9. Assessment of the Pacific ocean perch stock in the Gulf of Alaska

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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in alternate (even) years we present an executive summary to recommend harvest levels for the next two years. Please refer to last year's full stock assessment report for further information regarding the assessment model (Hanselman et al., 2011, available online at http://www.afsc.noaa.gov/REFM/docs/2011/GOApop.pdf). A full stock assessment document with updated assessment and projection model results will be presented in next year's SAFE report.

We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska Pacific ocean perch which qualifies as a Tier 3 stock. For an off-cycle year, we do not re-run the assessment model, but do update the projection model with new catch information. This incorporates the most current catch information without re-estimating model parameters and biological reference points.

Summary of changes in Assessment Inputs

Changes in the input data: There were no changes made to the assessment model inputs since this was an off-cycle year. New data added to the projection model included an updated 2011 catch and new estimated catches for 2012-2014.

Changes in assessment methodology: There were no changes in assessment methodology since this was an off-cycle year.

Summary of Results

New catch estimates for this year's projection model are an updated 2011 catch of 14,211 t, and estimated 2012-2014 catches of 15,396 t, 14,210 t, and 13,960 t, respectively. The 2012 catch was estimated by expanding the October 1, 2012 official catch by a factor of 1.05, which represents the average fraction of catch taken between October 1 and December 31 in the last three complete years (2009-2011). To estimate future catch, we updated the yield ratio (0.86), which was the average of the ratio of catch to ABC for the last three complete catch years (2009-2011). The updated yield ratio was then multiplied by the projected ABCs for 2013 and 2014 from the 2011 assessment model to generate catches for those years. The yield ratio was the same as last year's ratio of 0.86 and the expansion factor was slightly higher than last year's expansion factor of 1.04.

For the 2013 fishery, we recommend the maximum allowable ABC of 16,412 t from the updated projection model. This ABC is slightly less than last year's ABC of 16,918 t and similar to last year's projected 2013 ABC of 16,500 t. Recommended ABCs from area apportionments are 2,040 t for the Western area, 10,926 t for the Central area, and 3,446 t for the Eastern area. Using the same ratio of estimated biomass in the closed versus open Eastern area as the 2011 assessment (0.48), ABCs from area apportionments are 1,641 t for the W. Yakutat area, which will leave 1,805 t unharvested in the Southeast/Outside area.

Reference values for Pacific ocean perch are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not being subjected to overfishing last year, is not currently overfished, nor is it approaching a condition of being overfished.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2012	2013	2013	2014
M (natural mortality rate)	0.062	0.062	0.062	0.062
Tier	3a	3a	3a	3a
Projected total (ages 2+) biomass (t)	348,168	346,171	345,260	343,561
Female spawning biomass (t)				
Projected	107,769	107,914	107,511	107,325
$B_{100\%}$	234,689	234,689	234,689	234,689
$B_{40\%}$	93,876	93,876	93,876	93,876
$B_{35\%}$	82,141	82,141	82,141	82,141
F_{OFL}	0.138	0.138	0.138	0.138
$maxF_{ABC}$	0.119	0.119	0.119	0.119
F_{ABC}	0.119	0.119	0.119	0.119
OFL (t)	19,498	19,021	**18,919**	18,601
maxABC (t)	16,918	16,500	16,412	16,133
ABC (t)	16,918	16,500	**16,412**	16,133
Status	As determined *last* year for:		As determined *this* year for:	
	2010	2011	2011	2012
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Updated catch data (t) for Pacific ocean perch in the Gulf of Alaska as of October 1, 2012 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org) are summarized in the following table. The 2012 catch in the western GOA exceeded the 2012 ABC and OFL in that area.

Year	Western	Central	Eastern	West Yakutat	E. Yakutat/ Southeast	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
2011	1,818	10,523		1,870	< 1	14,211	16,997	16,997
2012	2,451	10,520		1,682	< 1	14,654	16,918	16,918

Area Apportionment

The apportionment percentages are the same as in the 2011 full assessment. The following table shows the recommended apportionment for 2013. Please refer to last year's full stock assessment report for information regarding the apportionment rationale for Pacific ocean perch.

	Western	Central	Eastern	Total
Area Apportionment	12.4%	66.6%	21.0%	100%
Area ABC (t)	**2,040**	**10,926**	**3,446**	**16,412**
OFL (t)	2,351	12,595	3,973	**18,919**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is the same as last year at 0.48. This results in the following apportionment of the Eastern Gulf area:

	West Yakutat	East Yakutat/ Southeast
Area ABC (t)	1,641	1,805

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Pacific ocean perch	2011	330,480	19,566	16,997	16,997	14,211
	2012	348,168	19,498	16,918	16,918	14,654
	2013	345,260	18,919	16,412		
	2014	343,561	18,601	16,133		

Stock/ Assemblage	Area	2012 OFL	ABC	TAC	Catch[2]	2013 OFL	ABC	2014 OFL	ABC
Pacific ocean perch	W	2,423	2,102	2,102	2,451	2,351	2,040	2,312	2,005
	C	12,980	11,263	11,263	10,520	12,595	10,926	12,383	10,740
	WYAK		1,692	1,692	1,682		1,641		1,613
	SEO		1,861	1,861	< 1		1,805		1,775
	E	4,095	--	--	--	3,973		3,906	
	Total	19,498	16,918	16,918	14,654	18,919	16,412	18,601	16,133

[1]Total biomass (ages 2+) from the age-structured model

[2]Current as of October 1, 2012. Source: NMFS Alaska Regional Office Catch Accounting System via the AKFIN database (http://www.akfin.org).

SSC and Plan Team Comments on Assessments in General

"The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments." (SSC, December 2011)

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal." (Plan Team, September 2012)

"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years." (Plan Team, September 2012)

SSC and Plan Team Comments Specific to this Assessment

"The Team asks the [rockfish] *authors to investigate whether the conversion matrix has changed over time. Additionally, the Team requests that the criteria for omitting data in stock assessment models be based upon the quality of the data (e.g. bias, sampling methods, information content, redundancy with other data, etc.) rather than the effect of the data on modeled quantities."* (Plan Team, November 2011)

"Future research will take another look at growth data, and similar to other rockfish assessments, another examination of the age and length bins – particularly in the plus age group. The author also intends to look at fishery spatial patterns. The [GOA Plan] *Team supported these activities."* (Plan Team, November 2011)

"The SSC looks forward to a review of the stock structure template applied to POP in the GOA, as well as an examination of growth data, age and length bins (including the plus group), and fishery spatial patterns during the next assessment cycle." (SSC, December 2011)

Responses to Comments and Research Priorities for Full Assessment

We did provide a response to the SSC comments regarding the stock structure template and presented a stock structure analysis at the September, 2012 Joint Plan Team meeting. The stock structure analysis is attached following this summary. Responses to the previously listed SSC and Plan Team Comments will be provided in next year's full stock assessment report. To address several of these comments, we plan to follow the recommendations listed in the various working group reports (e.g. the retrospective analysis report) submitted to the Plan Team in September 2012. In addition, we anticipate that many of the comments specific to the Pacific ocean perch assessment will be considered in the upcoming 2013 Center for Independent Experts (CIE) Alaska rockfish scientific peer review. Evaluation of assessment methods to estimate model parameters, uncertainty, and projections as well as recommendations or prioritizations for future research to improve the assessments will likely be part of this process. New maturity estimates for Gulf of Alaska Pacific ocean perch will likely be available for the 2013 assessment and could have a significant effect on the recommended harvest rate.

Appendix 9A:

Evaluation of stock structure for Gulf of Alaska Pacific ocean perch

September, 2012

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Executive Summary

We present various types of information about Gulf of Alaska (GOA) Pacific ocean perch (POP) to evaluate potential stock structure for this species. We follow the stock structure template recommended by the Stock Structure Working Group (SSWG) and elaborate on each category within this framework. Harvest and trend data indicate population levels are stable and that fishing effort appears consistent with abundance distribution. POP are long-lived with a higher generation time than most groundfish. The distribution is extremely patchy and highly aggregated but there is little information regarding spawning, reproduction, larval dispersal, behavior, or movement. Growth differences among regions in the GOA are significantly different but perhaps not biologically meaningful. Genetic analyses have revealed a strong isolation by distance pattern which implies that POP have limited lifetime dispersal. Currently, GOA POP is managed as a Tier 3a species with area-specific Acceptable Biological Catch (ABC) and area-specific Overfishing Level (OFL). Given that localized depletion appears to occur infrequently in the GOA and that total POP catches are less than 90% of maximum permissible ABC, the risk of overfishing the overall population is low. However, overages have occurred recently to the area specific ABC and OFL for Western GOA. We strongly recommend that ABCs be allocated by management area (Western, Central, and Eastern) or smaller (NMFS areas 610-650). However, we believe that the original rationale for area-specific OFLs from the rebuilding plan no longer exists because the overall population is above target levels and is less vulnerable to occasional overages. A compromise might be to have an OFL for the fished portion (Western, Central and West Yakutat areas combined) and the unfished portion (East Yakutat and Southeast).

Introduction

The Stock Structure Working Group (SSWG) was formed in 2009 to develop a set of guidelines to assist stock assessment authors in providing recommendations on stock structure for Alaska stocks. The framework was presented at the September 2009 joint Groundfish Plan Team and a report was drafted shortly thereafter that included a template for presenting various scientific data for inferring stock structure. In November, 2010, The Gulf of Alaska Groundfish Plan Team (GOA GPT) discussed the advantages of having all stock assessment authors evaluate stock structure characteristics of specific stocks. There have been recent overages of the Pacific ocean perch (POP) Acceptable Biological Catch (ABC) and area-specific Overfishing Level (OFL) in the Western Gulf of Alaska, and the authors were requested to evaluate current management units for Pacific ocean perch. We believe the stock structure template is necessary to adequately address these questions.

