	Diving seabirds	0	0.001	0	0.01	0.01	0	0	0.01	0.01	0	0.01	0	0
a → a	SP	Diving seabirds	0	0.001	0	0.01	0.01	0	0	0.01	0.01	0	0.01	0	0
j → j	REP	Transient orcas	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → j	REP	Transient orcas	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → a	REP	Transient orcas	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → a	REP	Transient orcas	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → j	PIN	Pinnipeds	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → j	PIN	Pinnipeds	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → a	PIN	Pinnipeds	0	0	0	0	0	0	0	0.01	0	0	0	0	0
a → a	PIN	Pinnipeds	0	0	0	0	0	0	0	0.01	0	0	0	0	0
j → j	WHB	Baleen whales	0	0	0	0	0.01	0.0001	0	0	0.01	0	0.01	0	0
a → j	WHB	Baleen whales	0	0	0	0	0.01	0.0001	0	0	0.01	0	0.01	0	0
j → a	WHB	Baleen whales	0	0	0	0	0.01	0.0001	0	0	0.01	0	0.01	0	0
a → a	WHB	Baleen whales	0	0	0	0	0.01	0.0001	0	0	0.01	0	0.01	0	0
j → j	WHT	Toothed whales	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
a → j	WHT	Toothed whales	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
j → a	WHT	Toothed whales	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
a → a	WHT	Toothed whales	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
j → j	WDG	Otters	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
a → j	WDG	Otters	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
j → a	WDG	Otters	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
a → a	WDG	Otters	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
	ZG	Gelatinous zooplankton	0	0	0.001	0	0	0.0001	0.01	0	0	0	0	0.0001	0.002
	ZL	Lg. zooplankton	0	0	0.001	0	0	0.0001	0	0	0	0	0	0.0005	0.002
	ZM	Meso-zooplankton	0	0	0.001	0	0	0.0001	0.01	0	0	0	0	0.0005	0.002
	ZS	Micro-zooplankton	0	0	0.001	0	0	0.0001	0.01	0	0	0	0	0.0005	0.0002
	BD	Deposit feeders	.05	0	0.001	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.0005	0.002

Table B-6 continued. Parameters in the calibrated model for consumption (variable *a* in Equation 10) of macroalgae, seagrass, bacteria, meiobenthos, detritus, and carrion. A value of 0 indicates cases where that predator does not eat that prey.

Stages*	Predator		Prey group										Large phyto-plankt.	Small phyto-plankt.	
			Macro algae	Sea grass	Pelagic bacteria	Sed. bacteria	Meio-benthos	Labile detritus	Refr. detritus	Carrion	Labile detritus in sed.	Refract. detritus in sed.			Carrion in sed.
	Code	Group	MA	SG	PB	BB	BO	DL	DR	DC	DLsed	DRsed	DCsed	PL	PS
	BO	Meiobenthos	0	0	0.001	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00001	0.00001
	BC	Carnivorous infauna	0	0	0	0.01	0.01	0.0001	0.001	0.01	0.01	0.01	0.01	0	0
	BFS	Shallow benthic filter feeders	0	0	0.001	0.01	0.01	0.0001	0.01	0	0.01	0.01	0	0.0025	0.002
	BFF	Other benthic filter feeders	0	0	0.001	0.01	0.01	0.0001	0.01	0	0.01	0.01	0	0.00015	0.0005
	BFD	Deep benthic filter feeders	0	0	0.001	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0	0
	BMS	Shallow macro-zoobenthos	0	0	0	0.01	0.01	0.0001	0.01	0.01	0.01	0.01	0.01	0	0
	BML	Mega-zoobenthos	0	0	0.001	0.01	0.01	0.0001	0.01	0.01	0.01	0.01	0.01	0	0
	BMD	Deep macro-zoobenthos	0	0	0	0.01	0.01	0	0	0.01	0.01	0.01	0.01	0	0
	BG	Benthic grazers	0.5	0.1	0	0.01	0	0	0	0	0.01	0.01	0.01	0	0
	CEP	Cephalopods	0	0	0	0	0	0.01	0	0.01	0	0	0	0	0
	PWN	Shrimp	0	0	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.01	0	0
	PWN	Shrimp	0	0	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.01	0	0

* In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

Table B-7. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups are primarily birds (FVO) and fish. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
j → j	FPL	Large planktivores	1	<i>1,000</i>	0	1	<i>2,000</i>	0.6667		1	1	<i>1,000</i>	1
a → j	FPL	Large planktivores		<i>100</i>								<i>5,000</i>	
j → a	FPL	Large planktivores	<i>1,000</i>	<i>1,000</i>	0	<i>100</i>	<i>200</i>	0.6667		<i>100</i>	<i>10</i>	<i>1,000</i>	<i>10</i>
a → a	FPL	Large planktivores		<i>10,000</i>								<i>1,000</i>	
j → j	FPS	Small planktivores	1	0.02	0	1	1	0.6667		1	1	0.5	1
a → j	FPS	Small planktivores											
j → a	FPS	Small planktivores	0.03	0.3	0	0.333	0.02	0.6667		0.01	1	0.05	1
a → a	FPS	Small planktivores											
j → j	FVD	Large flatfish			0	0.004				0.015	1	0.1	0.3333
a → j	FVD	Large flatfish										1	1
j → a	FVD	Large flatfish	1	0.5	0	0.004	1			0.015	0.25	0.1	0.8
a → a	FVD	Large flatfish	1	0.5								1	
j → j	FVS	Large demersal predators	<i>100</i>	<i>10</i>	0	0.5				<i>10</i>	1	1	1
a → j	FVS	Large demersal predators		<i>10</i>								1	1
j → a	FVS	Large demersal predators	1	1	0	0.5	1			<i>10</i>	1	1	1.2
a → a	FVS	Large demersal predators	1	1					0.25			1	
j → j	FVT	Large pelagic predators	<i>200</i>	1			<i>100</i>	2		1		<i>100</i>	
a → j	FVT	Large pelagic predators	<i>50</i>	<i>10</i>				1		1		<i>100</i>	
j → a	FVT	Large pelagic predators	<i>200</i>	2			<i>100</i>	2		1		<i>33.33</i>	
a → a	FVT	Large pelagic predators	<i>50</i>	<i>10</i>				1		2		<i>100</i>	
j → j	FVO	Shearwaters	1	0.1			1	0.1667		1		1	
a → j	FVO	Shearwaters		1								1	
j → a	FVO	Shearwaters	1	0.1			1	0.1667		0.1		1	
a → a	FVO	Shearwaters		1								1	
j → j	FVB	Salmon	1	1			0.02	0.6667		1		1	
a → j	FVB	Salmon		1								1	
j → a	FVB	Salmon											
a → a	FVB	Salmon											

Table B-7 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups are primarily birds (FVO) and fish. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
j → j	FMM	Hake	0.2	0.01	0	1	0.003	0.0033		0.002	1	1	1
a → j	FMM	Hake		1								1	1
j → a	FMM	Hake	0.1	0.01	0	0.01	0.003	0.0033		0.002	1	1	0.5
a → a	FMM	Hake		1								1	
j → j	FMN	Sablefish	1	0.1	0	0.05				1	1	1	1
a → j	FMN	Sablefish		0.1								1	1
j → a	FMN	Sablefish	1	0.1	0	0.05				1	1	1	1
a → a	FMN	Sablefish	1	1						0.013	1	1	
j → j	FBP	Deep vertical migrators	1	1				1.3333		1		1	
a → j	FBP	Deep vertical migrators											
j → a	FBP	Deep vertical migrators	1	2			0.4	1		0.1	1	2	1
a → a	FBP	Deep vertical migrators		10								10	
j → j	FDD	Deep miscellaneous fish			0					0.5	0.5	1	0.6
a → j	FDD	Deep miscellaneous fish										1	1
j → a	FDD	Deep miscellaneous fish			0	0.01				0.5	0.5	1	0.6
a → a	FDD	Deep miscellaneous fish										1	
j → j	FDS	Midwater rockfish	1	10		0.01	100			0.01	1	0.1	1
a → j	FDS	Midwater rockfish		10									
j → a	FDS	Midwater rockfish	1	1	0	0.01	1			0.01	1	0.1	1
a → a	FDS	Midwater rockfish	1	1						3E-04	1	1	
j → j	FDB	Small shallow rockfish	1	0.1						1		1	
a → j	FDB	Small shallow rockfish		1								1	
j → a	FDB	Small shallow rockfish	1	0.1		0.025	1			1		1	
a → a	FDB	Small shallow rockfish		1								1	
j → j	FDC	Deep small rockfish		1	0					0.1	1	1	1
a → j	FDC	Deep small rockfish		1								1	1
j → a	FDC	Deep small rockfish	1	1	0					0.1	1	1	1
a → a	FDC	Deep small rockfish										1	

