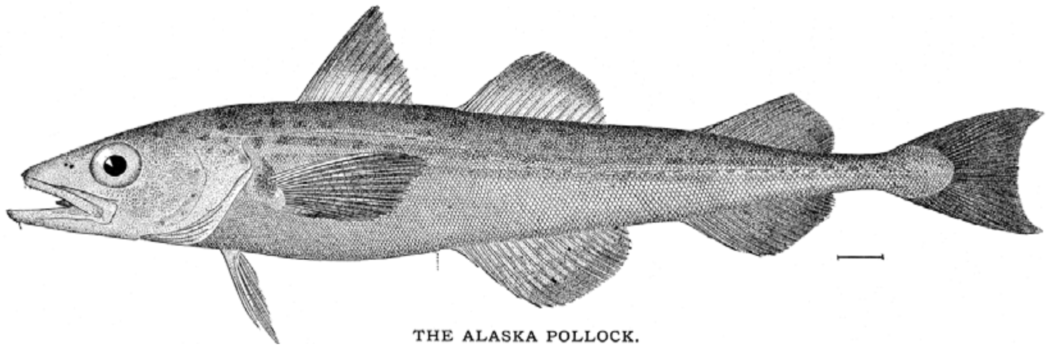
Evaluation of stock structure for Aleutian Islands pollock



THE ALASKA POLLOCK.

Steven J. Barbeaux

NMFS-Alaska Fisheries Science Center, Seattle, WA

Executive Summary

In this document, various types of information pertaining to stock structure for the Aleutian Islands (AI) pollock are considered, following the template recommended by the Stock Structure Working Group (SSWG). Although AI pollock have been managed separately from EBS, GOA, and Bogoslof pollock since the beginning of fisheries management in the BSAI, only since 2005 has this population been managed under an age-structured Tier 3 assessment model. Separation of the AI pollock as a distinct managed stock was done at the outset of US management of North Pacific pollock stocks in recognition of meristic differences identified in early morphological studies and the danger of higher local exploitation on this much smaller portion of the pollock population.

Besides historic separation of management and difference in fishing patterns, a separation of AI pollock from the other three recognized North Pacific pollock stocks can be justified through a weak genetic isolation by distance (IBD) pattern along the Aleutian Island archipelago between North American and Asian populations, the identification of distinct and consistent spawning sites, the finding of an apparent (albeit weak) physical barrier at Amukta Pass, and the existence of a consistent differences in size at age among the Eastern Bering Sea, Gulf of Alaska, and Aleutian Islands pollock from summer survey data (Table 1). Within the AI region there doesn't appear to be justification for further subsetting of the pollock stock, although data on pollock in this area is sparse.

Introduction

The Aleutian Islands region has been defined for management purposes as the area inside the US Exclusive Economic Zone (EEZ) along the Aleutian Islands Archipelago west of 170° W longitude (Fig. 1). Walleye pollock (*Theragra chalcogramma;* hereafter pollock) are semi-pelagic schooling gadoids that are widely distributed in the North Pacific Ocean ranging from the Sea of Japan in the west to Northern California in the East. The largest concentrations of pollock occur in the Eastern Bering Sea. Pollock is a relatively fast growing and short-lived species. At the present there are four management stocks recognized by the North Pacific Fisheries Management Council within the US EEZ. This includes the Eastern Bering Sea (EBS) stock , the Gulf of Alaska (GOA)stock, the Bogoslof Island /Aleutian Basin stock, and the Aleutian Islands (AI) stock. This document considers the stock delineation of the AI pollock from the other three and evidence towards any possible biological divisions within the currently defined AI stock.

Harvest and Trends

AI pollock have been managed as a separate subpopulation from the EBS, GOA, and Bogoslof components of the North Pacific pollock population since the inception of domestic management of this species in the late 1970's. In the 1980s optimum yield levels for AI pollock were set using a variety of means, from 10% of the estimated biomass to using the $F_{0.1}$ rate of 0.31 from the EBS applied to an estimate of exploitable biomass. How the estimates of exploitable biomass were obtained during this time period was not consistent. The mean fishing mortality rates of the AI pollock stock during the foreign and joint venture fisheries between 1978 and 1989 averaged 0.10 (a maximum in 1980 of 0.26; Fig. 2). During the foreign and joint venture fisheries the majority of pollock catch (Fig. 3) was harvested from the Eastern Aleutian Islands Area (541). In 1978 catch in the Western AI (543) exceeded Eastern Catch, but overall AI region removals were less than 10,000 t. In 1985 catch in the Central AI area (542) exceeded the catch from the Eastern AI. For this time period biomass trends from the bottom trawl survey shows a nearly even split of pollock between the Eastern (541) and Central (542) AI regions (Fig. 4). The rise in biomass in the early 1980s and steep decline in the late 1980s and early 1990s mirrors the trends in spawning biomass in both the GOA and EBS (Fig. 5). This trend for the AI and GOA follows the rise and fall of several late-1970s year classes (particularly the 1978 year class) which were in general very high for all three stocks (Fig. 6), while the late 1980s and early 1990s recruitments were generally poor (with the notable exception of the 1989 year class which was above average for all three stocks).