Sebastes rockfish species in Federal waters of the Gulf of Alaska (GOA) were first split into three broad management assemblages by the North Pacific Fishery Management Council (NPFMC) in 1988: slope rockfish, PSR, and demersal shelf rockfish. Since 1988, major modifications have occurred to break out these broad groupings into finer scale assemblages. GOA POP has been managed as a single stock since 1991. In the 1994 groundfish specifications, POP were assigned area-specific OFLs because they were declared overfished and under a rebuilding plan. The specifications also stated that:

POP stocks will be considered to be rebuilt when the total biomass of mature females is equal to or greater than B_{MSY} (currently estimated at 150,000 mt)[1].

Currently, GOA POP is managed as a Tier 3a stock (spawning biomass is above $B_{40\%}$) with area-specific ABC and area-specific OFL. Included here is a summary of what is known regarding the population of POP in the GOA relevant to stock structure concerns along with an evaluation of the stock structure template, author recommendations, and potential management implications to be considered. Some of this information is excerpted from the most recent full stock assessment and can be found in more detail there (Hanselman et al. 2011).

Distribution

POP has a wide distribution in the North Pacific from southern California around the Pacific rim to northern Honshu Is., Japan, including the Bering Sea. The species appears to be most abundant in northern British Columbia, the Gulf of Alaska, and the Aleutian Islands (Allen and Smith 1988). Adults are found primarily offshore on the outer continental shelf and the upper continental slope in depths 150-420 m. Seasonal differences in depth distribution have been noted by many investigators. In the summer, adults inhabit shallower depths, especially those between 150 and 300 m. In the fall, the fish apparently migrate farther offshore to depths of ~300-420 m. They reside in these deeper depths until about May, when they return to their shallower summer distribution (Love et al. 2002). This seasonal pattern is probably related to summer feeding and winter spawning. Although small numbers of POP are dispersed throughout their preferred depth range on the continental shelf and slope, most of the population occurs in patchy, localized aggregations (Hanselman et al. 2001). POP are generally considered to be semi-demersal but there can at times be a significant pelagic component to their distribution. POP often move off-bottom during the day to feed, apparently following diel euphausiid migrations (Brodeur 2001). Commercial fishing data in the GOA since 1995 show that pelagic trawls fished off-bottom have accounted for as much as 20% of the annual harvest of this species.

Life History

There is much uncertainty about the life history of POP, although generally more is known than for other rockfish species (Kendall and Lenarz 1986). The species appears to be viviparous (the eggs develop internally and receive at least some nourishment from the mother), with internal fertilization and the release of live young. Insemination occurs in the fall, and sperm are retained within the female until fertilization takes place ~2 months later. The eggs hatch internally, and parturition (release of larvae) occurs in April-May. Information on early life history is very sparse, especially for the first year of life. POP larvae are pelagic and drift with the current, and oceanic conditions may sometimes cause advection to suboptimal areas (Ainley et al. 1993) resulting in high recruitment variability. However, larval studies of rockfish have been hindered by difficulties in species identification since many larval rockfish species share the same morphological characteristics (Kendall 2000). Genetic techniques using allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Li 2004) are capable of identifying larvae and juveniles to species. Post-larval and early young-of-the-year POP have been positively identified in offshore, surface waters of the GOA (Gharrett et al. 2002), which suggests this may be the preferred habitat of this life stage. Transformation to a demersal existence may take place within the first year (Carlson and Haight 1976). Small juveniles probably reside inshore in very rocky, high relief areas, and by age 3 begin to

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[1] Sec. 672.20(a)(2). http://alaskafisheries.noaa.gov/prules/noa_18103.pdf

migrate to deeper offshore waters of the continental shelf (Carlson and Straty 1981). As they grow, they continue to migrate deeper, eventually reaching the continental slope where they attain adulthood.

POP are mostly planktivorous (Carlson and Haight 1976; Yang 1993; Yang et al. 2006). In a sample of 600 juvenile perch stomachs, Carlson and Haight (1976) found that juveniles fed on an equal mix of calanoid copepods and euphausiids. In a later study, Yang et al. (2006) sampled larger juveniles and adults and found them to feed primarily on euphausiids, and to a lesser degree, copepods, amphipods and mysids. In the Aleutian Islands, myctophids have increasingly comprised a substantial portion of the POP diet, which also compete for euphausiid prey (Yang et al. 2006). POP and walleye pollock (*Theragra chalcogramma*) probably compete for the same euphausiid prey as euphausiids make up about 50% of the pollock diet (Yang et al. 2006). Consequently, the large removals of POP by foreign fishermen in the Gulf of Alaska in the 1960s may have allowed walleye pollock stocks to greatly expand in abundance.

Predators of adult POP are likely sablefish, Pacific halibut, and sperm whales (Major and Shippen 1970). Juveniles are consumed by seabirds (Ainley et al. 1993), other rockfish (Hobson et al. 2001), salmon, lingcod, and other large demersal fish.

POP is a slow growing species, with a low rate of natural mortality (estimated at 0.06), a relatively old age at 50% maturity (10 years for females in the Gulf of Alaska), and a very old maximum age of 98 years in Alaska (88 years maximum age in the Gulf of Alaska). Age at 50% recruitment to the commercial fishery has been estimated to be between 7 and 8 years in the Gulf of Alaska. Despite their viviparous nature, they are relatively fecund with number of eggs/female in Alaska ranging from 10,000-300,000, depending upon size of the fish (Leaman 1991). Rockfish in general were found to be about half as fecund as warm water snappers with similar body shapes (Haldorson and Love 1991).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-compression could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Research on black rockfish (*Sebastes melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. de Bruin et al. (2004) examined POP and rougheye rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for POP or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. Spencer et al. (2007) showed that the effects of enhanced larval survival from older mothers decreased estimated F_{msy} (the fishing rate that produces maximum sustainable yield) by 3% to 9%, and larger decreases in stock productivity were associated at higher fishing mortality rates that produced reduced age compositions. Preliminary work at Oregon State University examined POP of adult size by extruding larvae from harvested fish near Kodiak, and found no relationship between spawner age and larval quality (Heppell et al. 2009). However, older spawners tended to undergo parturition earlier in the spawning season than younger fish. These data are currently still being analyzed.

Fishery

A POP trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960s. This fishery developed rapidly, with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965, when a total of nearly 350,000 metric tons (t) was caught. This apparent overfishing resulted in a precipitous decline in catches in the late 1960s. Catches continued to decline in the 1970s, and by 1978 catches were only 8,000 t (Figure 9A.1A). Foreign fishing dominated the fishery from 1977 to 1984, and catches generally declined during this period. Most of the catch was taken by Japan. Catches reached a minimum in 1985, after foreign trawling in the Gulf of Alaska was prohibited.

The domestic fishery first became important in 1985 and expanded each year until 1991 (Figure 9A.1B). Much of the expansion of the domestic fishery was apparently related to increasing annual quotas; quotas increased from 3,702 t in 1986 to 20,000 t in 1989. In the years 1991-95, overall catches of slope rockfish diminished as a result of the more restrictive management policies enacted during this period. The restrictions included: (1) establishment of the management subgroups, which limited harvest of the more desired species; (2) reduction of total allowable catch (TAC) to promote rebuilding of POP stocks; and (3) conservative in-season management practices in which fisheries were sometimes closed even though substantial unharvested TAC remained. These closures were necessary because, given the large fishing power of the rockfish trawl fleet, there was substantial risk of exceeding the TAC if the fishery were to remain open. Since 1996, catches of POP have increased again, as good recruitment and increasing biomass for this species have resulted in larger TAC's. In the last several years, the TAC's for POP have been fully taken (or nearly so) in each management area except Southeast Outside. (The prohibition of trawling in Southeast Outside during these years has resulted in almost no catch of POP in this area.)

Abundance

Biomass estimates of POP were relatively low in 1984 to 1990, increased markedly in both 1993 and 1996, and became substantially higher in 1999 and 2001 with much uncertainty (some of this uncertainty was because the EGOA was not sampled in 2001) (Figure 9A.2A). Biomass estimates in 2003 have less sampling error with a total similar to the 1993 estimate indicating that the large estimates from 1996-2001 may have been a result of a few anomalous catches. However, in 2005 the estimate was similar to 1996-2001, but was more precise. To examine these changes in more detail, the biomass estimates for POP in each statistical area (610-650 from Western GOA to Eastern GOA) are presented in Figure 9A.2B. The large rise in 1993, which the confidence intervals indicate was statistically significant compared with 1990 (Figure 9A.2A), was primarily the result of big increases in biomass in the Central and Western Gulf of Alaska. The Kodiak area increased greater than ten-fold, from 15,765 t in 1990 to 153,262 t in 1993. The 1996 survey showed continued biomass increases in all areas, especially Kodiak, which more than doubled compared with 1993. In 1999, there was a substantial decline in biomass in all areas except Chirikof, where a single large catch resulted in a very large biomass estimate. In 2001, the biomass estimates in both the Shumagin and Kodiak areas were the highest of all the surveys. In particular, the biomass in Shumagin was much greater than in previous years; the increased biomass here can be attributed to very large catches in two survey hauls. In 2003 the estimated biomass in all areas except for Chirikof decreased, where Chirikof returned from a decade low to a more average value. The rise in biomass in 2005 can be attributed to large increases in the Shumagin and Kodiak areas. In 2007, the biomass dropped about 10% from 2005, with the bulk of that drop in the Shumagin area. POP continued to be more uniformly distributed than in the past (Figure 9A.3). In 2009, total biomass was similar to 2007, and is the fourth survey in a row with relatively high precision. The biomass in the Shumagin dropped severely from 2005 to 2009, but increased from 2009 – 2011. It also appeared some of the biomass was consolidating around Kodiak Island (Figure 9A.3). In 2011, total biomass increased from 2009, but was quite similar to the mean of the last decade. Precision remains reasonably high relative to the 1990s.