Table B-7 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups are primarily birds (FVO) and fish. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
j → j	FDO	Deep large rockfish		1	0					1	1	1	1
a → j	FDO	Deep large rockfish		1								1	1
j → a	FDO	Deep large rockfish	1	0.2		0.1		0.0667		1	1	1	0.5
a → a	FDO	Deep large rockfish							0.025	1		1	
j → j	FDE	Miscellaneous nearshore			0	1			1			0.03	
a → j	FDE	Miscellaneous nearshore										1	
j → a	FDE	Miscellaneous nearshore	0.06	0.01	0	0.002	0.1			0.1		0.4	
a → a	FDE	Miscellaneous nearshore										0.5	
j → j	FDf	Small flatfish		1	0	0.1	0.5			0.1	1	1	1
a → j	FDf	Small flatfish										1	1
j → a	FDf	Small flatfish		1	0	0.1	1			0.1	1	1	1
a → a	FDf	Small flatfish		1								1	
j → j	SHD	Large demersal sharks			0	1				1	1	1	1
a → j	SHD	Large demersal sharks				0.025				0.5	1	1	1
j → a	SHD	Large demersal sharks			0	1				1	1	1	1
a → a	SHD	Large demersal sharks				0.025				0.5	1	1	1
j → j	SHP	Miscellaneous pelagic sharks	0.1	0.01		0.0002	0.1	0.04	0.2	0.2	0.5	0.02	1
a → j	SHP	Miscellaneous pelagic sharks	1	0.2		0.001		0.4	1	0.002	1	0.4	1
j → a	SHP	Miscellaneous pelagic sharks	0.05	0.01		0.0002	0.1	0.04	0.2	0.2	0.5	0.006	1
a → a	SHP	Miscellaneous pelagic sharks	1	1		0.001	0.5	0.4	1	0.002	1	0.4	1
j → j	SHB	Small demersal sharks		1	0	0.02		0.1667		0.1	1	1	1
a → j	SHB	Small demersal sharks		1				0.3333				1	1
j → a	SHB	Small demersal sharks		1	0	0.02		0.1667		0.1	1	1	1
a → a	SHB	Small demersal sharks		1				0.3333			1	1	1
j → j	SHR	Shallow large rockfish	1	1	0	0.2	0.1			0.1	1	0.2	
a → j	SHR	Shallow large rockfish		1								1	
j → a	SHR	Shallow large rockfish	1	1	0	0.2	0.1			0.1	1	0.2	
a → a	SHR	Shallow large rockfish		1								1	

Table B-7 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups are primarily birds (FVO) and fish. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
j → j	SSK	Skates, rays			0	0.025				0.1	1	1	1
a → j	SSK	Skates, rays										1	1
j → a	SSK	Skates, rays			0	0.025				0.1	1	1	1
a → a	SSK	Skates, rays										1	1
j → j	SB	Surface seabirds	1	1			1	0.3333		1		1	
a → j	SB	Surface seabirds		1								1	
j → a	SB	Surface seabirds	1	1			1	0.3333		1		1	
a → a	SB	Surface seabirds		1								1	
j → j	SP	Diving seabirds	1	1			1	0.3333		1		1	
a → j	SP	Diving seabirds		1								1	
j → a	SP	Diving seabirds	1	1			1	0.3333		1		1	
a → a	SP	Diving seabirds										1	
j → j	REP	Transient orcas							0.2				
a → j	REP	Transient orcas							1				
j → a	REP	Transient orcas							0.2				
a → a	REP	Transient orcas							1				
j → j	PIN	Pinnipeds	0.5	0.01	0	0.0003	0.05	0.0167		0.1	0.333	0.05	1
a → j	PIN	Pinnipeds	0.0333	1	0	0.001	0.004			0.002	1	0.6	1
j → a	PIN	Pinnipeds	0.5	0.01	0	0.0003	0.05	0.0167		0.1	0.333	0.05	1
a → a	PIN	Pinnipeds	0.0333	1	0	0.001	0.004	0.25		0.006	1	0.6	1
j → j	WHB	Baleen whales											
a → j	WHB	Baleen whales											
j → a	WHB	Baleen whales											
a → a	WHB	Baleen whales											
j → j	WHT	Toothed whales	1	0.2	0	0.2	0.02	0.0067		0.2	0.25	1	1
a → j	WHT	Toothed whales	0.3333	1	0	0.1	0.02	0.0667		0.033	1	1	1
j → a	WHT	Toothed whales	0.3333	1	0	0.2	0.02	0.0067		0.2	0.25	1	1
a → a	WHT	Toothed whales	0.3333	0.2	0	0.1	0.02	0.0667		0.033	1	1	1

Table B-7 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups are primarily birds (FVO) and fish. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FPL	FPS	FVD	FVS	FVB	FVT	FVO	FMM	FMN	FBP	FDD
j → j	WDG	Otters			0								
a → j	WDG	Otters											
j → a	WDG	Otters			0								
a → a	WDG	Otters											
	ZG	Gelatinous zooplankton	1	0.1			0.1	0.2		0.1		1	
	ZL	Large zooplankton											
	ZM	Mesozooplankton											
	ZS	Microzooplankton											
	BD	Deposit feeders											
	BO	Meiobenthos											
	BC	Carnivorous infauna											
	BFS	Shallow benthic filter feeders											
	BFF	Other benthic filter feeders											
	BFD	Deep benthic filter feeders											
	BMS	Shallow macro-zoobenthos			0	1						1	1
	BML	Mega-zoobenthos			0	1				1	1	1	1
	BMD	Deep macro-zoobenthos											
	BG	Benthic grazers											
	CEP	Cephalopods	1	1		1	1	1		1	1	1	1
	PWN	Shrimp											
	PWN	Shrimp											

* In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

Table B-8. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include fish and sharks. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDf	SHB	SHD	SHP	SHR	SSK
j → j	FPL	Large planktivores	<i>1,000</i>	1	1							1	
a → j	FPL	Large planktivores											
j → a	FPL	Large planktivores	<i>300</i>	<i>50</i>	<i>100</i>							<i>100</i>	
a → a	FPL	Large planktivores	0.3										
j → j	FPS	Small planktivores	<i>0.002</i>	0.5	5							1	
a → j	FPS	Small planktivores											
j → a	FPS	Small planktivores	<i>0.001</i>	1	0.2								
a → a	FPS	Small planktivores											
j → j	FVD	Large flatfish	<i>0.005</i>	0.2	1.2	<i>0.02</i>	<i>10</i>	1				0.5	<i>0.0001</i>
a → j	FVD	Large flatfish	<i>0.0333</i>		0.4	1		1					
j → a	FVD	Large flatfish	<i>0.005</i>	<i>0.004</i>	0.12	<i>0.01</i>	1	<i>0.05</i>	1			0.5	<i>0.0001</i>
a → a	FVD	Large flatfish	<i>0.0333</i>		0.4	1		1	1				1
j → j	FVS	Large demersal predators	3.3333	1	<i>50</i>	<i>0.1</i>		1					
a → j	FVS	Large demersal predators	3.3333		5	1		1					
j → a	FVS	Large demersal predators	3.3333	0.2	<i>10</i>	<i>0.1</i>	1	0.2	1			1	0.0375
a → a	FVS	Large demersal predators	3.3333		1	<i>10</i>		0.167	1				<i>0.05</i>
j → j	FVT	Large pelagic predators	1	1	1								
a → j	FVT	Large pelagic predators	<i>10</i>		<i>20</i>								
j → a	FVT	Large pelagic predators	1	<i>10</i>	<i>100</i>							1	
a → a	FVT	Large pelagic predators	3		<i>20</i>								
j → j	FVO	Shearwaters		1	1							1	
a → j	FVO	Shearwaters											
j → a	FVO	Shearwaters		1	1							1	
a → a	FVO	Shearwaters											
j → j	FVB	Salmon	3.3333	0.2	1							1	
a → j	FVB	Salmon	5										
j → a	FVB	Salmon	1										
a → a	FVB	Salmon	1.5										