From 1991 through 2005 the AI pollock OFL was assessed using the latest AI bottom trawl survey biomass estimate multiplied by natural mortality. In 1997 this system became known as Tier 5 and maximum ABC was introduced as the biomass estimate multiplied by 0.75 of natural mortality. The proposed Tier 3 stock assessment models in 2003 through 2007 recommended exclusion of catch from the Aleutian Basin from the model and a spatial buffer between the Bogoslof and Aleutian Island stock delineation between 170° and 174° W longitude based on historic catch locations (Fig. 2). Two separate models had been presented in 2003 through 2007 with and without the spatial buffer, with the buffered model being the assessment authors' chosen model. The SSC and Plan Team accepted the Tier 3 model for AI pollock management in 2005. In 2007 a CIE review rejected the spatially buffered assessment model and the plan team and SST, on the advice of the CIE review team, decided that the non-spatially buffered model would be the default spatial configuration considered for future management. Since 2008 the AI pollock stock has been managed using the non-spatially buffered tier 3 age-structured assessment model.

In 1990 through 2012 pollock biomass in the AI remained below the 1980s levels. Except for the 1989 and 2000 year classes, recruitment remained below average for this time period (Fig. 6). All three of these good recruitment years were matched in the GOA and EBS. However, the EBS and GOA had other above average year classes (1990, 1992, 1996, 1997, 1999, and 2006 for the EBS and 1990, 1996, 2001, and 2006 for the GOA) that boosted their spawning biomass in the mid-1990s while the AI spawning stock biomass continued to decline through 2001. Fishing activity was concentrated in the Eastern AI (541) for 1990 through 1994 with 96% of the catch coming from the Eastern AI for this time period (Fig. 4). As catch rates declined the fishery moved west and for 1995 through 1997 61% of the AI pollock catch was taken in the Central AI (541). Fishing effort again moved in 1998 when the majority (76%) of the AI pollock catch was taken from area 543. Again a declining catch rates in the Eastern and Central AI was blamed for the move. The AI pollock stock encountered higher fishing mortality rates in the 1990s than during the foreign and joint venture fisheries with an average of 0.28 (maximum of 0.39 in 1995), but was closed to directed fishing in 1999 due to concerns over prey competition with the endangered Steller Sea lion. Since reopening in 2005 fishing mortality rates have been well below harvest specifications, at nearly the same rate as when the fishery was closed. Between 1999 and 2012 annual average fishing mortality rates over all ages were less than 0.02 (mean $F_{1999\text{-}2012}$ = 0.01, maximum of 0.017 in 2007). Spawning biomass is the AI has been rising slowly since its lowest level in 2000, but still remains below 1980s levels as recruitment has been below average since 2001.

Barriers and phenotypic characters

The temperature, salinity, and nutrient load changes at Samalga Pass between 169° W and 170° W longitude (Ladd *et al*. 2005, Mordy *et al.* 2005) due to Aleutian-wide current patterns. This biophysical break in the Aleutian Archipelago matches the transition from the EBS to AI management areas. At this pass surface waters change from coastal conditions in the east (warm, fresh, and nutrient-poor) to more oceanic conditions in the west (cold, salty, and nutrient-rich). Logerwell *et al.* (2005) found significant differences in demersal ichthyofauna assemblages, diets, and growth on the eastern and western sides of Samalga Pass consistent with a major biophysical transition zone. Logerwell *et al.* (2005) also identified step changes in ichthyofaunal characteristics at Buildir Island and Amchitka Pass, as well as some longitudinal trends in demersal fish characteristics that indicate continuous physical and biological variation along the length of the Aleutian Islands Archipelago.