Application of Stock Structure Template

To evaluate POP stock structure, we utilize the existing framework for defining spatial management units introduced by Spencer et al. (2010) (Table 9A.1). In the following sections, we elaborate on the available information used to respond to specific factors and criterion for defining GOA POP stock structure. This information is summarized in Table 9A.2.

<u>Harvest and trends</u>

Fishing mortality

The fully-selected fishing mortality time series indicates a large rise in the 1960s followed by precipitous declines from late 1980's through the late 1990's and has been steady since 2000 (Figure 9A.4). Since 2000, these levels have been well below $F_{40\%}$, the maximum permissible fishing mortality for ABC.

Spatial concentration of fishery relative to abundance

In a study on localized depletion of Alaskan rockfish, Hanselman et al. (2007) showed that POP are sometimes highly depleted in a few areas 5,000-10,000 km^2 in size, but a similar amount of fish return in the following year. This result suggests that there is enough movement on an annual basis to prevent serial depletion and deleterious effects on stock structure. In general, there is little evidence for localized depletion of POP in the Gulf of Alaska. The local populations may be large enough compared to the existing catch limits that significant depletions do not occur.

We utilized the observed fishery catch and trawl survey data to generate a series of spatial distribution maps of POP concentrations. We developed maps of mean conditions to identify long-term patterns in POP distribution (Figure 9A.6). In order to compare the trawl survey and the fishery data on the same map, we created an interpolated raster image of the trawl survey data from 1984-2011 (Figure 9A.6A). The trawl survey provided the most complete spatial coverage and catch (kg) was available by haul. Based on this survey data, POP are distributed in a narrow depth band along the shelf break near the 200 m isobath with high aggregations corresponding to many of the major canyons along the shelf break, particularly in the Amatuli Gully (shelf region southwest of Prince William Sound) and Portlock Bank region. We then calculated mean fishery catches by aggregating the observed fishery data in a raster image and converting the centroids of each raster cell to points at a 50 km grid resolution. Observed fishery data was available from 1993-2011. In general, the mean catches for the observed fishery are distributed similarly to the trawl survey (Figure 9A.6B). The exception is the Eastern Gulf area where we see the impact of Amendment 41 prohibiting trawling east of the 140^{o}W line. This essentially splits the Yakutat region into two smaller areas and could serve to protect a section of the POP population in the Eastern Gulf region from exploitation.

Population trends

NMFS trawl surveys have been conducted in the GOA since 1984. Despite high variability in survey catches and biomass estimates, the biomass of POP population levels have increased substantially since the 1990s (Figure 9A.2A). Model predicted total biomass estimates indicate an increasing trend over time (Figure 9A.5). Population trends within regions are similar to overall trend but tend to fluctuate more because of the highly variable survey catch rates (Figure 9A.2B, Figure 9A.3).

<u>Barriers and phenotypic characters</u>

Generation time

Rockfish in the GOA are typically slow growing and long-lived. The maximum age of POP in the GOA is 88 years, but the average survey age was 11.4 years in 2009. The estimate of natural mortality is 0.062. We estimated generation time for POP at 27 years following the methods described in Restrepo et al. 1998 and the estimates of biological parameters available from the POP age-structured model (Hanselman et al. 2011). The age at 50% maturity of POP in the GOA is 10 years. In comparison to larger slope rockfish in the GOA (e.g., rougheye rockfish), these values indicate POP has a lower generation time, likely due to the higher natural mortality and earlier maturity.

Physical limitations

General circulation in the GOA is dominated by two major current systems: the northward flowing Alaska Current which narrows and intensifies near Prince William Sound to become the westward flowing Alaskan Stream and the narrow, counter-clockwise flowing Alaska Coastal Current (Weingartner et al. 2009). Bathymetry is highly complex in the GOA, with a wide central and narrow east/west continental shelf that is innervated with large gullies and canyons (Ladd et al. 2005). Marine species such as POP with pelagic larval stages have potential for high dispersal due to the dominant current systems; however, actual extent of dispersal is unknown. Recent genetic studies suggest POP adults belong to neighborhoods at geographic scales less than 400 km indicating limited dispersal (Palof et al. 2011).

Interaction with high relief bathymetric features such as submarine canyons during the demersal settlement stage may cause dispersal to be more localized. The spatial distribution of POP from the trawl survey suggests there may be some association with these gully regions as marked by the 200 m bathymetry line (Figure 9A.6a). Bathymetric steering into canyons with strong tidal mixing has been suggested as a cross-shelf transport mechanism for several flatfish species in the GOA that have a similar early life history to POP (Bailey et al. 2008).

Growth differences

Weights, lengths and ages from the bottom trawl survey are our primary means to assess regional growth differences. Otoliths are taken on the GOA bottom trawl survey and POP samples have been aged for all survey years except 2001 (Table 9A.3). These ages are taken on a length-stratified system in which several fish are taken from each length category. An age-length key for the area and year are then applied to get the correct estimate of proportion-at-age for the survey area. Weights are taken for all otolith specimens presently, but not always historically. Lengths are taken randomly throughout the survey. The distribution of samples across areas is shown below:

Sample size	Western GOA	Central GOA	Eastern GOA
Weights	1,308	3,488	2,373
Ages	2,515	7,887	6,483
Lengths	35,483	90,600	83,908

The highest age collected over these survey years was 88. Mean length, age, weight, differences were tested using the Tukey Honest Significant Differences test to account for multiple testing between areas. Length data were available for all survey years (Table 9A.3). We summarize some comparisons between areas in Table 9A.4. The mean length was significantly different across all regions, but the actual difference is small. The huge sample size gives hypersignificant results. The average age ranged from 9 to 12 across areas over all survey years available and all areas were significantly different from each other. Mean weight was only significantly different in the Central GOA. Significance of the proportion of males was tested against a two-sided null hypothesis of 0.5 of the binomial distribution. All areas had a sex ratio of males that was significantly higher than 0.5 and all were significantly different from each other.

To evaluate whether there were growth differences between areas, we fit von Bertalanffy growth curves to the mean length-at-age and weight-at-age data by area. This showed significantly different growth curves by management area (Figures 7, 8). The growth curves by area were then tested against each other using likelihood ratio tests at an alpha=0.05. Models sharing parameters were tested against the full model where all parameters were estimated for each area. Table 9A.4 shows the parameters that were significantly different between areas using these tests. All three growth parameters in the eastern GOA (EGOA) were significantly different than both the central and western GOA (CGOA and WGOA, respectively). For all areas, the estimates of L_∞, and κ were significantly different from each other. For the weight-at-age curves we fixed β to the overall allometric value of 2.97 for all curves. W_∞ was significantly different across all areas, while kappa was only significantly different in the EGOA. The estimate of t_0 was not significantly different in any areas.

The observed spatial differences are potentially due to stock structure, variable harvest levels by management area (e.g., EGOA POP grow slower to a larger size with no fishing), true area-specific life history characteristics because of environmental conditions, or a combination of all three.

Age/size structure

The best available knowledge on the age and size structure of POP in the GOA comes from bottom trawl survey data. There is also age and size structure collected from the fishery. Survey size and age compositions suggest that recruitment of POP is autocorrelated with relatively infrequent recruitment events that are 2-3 times average. These recruitment events can be tracked in the age composition data. Large differences in where recruitment occurs may be evidence of stock structure and can provide information on the patterns of larval dispersal. In Figure 9A.9, we show the 5 largest year classes of POP as they recruit to the survey by area. The five year classes all show up in each area, but sometimes at differing survey years and magnitudes. For example, the 1986 and 1987 year classes show up strongly in the EGOA and CGOA, but weakly in the WGOA. On the other hand, the 1998 and 1999 year classes show up strongly first in the EGOA, followed by the WGOA, then the CGOA. The 1987 year class still makes up a large proportion of the EGOA age-structure in 2009. In 2009, all the major year classes appear to have dissipated in the WGOA (Figure 9A.9). Some of these differences may be due to localized spawning and recruitment events or show evidence of higher than expected movement rates. The mean population age has fluctuated between 9 and 11.4 years. There is a clear west-east cline toward older fish caught in the fishery starting with NMFS area 620 (Chirikof) east toward NMFS area 650 (Southeast Alaska) which has been closed to trawling since 1998 (mean age 13.5 – 20.4 years). There has been an increase in mean age in the survey since 1987 and a decline in the mean fishery age since 1991 (Hanselman et al. 2011).

Spawning time differences

Fertilized ova and eyed embryos have been observed from February to April. Parturition is believed to occur in the spring. Similar to all other species of *Sebastes*, POP are viviparous with fertilization, embryonic development, and larval hatching occurring inside the mother. After extrusion, larvae are pelagic, but larval studies are hindered because they can only be positively identified by genetic analysis. Even if sufficient resources were available for genetic testing, there are insufficient survey data collected for larval rockfish. Therefore, indentifying differences in spawning times is not likely at this time.

Maturity-at age/length differences

Only one study has estimated 50% maturity at age for GOA POP (Lunsford 1999, 10 years). A forthcoming study (C. Conrath pers. comm.[2]) shows that maturity at age may be at a younger age than Lunsford (1999).

Morphometrics

Quast (1987) conducted a thorough investigation of POP morphometrics from the Bering Sea to Vancouver Island. He found when standardized to a body length of 26 cm, most of 18 characteristics changed in a V-shaped cline from west to east (i.e., measurements were smallest in the center of the study). The main exception was associated with a steady cline of belly lengthening as samples were collected further west. He concluded that declaring any subspecies of POP was premature (previously proposed by Matsubara (1943) and Barsukov (1964)), and that morphometric variation is due primarily to latitude, and may be a phenotypic response.

Meristics

Many studies have compared meristic counts across *Sebastes* species, but we were unable to locate any that compared meristic counts within POP spatially.