Table B-8 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include fish and sharks. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	PDF	SHB	SHD	SHP	SHR	SSK
j → j	FMM	Hake	2	0.05	0.05	0.01	0.5	1				1	
a → j	FMM	Hake	2		1	1		1					
j → a	FMM	Hake	1	0.002	0.05	0.002	1	0.015				1	0.0143
a → a	FMM	Hake	2					1					
j → j	FMN	Sablefish		0.04	1	1.5	1	1				1	
a → j	FMN	Sablefish	1		0.6	3		1					
j → a	FMN	Sablefish		0.04	1	0.3	1	0.025	1			1	0.0071
a → a	FMN	Sablefish	1	0.02		3	1	0.025	1				0.0063
j → j	FBP	Deep vertical migrators											
a → j	FBP	Deep vertical migrators											
j → a	FBP	Deep vertical migrators		0.1	1	1	1	1				1	
a → a	FBP	Deep vertical migrators											
j → j	FDD	Deep miscellaneous fish				0.2	1	0.05					0.002
a → j	FDD	Deep miscellaneous fish				1		0.3					
j → a	FDD	Deep miscellaneous fish		0.01		0.2	1	0.3	1				0.0013
a → a	FDD	Deep miscellaneous fish				1		0.3	1				
j → j	FDS	Midwater rockfish	0.2	0.1	10	0.2	10	1				1	
a → j	FDS	Midwater rockfish	2		1	1		1					
j → a	FDS	Midwater rockfish	0.2	0.004	1	0.2	1	1				1	
a → a	FDS	Midwater rockfish	2	1	0.1	1		1					
j → j	FDB	Small shallow rockfish	2	1	0.5			1					
a → j	FDB	Small shallow rockfish	3					1					
j → a	FDB	Small shallow rockfish	2	1	0.5			1				1	
a → a	FDB	Small shallow rockfish	3					1					
j → j	FDC	Deep small rockfish		1		0.4	1	1					
a → j	FDC	Deep small rockfish						1					
j → a	FDC	Deep small rockfish				0.4	1	1					
a → a	FDC	Deep small rockfish						1					

Table B-8 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include fish and sharks. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDf	SHB	SHD	SHP	SHR	SSK
j → j	FDO	Deep large rockfish		1		0.4	1	1					
a → j	FDO	Deep large rockfish				1		1					
j → a	FDO	Deep large rockfish	1.3333	0.02	0.5	0.4	0.2		1			1	
a → a	FDO	Deep large rockfish		0.02		1		1	1				1
j → j	FDE	Miscellaneous nearshore	1	0.1	1			1					
a → j	FDE	Miscellaneous nearshore											
j → a	FDE	Miscellaneous nearshore	0.004	0.1	0.1			1					0.0004
a → a	FDE	Miscellaneous nearshore	0.02		1			1					
j → j	FDf	Small flatfish	1	0.1	0.1	0.2	0.5	1					
a → j	FDf	Small flatfish	<i>10</i>										
j → a	FDf	Small flatfish	1	0.1	0.1	0.2	0.2	0.002					
a → a	FDf	Small flatfish	2										
j → j	SHD	Large demersal sharks	1					1	1	1			0.6
a → j	SHD	Large demersal sharks	1					1	1				0.3333
j → a	SHD	Large demersal sharks	1					1	1	1			0.6
a → a	SHD	Large demersal sharks	1					1	1				0.375
j → j	SHP	Miscellaneous pelagic sharks	0.002	0.02	0.005	0.1	0.5		1	1		0.5	
a → j	SHP	Miscellaneous pelagic sharks	0.005	0.002	0.1	0.5	1		1	1		0.05	
j → a	SHP	Miscellaneous pelagic sharks	1	0.02	0.005	0.1	0.5		1	1	1	0.5	0.0002
a → a	SHP	Miscellaneous pelagic sharks	0.005	0.002	0.1	0.5	0.2		1	1	1	0.05	
j → j	SHB	Small demersal sharks	0.4	2	0.05	0.4	1	1	1			1	
a → j	SHB	Small demersal sharks	1.4					1					
j → a	SHB	Small demersal sharks	1	1	0.3	0.4	1	0.002	1			1	0.04
a → a	SHB	Small demersal sharks	0.2					0.333	1				
j → j	SHR	Shallow large rockfish	0.2	0.1	0.6	1	1	1					
a → j	SHR	Shallow large rockfish	0.2		1			0.333					
j → a	SHR	Shallow large rockfish	0.2	1	1	1	0.1	1					
a → a	SHR	Shallow large rockfish	0.8		1			0.333					

Table B-8 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include fish and sharks. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDf	SHB	SHD	SHP	SHR	SSK
j → j	SSK	Skates, rays	0.2	1	0.1	0.4	1	1				1	0.4
a → j	SSK	Skates, rays	0.4					0.333					
j → a	SSK	Skates, rays	1	1	0.1	0.2	1	0.017				1	0.4
a → a	SSK	Skates, rays	0.4					0.25					1
j → j	SB	Surface seabirds		0.1	0.4							1	
a → j	SB	Surface seabirds											
j → a	SB	Surface seabirds		0.1	0.4							1	
a → a	SB	Surface seabirds											
j → j	SP	Diving seabirds	1	0.1	1	1	1					1	
a → j	SP	Diving seabirds	1.5										
j → a	SP	Diving seabirds	1	0.1	1	1	1					1	
a → a	SP	Diving seabirds	3										
j → j	REP	Transient orcas											
a → j	REP	Transient orcas											
j → a	REP	Transient orcas											
a → a	REP	Transient orcas											
j → j	PIN	Pinnipeds	1	0.01	0.01	0.1	0.6	0.025	1			0.3	0.001
a → j	PIN	Pinnipeds	0.005	0.0016	0.1	1	0.5	0.017	0.1			0.05	0.0007
j → a	PIN	Pinnipeds	1	0.01	0.01	0.1	0.6	0.025	1			0.3	0.001
a → a	PIN	Pinnipeds	0.005	0.0016	0.01	1	0.5	0.1	0.02			0.05	0.0007
j → j	WHB	Baleen whales											
a → j	WHB	Baleen whales											
j → a	WHB	Baleen whales											
a → a	WHB	Baleen whales											
j → j	WHT	Toothed whales	1	0.0167	0.05	0.3333	0.05	0.01	0.3333	1		0.6	0.002
a → j	WHT	Toothed whales	0.3333	0.02	0.05	1	0.5	0.06	0.2	1		0.02	0.0017
j → a	WHT	Toothed whales	1	0.0167	0.05	0.3333	0.15	0.01	0.3333	1		0.6	0.002
a → a	WHT	Toothed whales	0.3333	0.02	0.15	1	0.5	0.06	0.2	1		0.02	0.0017

Table B-8 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include fish and sharks. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group										
	Code	Group	FDE	FDS	FDB	FDC	FDO	FDI	SHB	SHD	SHP	SHR	SSK
j → j	WDG	Otters	1		1				1				1
a → j	WDG	Otters	1		1				1				
j → a	WDG	Otters	1		1				1				1
a → a	WDG	Otters	1		1				1				1
	ZG	Gelatinous zooplankton	0.1	0.1	0.1	1	0.5						0.01
	ZL	Large zooplankton											
	ZM	Mesozooplankton											
	ZS	Microzooplankton											
	BD	Deposit feeders											
	BO	Meiobenthos											
	BC	Carnivorous infauna											
	BFS	Shallow benthic filter feeders											
	BFF	Other benthic filter feeders											
	BFD	Deep benthic filter feeders											
	BMS	Shallow macro-zoobenthos	2	0.1	1	2	1	1	1			0.01	1
	BML	Mega-zoobenthos	1	1	1	1	1	1				1	
	BMD	Deep macro-zoobenthos											
	BG	Benthic grazers											
	CEP	Cephalopods	1	0.1	1	1	1						
	PWN	Shrimp											
	PWN	Shrimp											

* In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

Table B-9. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups include mammals and seabirds. A ratio of 1 indicates we did not change consumption parameters from their initial values. Ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group						
	Code	Group	SB	SP	PIN	REP	WHB	WHT	WDG
j → j	FPL	Large planktivores							
a → j	FPL	Large planktivores							
j → a	FPL	Large planktivores							
a → a	FPL	Large planktivores							
j → j	FPS	Small planktivores							
a → j	FPS	Small planktivores							
j → a	FPS	Small planktivores							
a → a	FPS	Small planktivores							
j → j	FVD	Large flatfish							
a → j	FVD	Large flatfish							
j → a	FVD	Large flatfish							
a → a	FVD	Large flatfish							
j → j	FVS	Large demersal predators							
a → j	FVS	Large demersal predators							
j → a	FVS	Large demersal predators							
a → a	FVS	Large demersal predators							
j → j	FVT	Large pelagic predators							
a → j	FVT	Large pelagic predators							
j → a	FVT	Large pelagic predators							
a → a	FVT	Large pelagic predators							
j → j	FVO	Shearwaters							
a → j	FVO	Shearwaters							
j → a	FVO	Shearwaters							
a → a	FVO	Shearwaters							
j → j	FVB	Salmon							
a → j	FVB	Salmon							
j → a	FVB	Salmon							
a → a	FVB	Salmon							
j → j	FMM	Hake							
a → j	FMM	Hake							
j → a	FMM	Hake							
a → a	FMM	Hake							
j → j	FMN	Sablefish							
a → j	FMN	Sablefish							
j → a	FMN	Sablefish							
a → a	FMN	Sablefish							
j → j	FBP	Deep vertical migrators							
a → j	FBP	Deep vertical migrators							
j → a	FBP	Deep vertical migrators							
a → a	FBP	Deep vertical migrators							

Table B-9 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups include mammals and seabirds. A ratio of 1 indicates we did not change consumption parameters from their initial values. Ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group						
	Code	Group	SB	SP	PIN	REP	WHB	WHT	WDG
j → j	FDD	Deep miscellaneous fish							
a → j	FDD	Deep miscellaneous fish							
j → a	FDD	Deep miscellaneous fish							
a → a	FDD	Deep miscellaneous fish							
j → j	FDS	Midwater rockfish							
a → j	FDS	Midwater rockfish							
j → a	FDS	Midwater rockfish							
a → a	FDS	Midwater rockfish							
j → j	FDB	Small shallow rockfish							
a → j	FDB	Small shallow rockfish							
j → a	FDB	Small shallow rockfish							
a → a	FDB	Small shallow rockfish							
j → j	FDC	Deep small rockfish							
a → j	FDC	Deep small rockfish							
j → a	FDC	Deep small rockfish							
a → a	FDC	Deep small rockfish							
j → j	FDO	Deep large rockfish							
a → j	FDO	Deep large rockfish							
j → a	FDO	Deep large rockfish	1.00	1.00	1.00				1.00
a → a	FDO	Deep large rockfish							
j → j	FDE	Miscellaneous nearshore							
a → j	FDE	Miscellaneous nearshore							
j → a	FDE	Miscellaneous nearshore							
a → a	FDE	Miscellaneous nearshore							
j → j	FDF	Small flatfish							
a → j	FDF	Small flatfish							
j → a	FDF	Small flatfish							
a → a	FDF	Small flatfish							
j → j	SHD	Large demersal sharks							
a → j	SHD	Large demersal sharks							
j → a	SHD	Large demersal sharks							
a → a	SHD	Large demersal sharks							
j → j	SHP	Miscellaneous pelagic sharks	0.33	0.43	1.00				1.00
a → j	SHP	Miscellaneous pelagic sharks	1.00	1.00	1.00				1.00
j → a	SHP	Miscellaneous pelagic sharks	0.25	0.43	1.25	1.00		1.00	1.00
a → a	SHP	Miscellaneous pelagic sharks	1.00	1.00	1.00	1.00	1.00	1.00	1.00
j → j	SHB	Small demersal sharks							
a → j	SHB	Small demersal sharks							
j → a	SHB	Small demersal sharks							
a → a	SHB	Small demersal sharks							

Table B-9 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups include mammals and seabirds. A ratio of 1 indicates we did not change consumption parameters from their initial values. Ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group						
	Code	Group	SB	SP	PIN	REP	WHB	WHT	WDG
j → j	SHR	Shallow large rockfish							
a → j	SHR	Shallow large rockfish							
j → a	SHR	Shallow large rockfish							
a → a	SHR	Shallow large rockfish							
j → j	SSK	Skates, rays							
a → j	SSK	Skates, rays							
j → a	SSK	Skates, rays							
a → a	SSK	Skates, rays							
j → j	SB	Surface seabirds							
a → j	SB	Surface seabirds							
j → a	SB	Surface seabirds							
a → a	SB	Surface seabirds							
j → j	REP	Transient orcas	0.25	0.43	1.50		0.01	10.0	1.00
a → j	REP	Transient orcas	1.00	1.00	1.50		1.00	1.00	1.00
j → a	REP	Transient orcas	0.25	0.43	1.50		0.01	1.00	1.00
a → a	REP	Transient orcas	1.00	1.00	1.50		1.00	1.00	1.00
j → j	PIN	Pinnipeds							
a → j	PIN	Pinnipeds							
j → a	PIN	Pinnipeds							
a → a	PIN	Pinnipeds							
j → j	WHB	Baleen whales							
a → j	WHB	Baleen whales							
j → a	WHB	Baleen whales							
a → a	WHB	Baleen whales							
j → j	WHT	Toothed whales							
a → j	WHT	Toothed whales							
j → a	WHT	Toothed whales							
a → a	WHT	Toothed whales							
j → j	WDG	Otters							
a → j	WDG	Otters							
j → a	WDG	Otters							
a → a	WDG	Otters							
	ZG	Gelatinous zooplankton							
	ZL	Large zooplankton							
	ZM	Mesozooplankton							
	ZS	Microzooplankton							
	BD	Deposit feeders							
	BO	Meiobenthos							
	BC	Carnivorous infauna							
	BFS	Shallow benthic filter feeders							

Table B-9 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups include mammals and seabirds. A ratio of 1 indicates we did not change consumption parameters from their initial values. Ratios less than or equal to 0.1 are light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages*	Predator		Prey group						
	Code	Group	SB	SP	PIN	REP	WHB	WHT	WDG
	BFF	Other benthic filter feeders							
	BFD	Deep benthic filter feeders							
	BMS	Shallow macro-zoobenthos							
	BML	Mega-zoobenthos							
	BMD	Deep macro-zoobenthos							
	BG	Benthic grazers							
	CEP	Cephalopods							
	PWN	Shrimp							
	PWN	Shrimp							

* In the stages column, $j \rightarrow j$ signifies juvenile predation on juveniles, $a \rightarrow j$ signifies adult predation on juveniles, $j \rightarrow a$ signifies juvenile predation on adults, and $a \rightarrow a$ signifies adult predation on adults.

Table B-10. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups shown are benthos, and most consumption parameters were left at their initial values, which corresponds to a ratio of 1. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predators		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
j → j	FPL	Large planktivores								1	
a → j	FPL	Large planktivores								1	
j → a	FPL	Large planktivores							1	1	
a → a	FPL	Large planktivores							1	1	
j → j	FPS	Small planktivores								1	
a → j	FPS	Small planktivores								1	
j → a	FPS	Small planktivores								1	
a → a	FPS	Small planktivores								1	
j → j	FVD	Large flatfish		1	1		1	1	1	1	1
a → j	FVD	Large flatfish		1	1		1	1	1	1	1
j → a	FVD	Large flatfish		1	1		1	1	1	1	1
a → a	FVD	Large flatfish		1	1		1	1	1	1	1
j → j	FVS	Large demersal pred.		1	1		1	1	1	1	1
a → j	FVS	Large demersal pred.		1	1		1	1	1	1	1
j → a	FVS	Large demersal pred.		1	1		1	1	1	1	1
a → a	FVS	Large demersal pred.		1	1		1	1	1	1	1
j → j	FVT	Large pelagic predators								1	
a → j	FVT	Large pelagic predators								1	
j → a	FVT	Large pelagic predators								1	
a → a	FVT	Large pelagic predators								1	
j → j	FVO	Shearwaters									
a → j	FVO	Shearwaters									
j → a	FVO	Shearwaters									
a → a	FVO	Shearwaters									
j → j	FVB	Salmon								1	
a → j	FVB	Salmon								1	
j → a	FVB	Salmon									
a → a	FVB	Salmon									