Behavior and movement

Spawning site fidelity

Little is known regarding the spawning habits of POP in the GOA. There is no information on whether migrations occur for breeding or spawning. Harvest or catch data from this time period (fall/winter) is sparse from fisheries or surveys so annual distribution changes are difficult to detect. In general POP move into deeper waters in the spawning period, but whether there are specific habitats or locations is unknown.

Mark-recapture data

Because rockfish are physoclistic and subject to barotrauma there is little information regarding movement studies of deep-water rockfish. It is unlikely that mark-recapture studies would be successful because POP inhabit deep depths and are typically caught with trawl nets.

Natural tags

No studies have addressed otolith microchemistry of POP in the GOA. Parasite infestation has been used as a natural occurring tag in some rockfish species in the GOA (Moles et al. 1998). However, no studies have addressed parasite tags in POP.

Genetics

A few studies have been conducted on the genetic stock structure of POP. Based on allozyme variation, Seeb and Gunderson (1988) concluded that POP are genetically quite similar throughout their range, and

[2] Chritina Conrath, RACE Division, Alaska Fisheries Science Center, NOAA Fisheries, Kodiak, AK.

genetic exchange may be the result of dispersion at early life stages. In contrast, analysis using microsatellite DNA techniques indicates that genetically distinct populations of POP exist (Palof 2008). Palof et al. (2011) report that there is low, but significant genetic divergence (FST = 0.0123) and there is a significant isolation by distance pattern. They also suggest that there is a population break near the Yakutat area from conducting a principle component analysis. Withler et al. (2001) found distinct genetic populations on a small scale in British Columbia. These populations may have been more subjected to physical barriers than the populations on the Alaskan continental shelf/slope break. Currently, genetic studies are underway that should clarify the genetic stock structure of POP and its relationship to population dynamics.

Isolation by distance

A survey of microsatellite variation was conducted among GOA and BS collections of adult POP. The results are consistent with a strong, geographically-based population structure (Palof et al. 2011). This work examined variation at 14 microsatellite loci in 12 distinct collection sites that range along the GOA from southern Southeast Alaska to the western Aleutian Islands and three areas along the BS continental slope. Pairwise tests between collections indicated that substantial divergence exists among all pairs. In addition, the divergence correlated with geographic separation of the collections and demonstrated an isolation-by-distance pattern (Figure 9A.10). In a subsequent project supported by NPRB, the Gharrett lab analyzed many (~2000) young-of-the-year (YOY) POP captured incidentally during juvenile salmon surveys in the GOA and BS. The biological and management interpretation of the divergence and the geographic differences among the YOY collections indicates that, even though prevailing currents have the potential to carry larval POP long distances counter clockwise around the eastern GOA, larvae appear to settle close to the area in which genetically similar adults, presumably their parents – inhabit and that the combined movements of larvae, juveniles, and adults is less than 200 km (Kamin et al. in prep).

Dispersal distance

While annual dispersal distances cannot be estimated with the genetic data available, a lifetime dispersal range or neighborhood size can be established. The neighborhood size reflects the average distance that an individual might move between its birth, and when it reproduces. A sensitivity analysis of estimates of neighborhood size from the adult genetic isolation by distance relationship yielded ranges from 70 to 140 km (Palof et al. 2011).

Pairwise genetic differences

Pairwise tests between collections indicated that substantial divergence exists among all pairs (Palof et al. 2011).

Summary, Implications, and Recommendations

We summarized the available information on stock structure for POP in the GOA in Table 9A.2. Harvest and trend data indicate population levels have increased and are now stable and that fishing mortality in recent years is below maximum permissible *F*. Fishing is focused in small spatial areas but distribution of effort appears to be consistent with abundance. Typical of *Sebastes* species, POP are long-lived and have a long generation time but have a lower generation time than the large deep-water *Sebastes*. Little information is available regarding reproduction and mechanisms responsible for larval dispersion, but POP are found throughout the GOA in varying levels of abundance. Growth differences among regions in the GOA are significant, but perhaps not biologically important. The strongest differences in biological parameters exist in the Eastern GOA, probably due to over a decade of extremely low fishing mortality because of the trawl closure. Behavior and movement information for most *Sebastes* species is lacking in the GOA. The only data on spawning movement is that they are found in deeper water during infrequent winter sampling. Recent genetic analyses have shown weak overall differentiation typical of marine species, but that differentiation shows a strong isolation by distance pattern. These data suggest lifetime movement of less than 400 km, despite POP having pelagic larvae which could potentially be carried large distances by oceanographic processes.

The current management regime apportions the stock and catch into three large geographical regions. Survey and fishery data indicate that abundance levels differ among the regions. Only the West Yakutat area of the Eastern GOA is open to trawling thus commercial harvest in the Eastern GOA is low. Because POP are patchily distributed and tend to be concentrated in small spatial areas of high relief there is concern for localized depletion. However, available data indicate localized depletion has occurred infrequently in the GOA, and when it has occurred the areas have been replenished in the following years. Mixing and dispersal of fish among areas is poorly estimated; therefore the capacity of the population for repopulating small spatial areas is unknown. The available genetic data shows population structure on a course scale, but whether fine-scale structure in the GOA exists such as that demonstrated by Withler et al. (2001) remains to be determined. If there is fine scale genetic population structure, it is difficult to determine if current management practices effectively protect POP populations from disproportionate harvest in certain areas. POP are of concern due to their apparent concentration in narrow depth bands along offshore banks and gullies, but no available data indicates that stock structure is at risk under the current management regime.

POP catches in the GOA are about 90% of maximum permissible and risk of global overfishing is low. Recent occasional occurrences of catches in excess of OFL in the Western GOA are of some concern, but are unlikely a serious threat at the low fishing mortality allowed on POP. If these overages became chronic, it could eventually have deleterious effects to the population in that area. The overall stock is well above target levels, so the original rationale of initiating area-specific OFL's in the rebuilding plan is no longer needed because there are multiple levels of precaution built into the current management recommendations and regular overharvest is unlikely. A compromise might be to have an OFL for the fished portion (Western, Central and West Yakutat areas combined) and the unfished portion (East Yakutat and Southeast). This would protect the stock in the unlikely event that the unused OFL in the Eastern GOA was all taken in a different area. Additionally, given the available evidence on GOA POP stock structure, the current resolution of spatial ABCs could potentially be increased to smaller areas such as NMFS areas 610-650 (five instead of three), without imposing quotas that were onerously small for management.

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Table 9A.1. Framework of types of information to consider when defining spatial management units (from Spencer et al. 2010).

Factor and criterion	Justification
Harvest and trends	
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	If this value is low, then conservation concern is low
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	If fishing is focused on very small areas due to patchiness or convenience, localized depletion could be a problem.
Population trends (Different areas show different trend directions)	Differing population trends reflect demographic independence that could be caused by different productivities, adaptive selection, differing fishing pressure, or better recruitment conditions
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	If generation time is long, the population recovery from overharvest will be increased.
Physical limitations (Clear physical inhibitors to movement)	Sessile organism; physical barriers to dispersal such as strong oceanographic currents or fjord stocks
Growth differences (Significantly different LAA, WAA, or LW parameters)	Temporally stable differences in growth could be a result of either short term genetic selection from fishing, local environmental influences, or longer-term adaptive genetic change.
Age/size-structure (Significantly different size/age compositions)	Differing recruitment by area could manifest in different age/size compositions. This could be caused by different spawning times, local conditions, or a phenotypic response to genetic adaptation.
Spawning time differences (Significantly different mean time of spawning)	Differences in spawning time could be a result of local environmental conditions, but indicate isolated spawning stocks.
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Temporally stable differences in maturity-at-age could be a result of fishing mortality, environmental conditions, or adaptive genetic change.
Morphometrics (Field identifiable characters)	Identifiable physical attributes may indicate underlying genotypic variation or adaptive selection. Mixed stocks w/ different reproductive timing would need to be field identified to quantify abundance and catch
Meristics (Minimally overlapping differences in counts)	Differences in counts such as gillrakers suggest different environments during early life stages.
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Primary indicator of limited dispersal or homing
Mark-recapture data (Tagging data may show limited movement)	If tag returns indicate large movements and spawning of fish among spawning grounds, this would suggest panmixia
Natural tags (Acquired tags may show movement smaller than management areas)	Otolith microchemistry and parasites can indicate natal origins, showing amount of dispersal
Genetics	
Isolation by distance (Significant regression)	Indicator of limited dispersal within a continuous population
Dispersal distance (<<Management areas)	Genetic data can be used to corroborate or refute movement from tagging data. If conflicting, resolution between sources is needed.
Pairwise genetic differences (Significant differences between geographically distinct collections)	Indicates reproductive isolation.

Table 9A.2. Summary of available data on stock structure evaluation of GOA POP. Template from Spencer et al. 2010.

Factor and criterion	Evidence of structure
	Harvest and trends
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	Recent years have low fishing mortality rates and catches are below ABC.
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Fishing appears to be distributed similar to survey abundance and distribution. Recent study found minimal localized depletion (Hanselman et al., 2007).
Population trends (Different areas show different trend directions)	Overall population trend is relatively stable or increasing. Regional biomass estimates are too variable to detect trends.
	Barriers and phenotypic characters
Generation time (e.g., >10 years)	Generation time is long (>10 years) but less than large deep-water *Sebastes* species.
Physical limitations (Clear physical inhibitors to movement)	No physical limitations known, but larval dispersal poorly understood.
Growth differences (Significantly different LAA, WAA, or LW parameters)	No major differences in growth among the Eastern GOA, Central GOA, and Western GOA.
Age/size-structure (Significantly different size/age compositions)	Age and size structures driven by major recruitment events. No major differences among regions in the GOA.
Spawning time differences (Significantly different mean time of spawning)	Unknown
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Unknown
Morphometrics (Field identifiable characters)	V-shaped cline from west to east of most characteristics, probably related to latitude or phenotypic expression
Meristics (Minimally overlapping differences in counts)	No known regional measurements
	Behavior & movement
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown
Mark-recapture data (Tagging data may show limited movement)	Mark-recapture data unavailable.
Natural tags (Acquired tags may show movement smaller than management areas)	Unknown
	Genetics
Isolation by distance (Significant regression)	Relatively strong significant IBD pattern
Dispersal distance (<<Management areas)	< 400 km, probably 70-140 km per generation, smaller than current management areas
Pairwise genetic differences (Significant differences between geographically distinct collections)	Yes, between 12 distant adult collections, also between Young-of-the-Year fish collected opportunistically.