Table B-10 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups shown are benthos, and most consumption parameters were left at their initial values, which corresponds to a ratio of 1. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predators		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
j → j	FMM	Hake						1	1	1	1
a → j	FMM	Hake						1	1	1	1
j → a	FMM	Hake						1	1	1	1
a → a	FMM	Hake						1	1	1	1
j → j	FMN	Sablefish		1	1	1	1	1	1	1	1
a → j	FMN	Sablefish		1	1	1	1	1	1	1	1
j → a	FMN	Sablefish		1	1	1	1	1	1	1	1
a → a	FMN	Sablefish		1	1	1	1	1	1	1	1
j → j	FBP	Deep vertical migrators								1	
a → j	FBP	Deep vertical migrators								1	
j → a	FBP	Deep vertical migrators								1	
a → a	FBP	Deep vertical migrators								1	
j → j	FDD	Deep miscellaneous fish		1	1	1	1	1	1	1	1
a → j	FDD	Deep miscellaneous fish		1	1	1	1	1	1	1	1
j → a	FDD	Deep miscellaneous fish		1	1	1	1	1	1	1	1
a → a	FDD	Deep miscellaneous fish		1	1	1	1	1	1	1	1
j → j	FDS	Midwater rockfish		1					1	1	1
a → j	FDS	Midwater rockfish		1					1	1	1
j → a	FDS	Midwater rockfish		1					1	1	1
a → a	FDS	Midwater rockfish		1					1	1	1
j → j	FDB	Small shallow rockfish		1				1	1	1	1
a → j	FDB	Small shallow rockfish		1				1	1	1	1
j → a	FDB	Small shallow rockfish		1				1	1	1	1
a → a	FDB	Small shallow rockfish		1				1	1	1	1
j → j	FDC	Deep small rockfish		1	1				1	1	1
a → j	FDC	Deep small rockfish		1	1				1	1	1
j → a	FDC	Deep small rockfish		1	1				1	1	1
a → a	FDC	Deep small rockfish		1	1				1	1	1

Table B-10 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups shown are benthos, and most consumption parameters were left at their initial values, which corresponds to a ratio of 1. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predators		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
j → j	FDO	Deep large rockfish		1	1			1	1	1	1
a → j	FDO	Deep large rockfish		1	1			1	1	1	1
j → a	FDO	Deep large rockfish						1	1		
a → a	FDO	Deep large rockfish		1	1			1	1	1	1
j → j	FDE	Miscellaneous nearshore		1			1	1	1	1	1
a → j	FDE	Miscellaneous nearshore		1			1	1	1	1	1
j → a	FDE	Miscellaneous nearshore		1			1	1	1	1	1
a → a	FDE	Miscellaneous nearshore		1			1	1	1	1	1
j → j	FDf	Small flatfish		1	1	1	1	1	1	1	1
a → j	FDf	Small flatfish		1	1	1	1	1	1	1	1
j → a	FDf	Small flatfish		1	1	1	1	1	1	1	1
a → a	FDf	Small flatfish		1	1	1	1	1	1	1	1
j → j	SHD	Large demersal sharks		1	1	1	1	1	1	1	1
a → j	SHD	Large demersal sharks		1	1	1	1	1	1	1	1
j → a	SHD	Large demersal sharks		1	1	1	1	1	1	1	1
a → a	SHD	Large demersal sharks		1	1	1	1	1	1	1	1
j → j	SHP	Misc. pelagic sharks						1	1		
a → j	SHP	Misc. pelagic sharks						1	1		
j → a	SHP	Misc. pelagic sharks						1	1		
a → a	SHP	Misc. pelagic sharks						1	1		
j → j	SHB	Small demersal sharks		1	1	1		1	1	1	1
a → j	SHB	Small demersal sharks		1	1	1		1	1	1	1
j → a	SHB	Small demersal sharks		1	1	1		1	1	1	1
a → a	SHB	Small demersal sharks		1	1	1		1	1	1	1
j → j	SHR	Shallow large rockfish		1				1	1	1	1
a → j	SHR	Shallow large rockfish		1				1	1	1	1
j → a	SHR	Shallow large rockfish		1				1	1	1	1
a → a	SHR	Shallow large rockfish		1				1	1	1	1

Table B-10 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups shown are benthos, and most consumption parameters were left at their initial values, which corresponds to a ratio of 1. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predators		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
j → j	SSK	Skates, rays		1	1	1	1	1	1	1	1
a → j	SSK	Skates, rays		1	1	1	1	1	1	1	1
j → a	SSK	Skates, rays		1	1	1	1	1	1	1	1
a → a	SSK	Skates, rays		1	1	1	1	1	1	1	1
j → j	SB	Surface seabirds		1							
a → j	SB	Surface seabirds		1							
j → a	SB	Surface seabirds		1							
a → a	SB	Surface seabirds		1							
j → j	SP	Diving seabirds		1				1		1	1
a → j	SP	Diving seabirds		1				1		1	1
j → a	SP	Diving seabirds		1				1		1	1
a → a	SP	Diving seabirds		1				1		1	1
j → j	REP	Transient orcas									
a → j	REP	Transient orcas									
j → a	REP	Transient orcas									
a → a	REP	Transient orcas									
j → j	PIN	Pinnipeds		1			1	1	1		
a → j	PIN	Pinnipeds		1			1	1	1		
j → a	PIN	Pinnipeds		1			1	1	1		
a → a	PIN	Pinnipeds		1			1	1	1		
j → j	WHB	Baleen whales		2	1		1	1	1	1	1
a → j	WHB	Baleen whales		2	1		1	1	1	1	1
j → a	WHB	Baleen whales		2	1		1	1	1	1	1
a → a	WHB	Baleen whales		2	1		1	1	1	1	1
j → j	WHT	Toothed whales		1	1			1	1		
a → j	WHT	Toothed whales		1	1			1	1		
j → a	WHT	Toothed whales		1	1			1	1		
a → a	WHT	Toothed whales		1	1			1	1		

Table B-10 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups shown are benthos, and most consumption parameters were left at their initial values, which corresponds to a ratio of 1. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predators		Prey group								
	Code	Group	BFS ^b	BFF ^c	BFD ^d	BG ^e	BMD ^f	BML ^g	BMS ^h	BD ⁱ	BC ^j
j → j	WDG	Otters		1		1	1	1	1	1	1
a → j	WDG	Otters		1		1	1	1	1	1	1
j → a	WDG	Otters		1		1	1	1	1	1	1
a → a	WDG	Otters		1		1	1	1	1	1	1
	ZG	Gelatinous zooplankton								1	
	ZL	Large zooplankton								1	
	ZM	Mesozooplankton									
	ZS	Microzooplankton									
	BD	Deposit feeders								1	
	BO	Meiobenthos									
	BC	Carnivorous infauna								1	1
	BFS	Shall. benthic filter feed.									
	BFF	Other benthic filter feed.									
	BFD	Deep benthic filter feed.						1		1	1
	BMS	Shall. macro-zoobenthos		1			1	1	1	1	1
	BML	Mega-zoobenthos		1		1		1		1	1
	BMD	Deep macro-zoobenthos		1		1	1	1		1	1
	BG	Benthic grazers									
	CEP	Cephalopods								1	
	PWN	Shrimp								1	1
	PWN	Shrimp								1	1

^a In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

^b BFS = shallow benthic filter feeders.

^c BFF = other benthic filter feeders.

^d BFD = deep benthic filter feeders.

^e BG = benthic grazers.

^f BMD = deep macro-zoobenthos.

^g BML = mega-zoobenthos.

^h BMS = shallow macro-zoobenthos.

ⁱ BD = deposit feeders.

^j BC = carnivorous infauna.

Table B-11. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include plankton, cephalopods, and shrimp. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWNjuv ^g	CEP ^h
j → j	FPL	Large planktivores	<i>1.000</i>	<i>40</i>	3.33333	0.00667		0.0001	
a → j	FPL	Large planktivores	<i>1.000</i>	<i>40</i>	3.33333	0.00667		0.0001	
j → a	FPL	Large planktivores	1	2	<i>10</i>			0.0001	
a → a	FPL	Large planktivores	1	2	<i>10</i>			0.0001	
j → j	FPS	Small planktivores	0.0008	0.002	0.002	0.002		0.001	
a → j	FPS	Small planktivores	0.0008	0.002	0.002	0.002		0.001	
j → a	FPS	Small planktivores	0.004	0.02	0.002			0.001	
a → a	FPS	Small planktivores	0.0008	0.002	0.002			0.001	
j → j	FVD	Large flatfish		0.1			0.05	0.1	0.3
a → j	FVD	Large flatfish		0.1			0.05	0.1	0.3
j → a	FVD	Large flatfish		0.1			0.05	0.1	0.3
a → a	FVD	Large flatfish		0.1			0.05	0.1	0.3
j → j	FVS	Large demersal pred.		0.5	0.05		0.08	0.1	0.5
a → j	FVS	Large demersal pred.		0.5	0.05		0.08	0.1	0.5
j → a	FVS	Large demersal pred.		0.1			0.08	0.1	0.5
a → a	FVS	Large demersal pred.		0.1			0.08	0.1	0.5
j → j	FVT	Large pelagic pred.	1	0.1	0.50251			1	1
a → j	FVT	Large pelagic pred.	1	1	0.50251			1	1
j → a	FVT	Large pelagic pred.	1	1				1	1
a → a	FVT	Large pelagic pred.	1	1				1	1
j → j	FVO	Shearwaters	0.2	0.1				0.1	
a → j	FVO	Shearwaters	2	0.01333				0.01	
j → a	FVO	Shearwaters	2	0.01333				0.01	
a → a	FVO	Shearwaters	2	0.01333				0.01	
j → j	FVB	Salmon	0.06	0.13333	0.1			0.1	0.1
a → j	FVB	Salmon	0.08	0.1	0.1			0.1	0.1
j → a	FVB	Salmon							
a → a	FVB	Salmon							
j → j	FMM	Hake	0.00006	0.00005	0.00005		0.0001	0.00005	0.1
a → j	FMM	Hake	0.00006	0.0001	0.0001		0.0001	0.0001	0.01
j → a	FMM	Hake	0.00006	0.0001			0.0001	0.0001	0.01
a → a	FMM	Hake	0.00006	0.001			0.0001	0.0001	0.01
j → j	FMN	Sablefish	0.006	0.001	0.01		0.01	0.01	0.1
a → j	FMN	Sablefish	0.006	0.001	0.01		0.01	0.01	0.1
j → a	FMN	Sablefish	0.006	0.001			0.01	0.01	0.1
a → a	FMN	Sablefish	0.01	0.001			0.01	0.01	0.1
j → j	FBP	Deep vert. migrators	1	0.1	0.1	0.2		0.01	
a → j	FBP	Deep vert. migrators	1	0.1	0.1	0.2		0.01	
j → a	FBP	Deep vert. migrators	1	0.1	0.05			0.01	
a → a	FBP	Deep vert. migrators	1	0.1	0.05			0.01	

Table B-11 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include plankton, cephalopods, and shrimp. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWN _{juv} ^g	CEP ^h
j → j	FDD	Deep misc. fish		0.1			0.07	0.1	
a → j	FDD	Deep misc. fish		0.1			0.07	0.1	
j → a	FDD	Deep misc. fish		0.1			0.07	0.1	
a → a	FDD	Deep misc. fish		0.1			0.07	0.1	
j → j	FDS	Midwater rockfish	0.0002	0.0001	0.001		0.0001	0.0001	0.05
a → j	FDS	Midwater rockfish	0.0002	0.0001	0.001		0.0001	0.0001	0.05
j → a	FDS	Midwater rockfish	0.0002	0.0001			0.0001	0.0001	0.05
a → a	FDS	Midwater rockfish	0.0002	0.0001			0.0001	0.0001	0.05
j → j	FDB	Small shall. rockfish	0.02	0.01	0.01		0.01	0.01	
a → j	FDB	Small shall. rockfish	0.02	0.01	0.01		0.01	0.01	
j → a	FDB	Small shall. rockfish	0.02	0.01	0.01		0.01	0.01	
a → a	FDB	Small shall. rockfish	0.02	0.01	0.01		0.01	0.01	
j → j	FDC	Deep small rockfish	0.01	0.01	0.01		0.01	0.01	
a → j	FDC	Deep small rockfish	0.01	0.01	0.01		0.01	0.01	
j → a	FDC	Deep small rockfish	0.01	0.01	0.01		0.01	0.01	
a → a	FDC	Deep small rockfish	0.01	0.01	0.01		0.01	0.01	
j → j	FDO	Deep large rockfish	0.002	0.01	0.01		0.01	0.01	0.01
a → j	FDO	Deep large rockfish	0.006	0.01	0.01		0.01	0.01	0.01
j → a	FDO	Deep large rockfish						0.01	0.01
a → a	FDO	Deep large rockfish	0.01	0.01			0.01	0.01	0.01
j → j	FDE	Misc. nearshore	1	1	0.625		0.1	1	
a → j	FDE	Misc. nearshore	1	1	0.625		0.1	1	
j → a	FDE	Misc. nearshore	1	1	0.625		0.1	1	
a → a	FDE	Misc. nearshore	1	1	0.625		0.1	1	
j → j	FDF	Small flatfish	0.002	0.01			0.01	0.01	
a → j	FDF	Small flatfish	0.002	0.01			0.01	0.01	
j → a	FDF	Small flatfish	0.002	0.01			0.01	0.01	
a → a	FDF	Small flatfish	0.002	0.01			0.01	0.01	
j → j	SHD	Large demersal sharks					1	1	1
a → j	SHD	Large demersal sharks					1	1	1
j → a	SHD	Large demersal sharks					1	1	1
a → a	SHD	Large demersal sharks					1	1	1
j → j	SHP	Misc. pelagic sharks						1	1
a → j	SHP	Misc. pelagic sharks						1	1
j → a	SHP	Misc. pelagic sharks						1	1
a → a	SHP	Misc. pelagic sharks						1	1
j → j	SHB	Small demersal sharks	0.02	0.1			0.05	0.1	
a → j	SHB	Small demersal sharks	0.02	0.1			0.05	0.1	
j → a	SHB	Small demersal sharks	0.02	0.1			0.05	0.1	
a → a	SHB	Small demersal sharks	0.02	0.1			0.05	0.1	

Table B-11 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include plankton, cephalopods, and shrimp. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWN _{juv} ^g	CEP ^h
j → j	SHR	Shallow large rockfish	1	0.1	0.0125		0.05	0.1	0.5
a → j	SHR	Shallow large rockfish	1	0.1	0.0125		0.05	0.1	0.5
j → a	SHR	Shallow large rockfish	1	0.1			0.05	0.1	0.5
a → a	SHR	Shallow large rockfish	1	0.1			0.05	0.1	0.5
j → j	SSK	Skates, rays					0.1		
a → j	SSK	Skates, rays					0.1		
j → a	SSK	Skates, rays					0.1		
a → a	SSK	Skates, rays					0.1		
j → j	SB	Surface seabirds	1	1				1	
a → j	SB	Surface seabirds	1	1				1	
j → a	SB	Surface seabirds	1	1				1	
a → a	SB	Surface seabirds	1	1				1	
j → j	SP	Diving seabirds	1	1	0.125		1	1	
a → j	SP	Diving seabirds	1	1	0.125		1	1	
j → a	SP	Diving seabirds	1	1	0.125		1	1	
a → a	SP	Diving seabirds	1	1	0.125		1	1	
j → j	REP	Transient orcas							
a → j	REP	Transient orcas							
j → a	REP	Transient orcas							
a → a	REP	Transient orcas							
j → j	PIN	Pinnipeds		0.1			0.1	0.1	0.1
a → j	PIN	Pinnipeds		0.1			0.1	0.1	0.1
j → a	PIN	Pinnipeds		0.1			0.1	0.1	0.1
a → a	PIN	Pinnipeds		0.1			0.1	0.1	0.1
j → j	WHB	Baleen whales	0.0001	1	0.0002		0.0001	0.001	
a → j	WHB	Baleen whales	0.0001	1	0.0002		0.0001	0.001	
j → a	WHB	Baleen whales	0.0001	0.1	0.0002		0.0001	0.001	
a → a	WHB	Baleen whales	0.0001	0.1	0.0002		0.0001	0.001	
j → j	WHT	Toothed whales		0.02				0.01	0.15
a → j	WHT	Toothed whales		0.02				0.01	0.15
j → a	WHT	Toothed whales		0.02				0.01	0.15
a → a	WHT	Toothed whales		0.02				0.01	0.15
j → j	WDG	Otters		1			1	1	1
a → j	WDG	Otters		1			1	1	1
j → a	WDH	Otters		1			1	1	1
a → a	WDG	Otters		1			1	1	1
	ZG	Gelatinous zooplank.	1	1	2	1		0.1	
	ZL	Large zooplankton	0.4	1	1.28205	1			
	ZM	Mesozooplankton			<i>10</i>	<i>10</i>			
	ZS	Microzooplankton				0.2			

Table B-11 continued. Ratio of final values/initial values for consumption parameter (variable *a* in Equation 10) to compare parameterization after calibration versus before calibration. Prey groups here include plankton, cephalopods, and shrimp. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group						
	Code	Group	ZG ^b	ZL ^c	ZM ^d	ZS ^e	PWN ^f	PWNjuv ^g	CEP ^h
	BD	Deposit feeders			0.3	0.2			
	BO	Meiobenthos				1			
	BC	Carnivorous infauna							
	BFS	Shall. benthic filter feeders			0.11765	2			
	BFF	Other benthic filter feeders			<i>100</i>	1			
	BFD	Deep benthic filter feeders		0.01	0.1	0.2	0.2		
	BMS	Shallow macro-zoobenthos					0.01	0.01	
	BML	Mega-zoobenthos					0.02		
	BMD	Deep macro-zoobenthos					0.2		
	BG	Benthic grazers							
	CEP	Cephalopods	1	0.2	1			0.1	
	PWN	Shrimp					0.0002		
	PWN	Shrimp					0.0002		

^a In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

^b ZG = gelatinous zooplankton.