Table 9A.3: Age and length samples sizes for Pacific ocean perch from AFSC GOA bottom trawl survey.

Year	Age Samples	Length Samples
1984	1,427	24,112
1987	1,824	18,086
1990	1,766	14,825
1993	1,492	18,567
1996	718	22,300
1999	963	12,707
2001	-	9,153
2003	1,003	18,479
2005	1,023	26,677
2007	1,177	20,990
2009	408	24,095
Total	11,801	209,991

Table 9A.4: Areal comparisons of biological parameters estimated from AFSC GOA bottom trawl survey data of Pacific ocean perch.

Parameter	WGOA	CGOA	EGOA	p-value*
Mean weight (g)	454	526	467	CGOA, <0.05
Mean length (mm)	31.2	33.7	31.0	All,<0.05
Mean age	9.0	12.4	10.9	All, <0.001
Proportion Male	***0.53***	***0.54***	***0.51***	All, <0.001
W_∞	EG, CG	EG, WG	WG,CG	
κ	EG	EG	WG,CG	
t_o	--	--	--	
L_∞	EG, CG	EG, WG	WG,CG	
κ	EG, CG	EG,WG	WG,CG	
t_o	EG	EG	WG,CG	

*p-value column refers to the between area comparisons. Proportions in bold refer to proportions that were significantly different than 0.5.

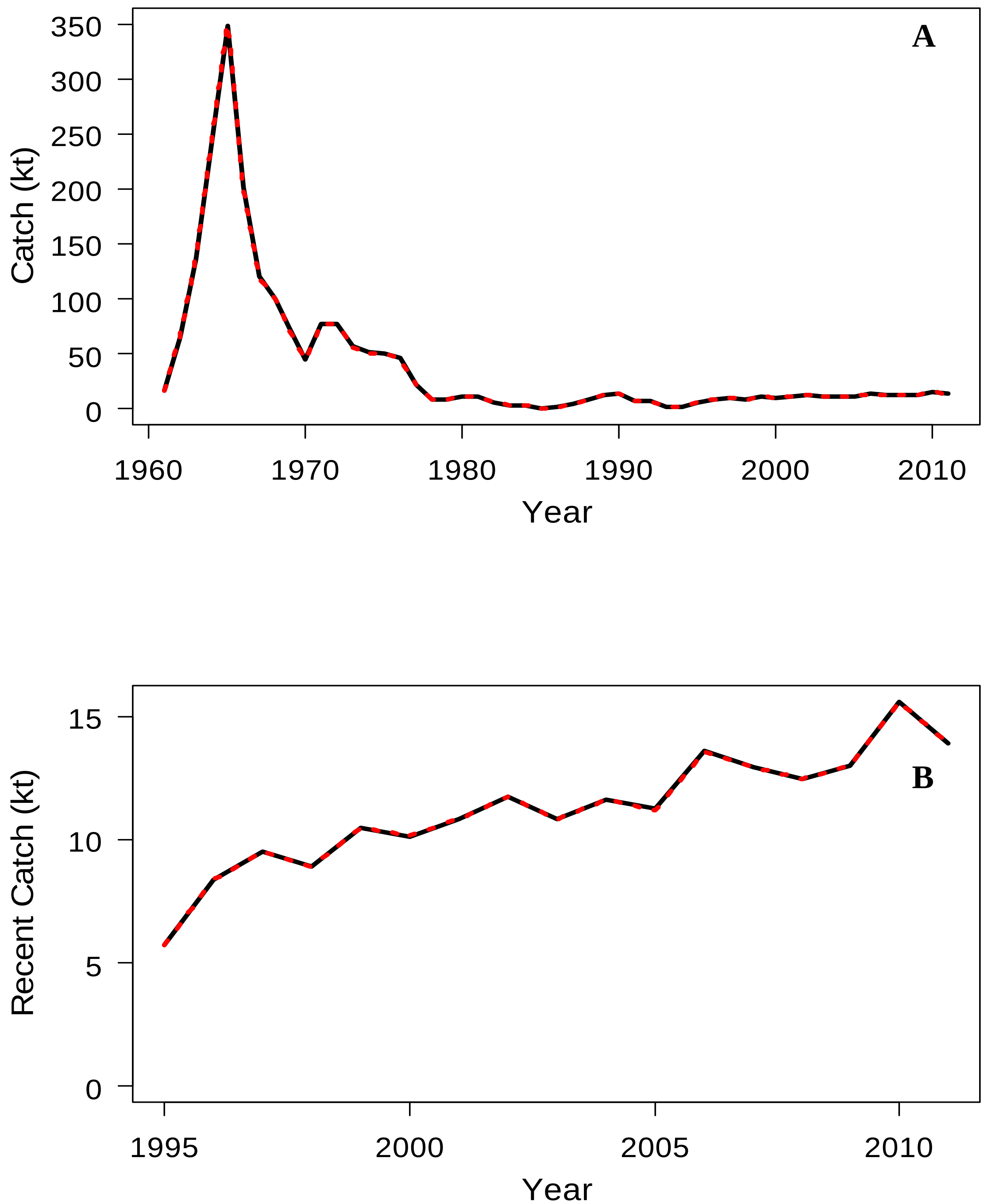


Figure 9A.1. Estimated commercial catches for GOA POP. Observed is solid line, model estimated is dashed line (from Hanselman et al. 2011). Panel A is long-term, Panel B is focused on recent years.

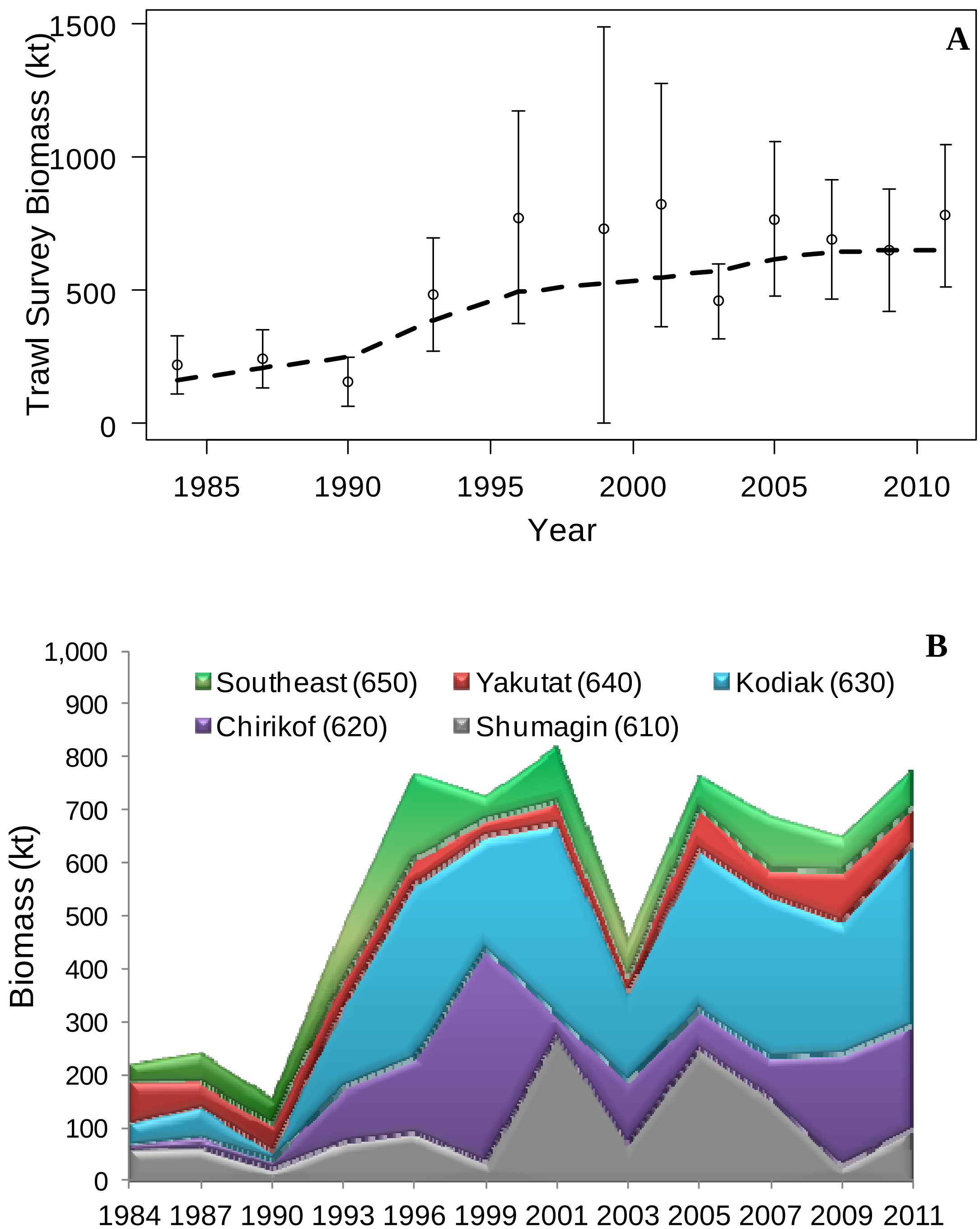


Figure 9A.2. (A) Observed and model predicted GOA POP total trawl survey biomass. Observed biomass is circles with 95% confidence intervals of sampling error (from Hanselman et al. 2011). (B) Survey biomass estimates by statistical area.

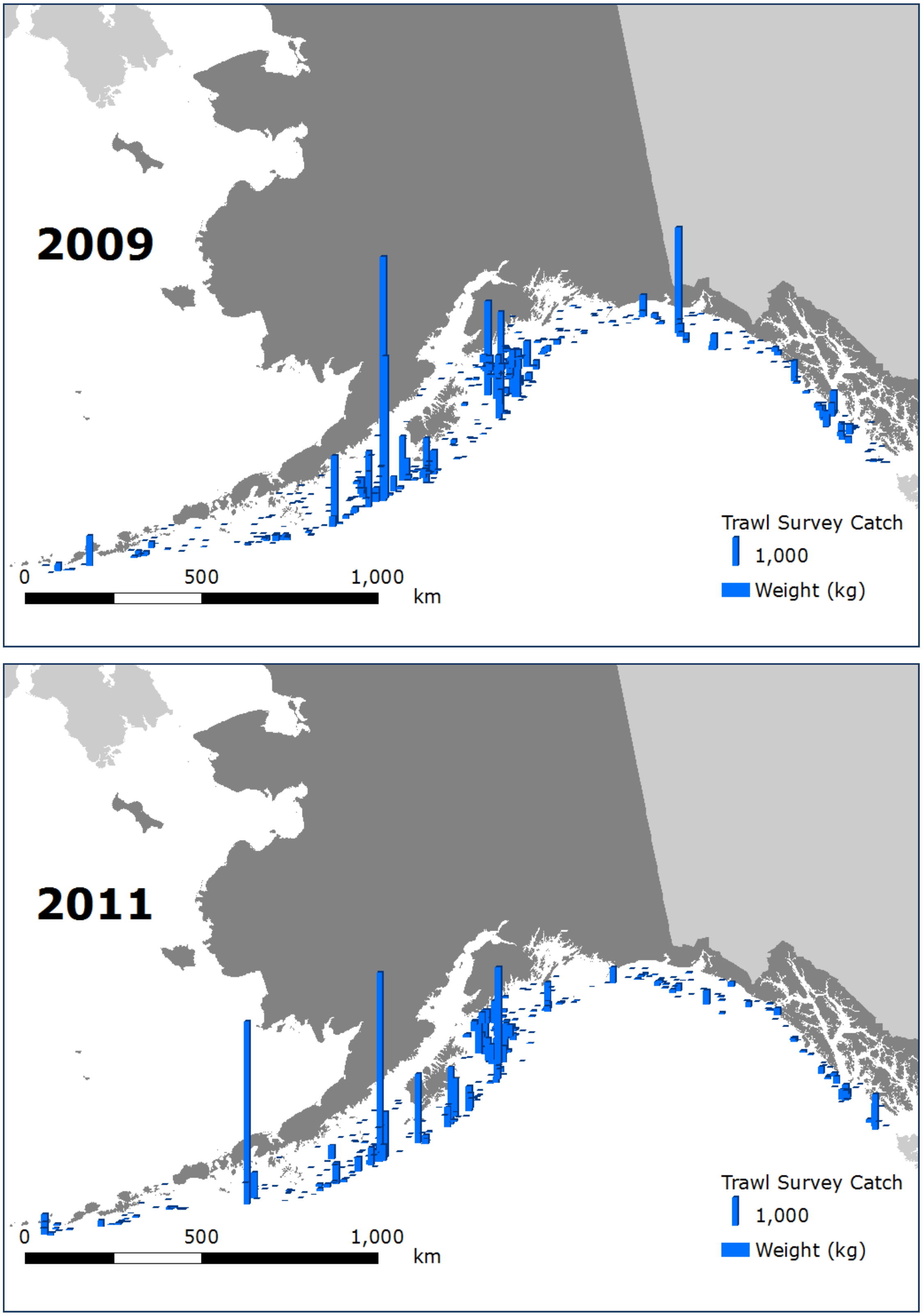


Figure 9A.3. Spatial distribution of POP in the Gulf of Alaska during the 2009, and 2011 NMFS trawls surveys.

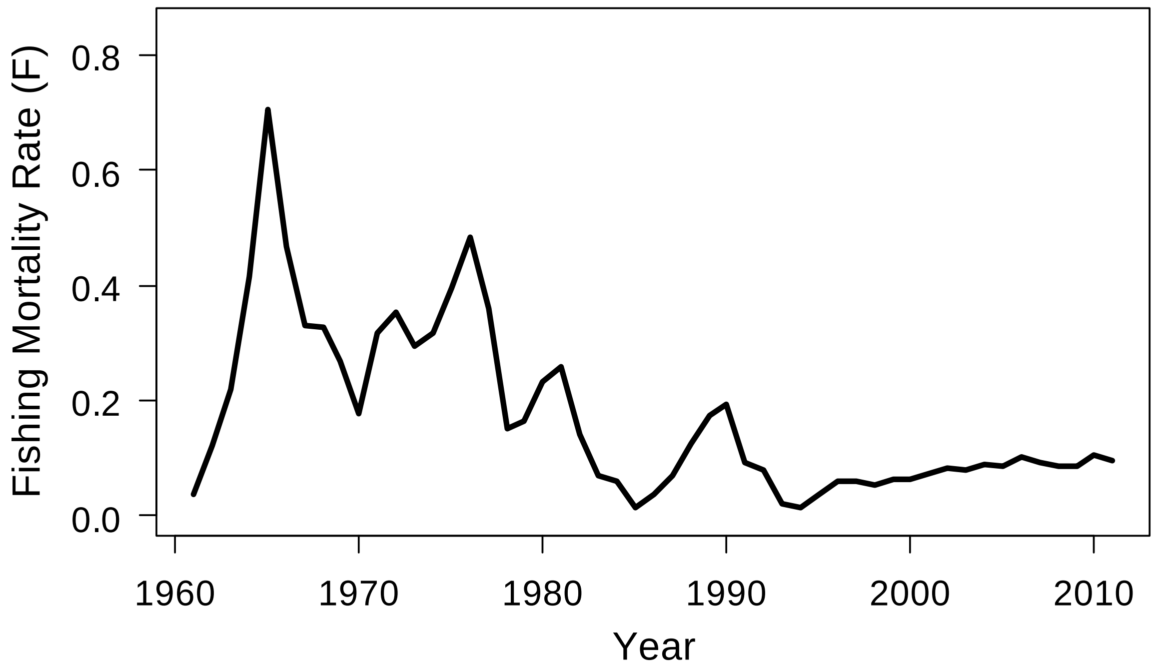


Figure 9A.4. Time series of estimated fully selected fishing mortality for GOA POP (from Hanselman et al. 2011).

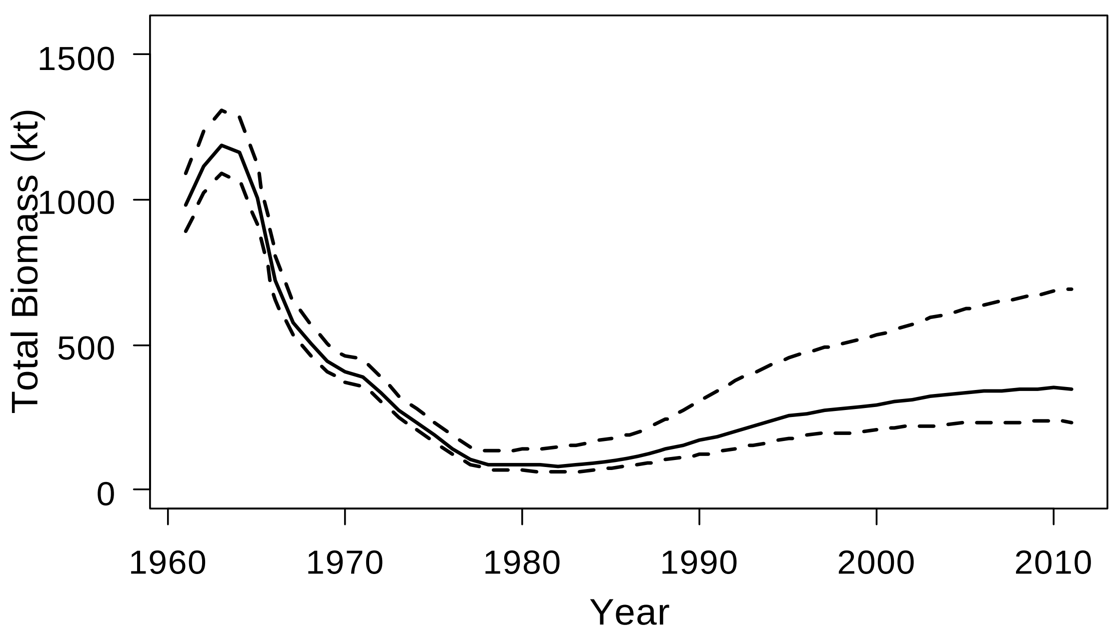
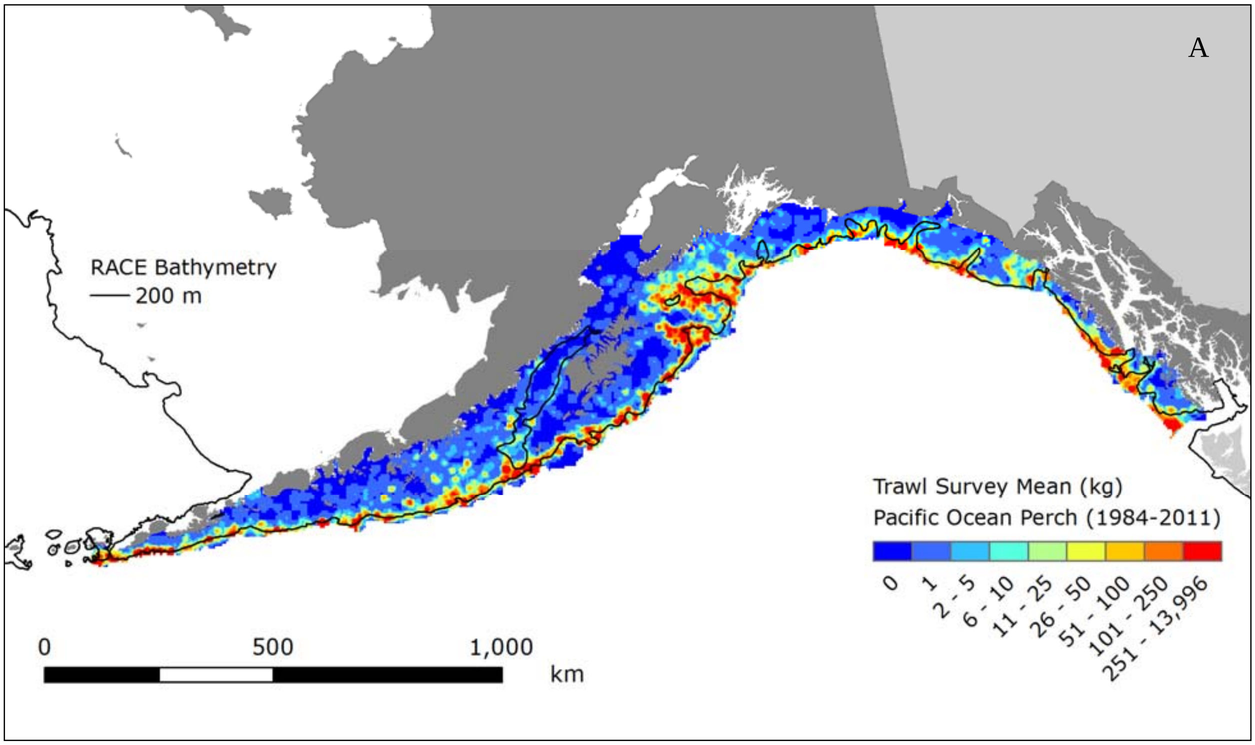