^c ZL = large zooplankton.

^d ZM = mesozooplankton.

^e ZS = microzooplankton.

^f PWN = shrimp.

^g PWNjuv = juvenile shrimp.

^h CEP = cephalopods.

Table B-12. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Consumed groups here include macroalgae, seagrass, bacteria, detritus, and carrion. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group													
			Macro algae MA	Sea grass SG	Pelagic bacteria PB	Sed. bacteria BB ^b	Meio-benthos BO	Labile detritus DL	Refr. detritus DR ^c	Carrion DC	Labile detritus in sed. DLsed ^d	Refr. detritus in sed. DRsed ^e	Carrion in sed. DCsed ^f	Large phytoplank. PL ^g	Small phytoplank. PS ^h	
j → j	FPL	Large planktivores			1.00										0.10	
a → j	FPL	Large planktivores			1.00										0.10	
j → a	FPL	Large planktivores			1.00											
a → a	FPL	Large planktivores			1.00											
j → j	FPS	Small planktivores			1.00										0.002	
a → j	FPS	Small planktivores			1.00										0.002	
j → a	FPS	Small planktivores			1.00											
a → a	FPS	Small planktivores			1.00											
j → j	FVD	Lg. flatfish				1.00	1.00	1.00			1.00	1.00			1.00	
a → j	FVD	Lg. flatfish				1.00	1.00	1.00			1.00	1.00			1.00	
j → a	FVD	Lg. flatfish									1.00					
a → a	FVD	Lg. flatfish									1.00					
j → j	FVS	Lg. demersal predators			1.00	1.00	1.00	1.00			1.00	1.00			1.00	
a → j	FVS	Lg. demersal predators			1.00	1.00	1.00	1.00			1.00	1.00			1.00	
j → a	FVS	Lg. demersal predators									1.00					
a → a	FVS	Lg. demersal predators									1.00					
j → j	FVT	Lg. pelagic predators			1.00						1.00					
a → j	FVT	Lg. pelagic predators			1.00						1.00					

Table B-12 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Consumed groups here include macroalgae, seagrass, bacteria, detritus, and carrion. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group										Large phyto-plank. PL ^g	Small phyto-plank. PS ^h			
			Macro algae MA	Sea grass SG	Pelagic bacteria PB	Sed. bacteria BB ^b	Meio-benthos BO	Labile detritus DL	Refr. detritus DR ^c	Carrion DC	Labile detritus in sed. DLsed ^d	Refr. detritus in sed. DRsed ^e			Carrion in sed. DCsed ^f		
j → a	FVT	Lg. pelagic predators															
a → a	FVT	Lg. pelagic predators															
j → j	FVO	Shearwaters									1.00						
a → j	FVO	Shearwaters									1.00						
j → a	FVO	Shearwaters									1.00						
a → a	FVO	Shearwaters									1.00						
j → j	FVB	Salmon			1.00			1.00									
a → j	FVB	Salmon			1.00			1.0									
j → a	FVB	Salmon															
a → a	FVB	Salmon															
j → j	FMM	Hake					1.00	0.01									
a → j	FMM	Hake					1.00	0.01									
j → a	FMM	Hake						0.01									
a → a	FMM	Hake						0.01									
j → j	FMN	Sablefish					1.00	0.01			1.00	1.00			1.00		
a → j	FMN	Sablefish					1.00	0.01			1.00	1.00			1.00		
j → a	FMN	Sablefish						0.01			1.00						
a → a	FMN	Sablefish						0.01			1.00						
j → j	FBP	Deep vert. migrators			1.00			0.01	1.00	1.00							
a → j	FBP	Deep vert. migrators			1.00			0.01	1.00	1.00							
j → a	FBP	Deep vert. migrators			1.00			0.01	1.00	1.00							
a → a	FBP	Deep vert. migrators			1.00			0.01	1.00	1.00							
j → j	FDD	Deep misc. fish				1.00	1.00	1.00	1.00	1.00	1.00				1.00		

Table B-12 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Consumed groups here include macroalgae, seagrass, bacteria, detritus, and carrion. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group													
			Macro algae MA	Sea grass SG	Pelagic bacteria PB	Sed. bacteria BB ^b	Meio-benthos BO	Labile detritus DL	Refr. detritus DR ^c	Carrion DC	Labile detritus in sed. DLsed ^d	Refr. detritus in sed. DRsed ^e	Carrion in sed. DCsed ^f	Large phytoplank. PL ^g	Small phytoplank. PS ^h	
a → j	FDD	Deep misc. fish				1.00	1.00	1.00	1.00	1.00	1.00				1.00	
j → a	FDD	Deep misc. fish				1.00	1.00	1.00	1.00	1.00	1.00				1.00	
a → a	FDD	Deep misc. fish				1.00	1.00	1.00	1.00	1.00	1.00				1.00	
j → j	FDS	Midwater rockfish			1.00				0.01			1.00	1.00		1.00	
a → j	FDS	Midwater rockfish			1.00				0.01			1.00	1.00		1.00	
j → a	FDS	Midwater rockfish									1.00					
a → a	FDS	Midwater rockfish									1.00					
j → j	FDB	Sm. Shallow rockfish			1.00	1.00	1.00		0.01			1.00	1.00		1.00	
a → j	FDB	Sm. Shallow rockfish			1.00	1.00	1.00		0.01			1.00	1.00		1.00	
j → a	FDB	Sm. Shallow rockfish			1.00	1.00	1.00		0.01			1.00	1.00		1.00	
a → a	FDB	Sm. Shallow rockfish			1.00	1.00	1.00		0.01			1.00	1.00		1.00	
j → j	FDC	Deep small rockfish			1.00	1.00	1.00		0.01			1.00	1.00		1.00	
a → j	FDC	Deep small rockfish			1.00	1.00	1.00		0.01			1.00	1.00		1.00	
j → a	FDC	Deep small rockfish			1.00	1.00	1.00		0.01			1.00	1.00		1.00	
a → a	FDC	Deep small rockfish			1.00	1.00	1.00		0.01			1.00	1.00		1.00	

Table B-12 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Consumed groups here include macroalgae, seagrass, bacteria, detritus, and carrion. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group												
			Macro algae MA	Sea grass SG	Pelagic bacteria PB	Sed. bacteria BB ^b	Meio-benthos BO	Labile detritus DL	Refr. detritus DR ^c	Carrion DC	Labile detritus in sed. DLsed ^d	Refr. detritus in sed. DRsed ^e	Carrion in sed. DCsed ^f	Large phytoplank. PL ^g	Small phytoplank. PS ^h
j → j	FDO	Deep large rockfish			1.00	1.00	1.00	0.01			1.00	1.00			1.00
a → j	FDO	Deep large rockfish			1.00	1.00	1.00	0.01			1.00	1.00			1.00
j → a	FDO	Deep large rockfish									1.00				
a → a	FDO	Deep large rockfish									1.00				
j → j	FDE	Misc. nearshore				1.00	1.00	1.00	1.00		1.00	1.00			1.00
a → j	FDE	Misc. nearshore				1.00	1.00	1.00	1.00		1.00	1.00			1.00
j → a	FDE	Misc. nearshore				1.00	1.00	1.00	1.00		1.00	1.00			1.00
a → a	FDE	Misc. nearshore				1.00	1.00	1.00	1.0		1.0	1.00			1.00
j → j	FDF	Small flatfish				1.00	1.00	0.01			1.00	1.00			1.00
a → j	FDF	Small flatfish				1.00	1.00	0.01			1.00	1.00			1.00
j → a	FDF	Small flatfish				1.00	1.00	0.01			1.00	1.00			1.00
a → a	FDF	Small flatfish				1.00	1.00	0.01			1.00	1.00			1.00
j → j	SHD	Large demer. sharks				1.00	1.00	1.00			1.00	1.00			1.00
a → j	SHD	Large demer. sharks				1.00	1.00	1.00			1.00	1.00			1.0
j → a	SHD	Large demer. sharks				1.00	1.00	1.00			1.00	1.00			1.00
a → a	SHD	Large demer. sharks				1.00	1.00	1.00			1.00	1.00			1.00
j → j	SHP	Misc. pelagic sharks									1.00				
a → j	SHP	Misc. pelagic sharks									1.00				