Figure 9A.5. Time series of predicted total biomass of GOA POP for author recommended model. Dashed lines represent 95% credible intervals from 5 million MCMC runs (from Hanselman et al. 2011).



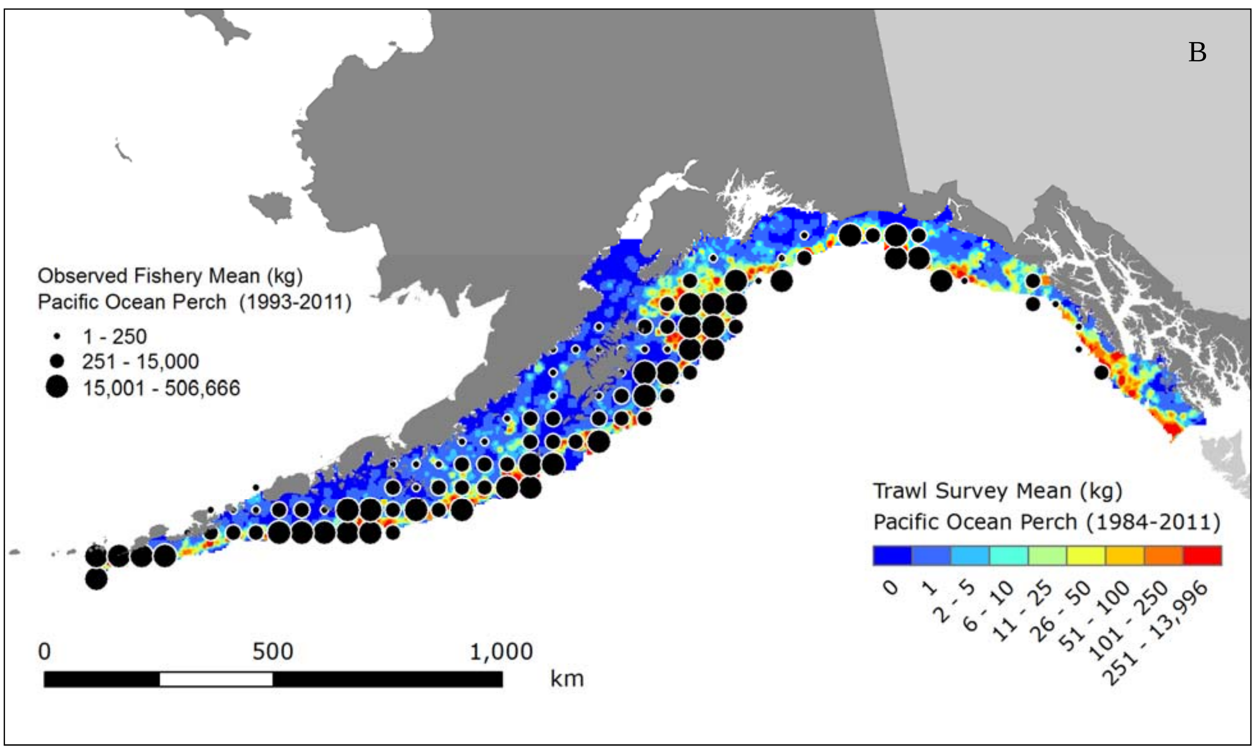


Figure 9A.6. Distribution maps of GOA POP for trawl survey mean conditions from 1984-2011 (A) and observed fishery catch mean (1993-2011) with trawl survey mean conditions (B).

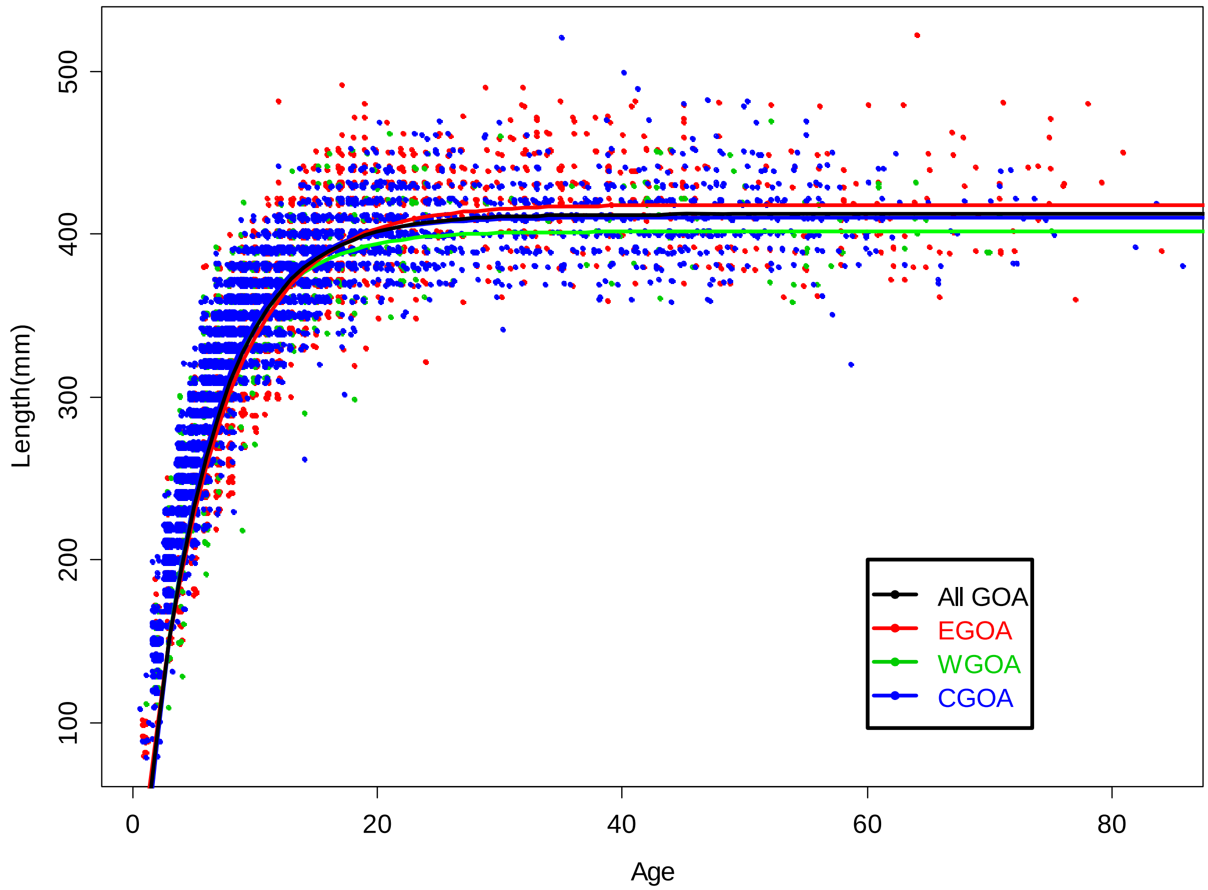


Figure 9A.7. Length-at-age and fitted von Bertalanffy growth curves for POP in the GOA using bottom trawl survey data for the Western GOA, Central GOA, Eastern GOA, and all GOA combined.

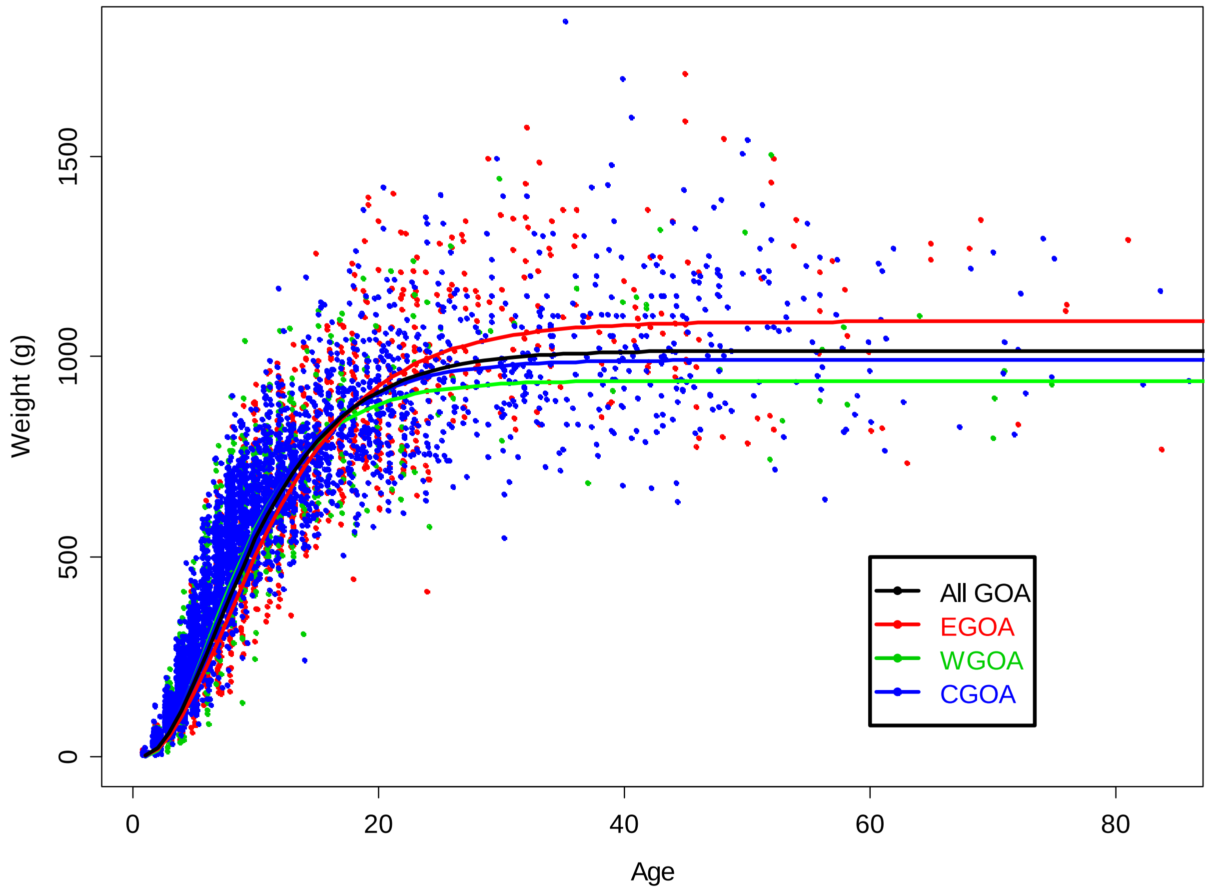


Figure 9A.8. Weight-at-age and fitted von Bertalanffy growth curves for POP in the GOA using bottom trawl survey data by individual region for the Western GOA, Central GOA, Eastern GOA, and all GOA combined.

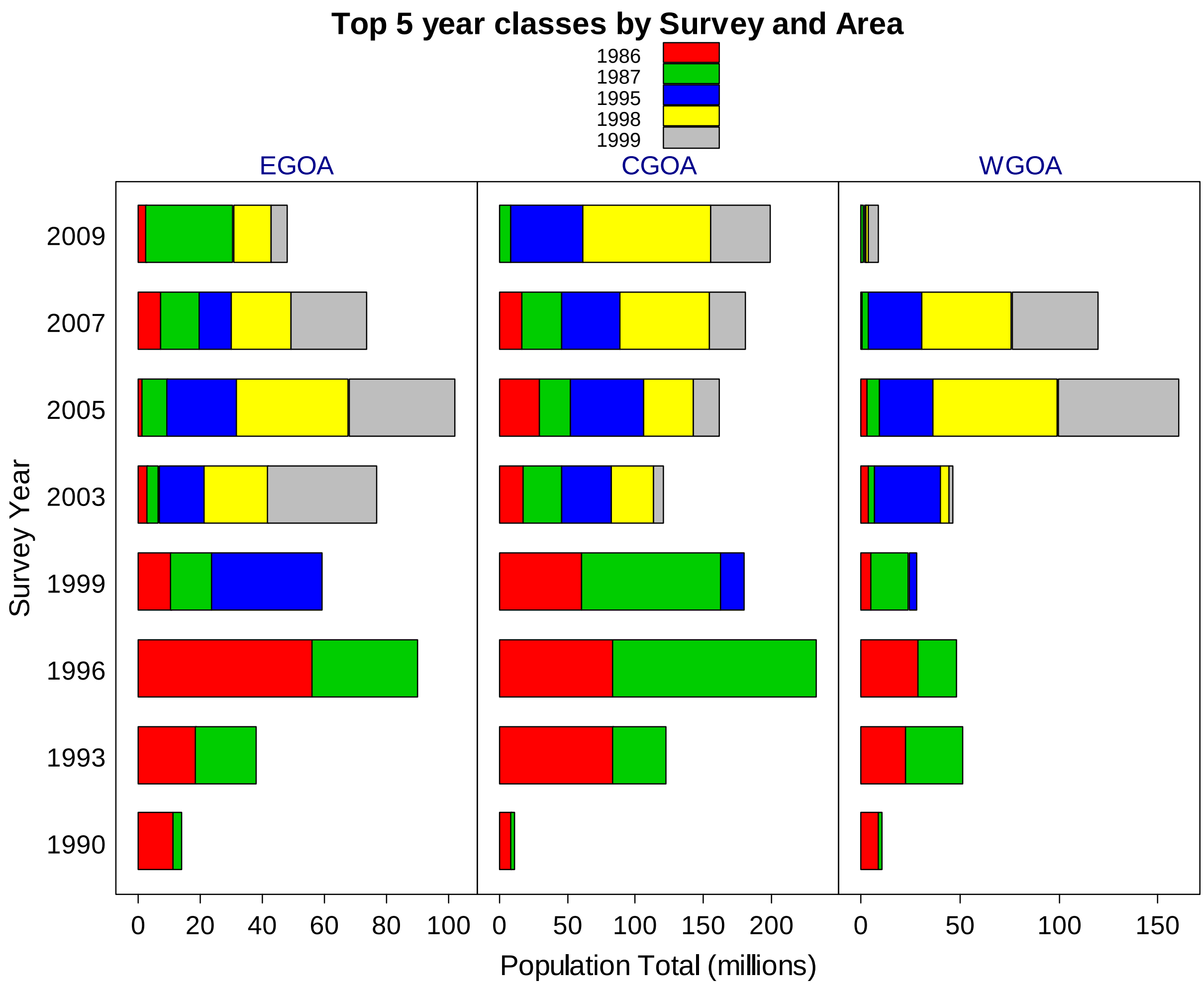


Figure 9A.9. The distribution of the five largest year classes of Gulf of Alaska Pacific ocean perch as they recruit to the trawl survey.

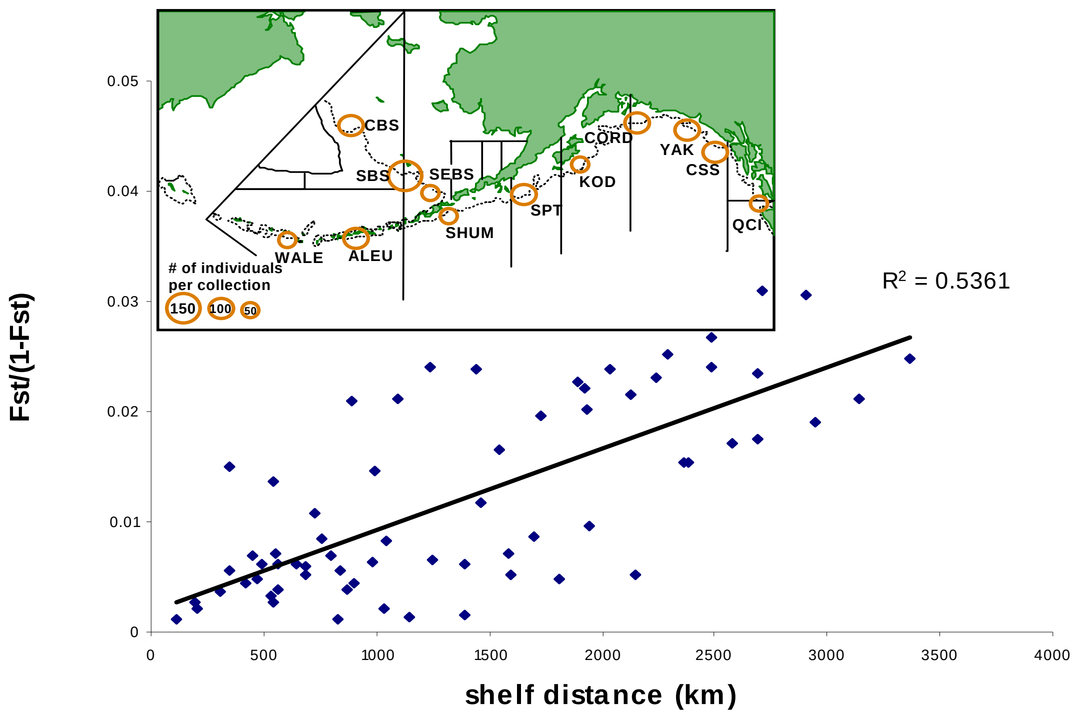


Figure 9A.10. Isolation by distance pattern for Alaska Pacific ocean perch and map of collection sites Adapted from Palof et al. (2011).

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