Table B-12 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Consumed groups here include macroalgae, seagrass, bacteria, detritus, and carrion. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group												
	Code	Group	Macro algae MA	Sea grass SG	Pelagic bacteria PB	Sed. bacteria BB ^b	Meio-benthos BO	Labile detritus DL	Refr. detritus DR ^c	Carrion DC	Labile detritus in sed. DLsed ^d	Refr. detritus in sed. DRsed ^e	Carrion in sed. DCsed ^f	Large phytoplank. PL ^g	Small phytoplank. PS ^h
j → a	SHP	Misc. pelagic sharks								1.00					
a → a	SHP	Misc. pelagic sharks								1.00					
j → j	SHB	Sm. Demersal sharks				1.00	1.00	1.00		1.00	1.00		1.00		
a → j	SHB	Sm. Demersal sharks				1.00	1.00	1.00		1.00	1.00		1.00		
j → a	SHB	Sm. Demersal sharks								1.00	1.00		1.00		
a → a	SHB	Sm. Demersal sharks								1.00	1.00		1.00		
j → j	SHR	Shallow lg. rockfish			1.00	1.00		1.00		1.00	1.00		1.00		
a → j	SHR	Shallow lg. rockfish			1.00	1.00		1.00		1.00	1.00		1.00		
j → a	SHR	Shallow lg. rockfish								1.00					
a → a	SHR	Shallow lg. rockfish								1.00					
j → j	SSK	Skates, rays				1.00	1.00	1.00		1.00	1.00		1.00		
a → j	SSK	Skates, rays				1.00	1.00	1.00		1.00	1.00		1.00		
j → a	SSK	Skates, rays				1.00	1.00	1.00		1.00	1.00		1.00		
a → a	SSK	Skates, rays				1.00	1.00	1.00		1.00	1.00		1.00		
j → j	SB	Surface seabirds								1.00					
a → j	SB	Surface seabirds					1.00			1.00					
j → a	SB	Surface seabirds								1.00					
a → a	SB	Surface seabirds								1.00					

Table B-12 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Consumed groups here include macroalgae, seagrass, bacteria, detritus, and carrion. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group										Large phytoplank. PL ^g	Small phytoplank. PS ^h	
			Macro algae MA	Sea grass SG	Pelagic bacteria PB	Sed. bacteria BB ^b	Meio-benthos BO	Labile detritus DL	Refr. detritus DR ^c	Carrion DC	Labile detritus in sed. DLsed ^d	Refr. detritus in sed. DRsed ^e			Carrion in sed. DCsed ^f
j → j	SP	Diving seabirds		1.00		1.00	1.00				1.00		1.00		
a → j	SP	Diving seabirds		1.00		1.00	1.00				1.0		1.00		1.00
j → a	SP	Diving seabirds		1.00		1.00	1.00				1.00		1.00		1.00
a → a	SP	Diving seabirds		1.00		1.00	1.00				1.00		1.00		1.00
j → j	REP	Transient orcas									1.00				
a → j	REP	Transient orcas									1.00				
j → a	REP	Transient orcas									1.00				
a → a	REP	Transient orcas									1.00				
j → j	PIN	Pinnipeds									1.00				
a → j	PIN	Pinnipeds									1.00				
j → a	PIN	Pinnipeds									1.00				
a → a	PIN	Pinnipeds									1.00				
j → j	WHB	Baleen whales					1.00	0.01				1.00		1.00	
a → j	WHB	Baleen whales					1.00	0.01				1.00		1.00	
j → a	WHB	Baleen whales					1.00	0.01				1.00		1.00	
a → a	WHB	Baleen whales					1.00	0.01				1.00		1.00	
j → j	WHT	Toothed whales									1.00			1.00	
a → j	WHT	Toothed whales									1.00			1.00	
j → a	WHT	Toothed whales									1.00			1.00	
a → a	WHT	Toothed whales									1.00			1.00	

Table B-12 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Consumed groups here include macroalgae, seagrass, bacteria, detritus, and carrion. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group													
			Macro algae MA	Sea grass SG	Pelagic bacteria PB	Sed. bacteria BB ^b	Meio-benthos BO	Labile detritus DL	Refr. detritus DR ^c	Carrion DC	Labile detritus in sed. DLsed ^d	Refr. detritus in sed. DRsed ^e	Carrion in sed. DCsed ^f	Large phytoplank. PL ^g	Small phytoplank. PS ^h	
j → j	WDG	Otters								1.00						
a → j	WDG	Otters								1.00						
j → a	WDG	Otters								1.00						
a → a	WDG	Otters								1.00						
	ZG	Gelatinous zooplankton			0.01				0.01	1.00				1.00	4.00	
	ZL	Large zooplankton			0.01				0.01					5.00	2.00	
	ZM	Mesozooplankton			0.01				0.01	1.00				<i>10.0</i>	0.25	
	ZS	Microzooplankton			0.01				0.01	1.00				<i>10.0</i>	0.004	
	BD	Deposit feeders	1.00		0.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.20	
	BO	Meiobenthos			0.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	<i>10.00</i>	1.00	
	BC	Carnivorous infauna				1.00	1.00	0.01	0.10	1.00	1.00	1.00	1.00			
	BFS	Shall. benthic filter feeders			0.1	1.00	1.00	0.01	1.00		1.00	1.00	1.00	0.3333	0.20	
	BFF	Other benthic filter feeders			0.01	1.00	1.00	0.01	1.00		1.00	1.00	1.00	1.00	1.00	
	BFD	Deep benthic filter feeders			0.01	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	BMS	Shall. macrozoobenthos				1.00	1.00	0.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	BML	Mega-zoobenthos			0.01	1.00	1.00	0.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
	BMD	Deep macrozoobenthos				1.00	1.00			1.00	1.00	1.00	1.00	1.00	1.00	
	BG	Benthic grazers	1.00	1.00							1.00	1.00	1.00			
	CEP	Cephalopods						1.00			1.00					

Table B-12 continued. Ratio of final values/initial values for consumption parameter (variable a in Equation 10) to compare parameterization after calibration versus before calibration. Consumed groups here include macroalgae, seagrass, bacteria, detritus, and carrion. A ratio of 1 indicates that we did not change consumption parameters from their initial values. Ratios equal to or greater than 10 are in dark gray and italics, and ratios less than or equal to 0.1 are in light gray. Blank cells indicate cases where that predator does not eat that prey.

Stages ^a	Predator		Prey group												
	Code	Group	Macro algae MA	Sea grass SG	Pelagic bacteria PB	Sed. bacteria BB ^b	Meio-benthos BO	Labile detritus DL	Refr. detritus DR ^c	Carrion DC	Labile detritus in sed. DLsed ^d	Refr. detritus in sed. DRsed ^e	Carrion in sed. DCsed ^f	Large phyto-plank. PL ^g	Small phyto-plank. PS ^h
	PWN	Shrimp			1.00	1.00	1.00	0.1	1.00	1.00	1.00	1.00	1.00		
	PWM	Shrimp			1.00	1.00	1.00	0.1	1.00	1.00	1.00	1.00	1.00		

^a In the stages column, j→j signifies juvenile predation on juveniles, a→j signifies adult predation on juveniles, j→a signifies juvenile predation on adults, and a→a signifies adult predation on adults.

^b BB = sedimentary bacteria.

^c DR = refractory detritus.

^d DLsed = labile detritus in sediment.

^e DRsed = refractory detritus in sediment.

^f DCsed = carrion in sediment.

^g PL = large phytoplankton.

^h PS = small phytoplankton.

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