There have been many morphometric and meristic studies on Bering Sea walleye pollock and equivocal results among these studies have not fully clarified stock delineations. Important to this paper most of the studies have not included samples from the Aleutian Islands area and therefore their results are only tangential to the interest of the current study. Bailey *et al.* (1999) provided an excellent summary of studies using phenotypic characteristics in their Table 2. There have only been two morphometric and meristic studies of note that have explicitly included samples from the Aleutian Islands area. Serobaba (1978) initially identified four subpopulations of pollock in the Bering Sea based on meristics; the eastern Bering Sea (EBS), western Bering Sea (WBS), northern Bering Sea (NBS), and southern Bering Sea or Aleutian Island (AI) group. It should be noted that the Serobaba (1978) study did not include any samples from the Aleutian Basin. The Serobaba (1978) study used 32 different measurements ranging from fork length, to various fin lengths, to the number of gill rakers and vertebrae. This study did not identify any set barriers for the stocks identified, suggested that all the groups intermingled at the margins of the zones they inhabit, and that it would be impossible to draw a distinct line between them. Although Serobaba(1978) identified the four stocks through morphological and meristic differences, low sample sizes for AI pollock precluded a statistically significant determination and it was suggested that AI and EBS pollock may actually be a single stock. In the same study Serobaba presented similar rates of parasite infestation for EBS and AI pollock further suggesting a single EBS and AI pollock stock. As data from the AI was limited, Serobaba did not make any remarks on possible differences among pollock within the AI.

Based on the comparison of seventeen landmark morphometric locations and size at age Dawson (1994) concluded that there were three distinguishable stocks in the Bering Sea. This study showed little difference between samples from northeastern and southeastern Bering Sea and these were lumped into a single eastern Bering Sea stock. The study also concluded that pollock from the eastern and western Bering Sea shelf were indistinguishable based on the meristics evaluated. However, the study concluded that pollock from the Aleutian Basin and Aleutian Islands were significantly different and constituted two distinct stocks. Data in this study were limited to those collected from the fishery and therefore did not cover the entire AI region. With such limitations this study did not consider differences among pollock within the AI.

For this evaluation the author examined the weight and length at age data collected from the summer bottom trawl surveys conducted by the Alaska Fisheries Science Center since 1980; annually in the eastern Bering Sea, biennially in the Gulf of Alaska, and triennially to biennially in the Aleutian Islands. Over all years there were 23,808 samples from the Bering Sea, 14,880 samples from the Gulf of Alaska, and 9,934 samples from the Aleutian Islands that were aged and had both a length and weight associated. Aleutian Islands pollock were heavier at age on average than Bering Sea pollock across all ages and were heavier at age than Gulf of Alaska pollock up to age 4 (Fig. 7). AI pollock are longer at age than BS and GOA pollock up until age 7, at which point the mean pollock length at age from all three regions are indistinguishable (Fig. 8 and Fig. 9). Over age 7 BS and GOA mean length at age exceed AI mean length at age by a small margin (< 2%). At age 1 BS pollock are only 75% the length and 40% the weight of AI pollock, but have a faster growth rate each year afterwards eventually exceeding AI pollock in length, but never achieve the same weight. GOA pollock at age 1 are 90% the length and 85% the weight of AI pollock, but also exceed the AI growth rate each following year, exceeding AI pollock in length and weight by age 8 and 5 respectively. Figure 9 shows the annual growth rate as a percentage of the previous age’s weight. In this figure it is clear that growth rates after the age of 2 are very similar across all regions, given the same temperature range EBS and GOA pollock are indistinguishable. However the growth between age 1 and age 2 is much greater in the GOA and EBS than in the AI even at the same surveyed temperature, this might suggest a lack of food or differential migration of larger fish out of the AI beginning at age 2. Across all regions there is a latitudinal trend in mean length and weight up to age 7(Fig. 10) with heavier and longer pollock in lower latitudes. This trend may be explained by higher temperatures in the south. At age 7 mean pollock length is the same across all latitudes, while pollock remain heavier at lower latitudes, whether this is due to faster growth in the north or migration cannot be discerned. Plotted on a map mean length and weight at age one is highest at the eastern extreme of the GOA and the western extreme of the AI (Fig 11 and Fig. 12). In the EBS the heaviest and longest pollock are observed in the outer domain. This pattern dissolves somewhat over time with the heaviest and longest fish at age eventually inhabiting the western GOA and inner domain of the EBS with fewer of the largest fish found in the AI. Whether this changing pattern in size at age is due to migration, differential growth, or fishing pressure is not discernible. The patterns observed are likely due to all of these factors with fishing and migration being more important in the older age classes and growth more important in creating the pattern observed at age 1.

Within the AI region the data were divided into the regions determined by Logerwell et al. (2005) for within AI region analysis. The West Aleutians data were defined as those from 170° E to 176° E longitude (170° E to Buildir Island), Central Aleutians as those from 176° E to 179° W longitude (from Buildir Island to Amchitka Pass), East Aleutians as those from 179° W to 170° W longitude (from Amchitka Pass to Samalga Pass) and eastern Bering Sea (EBS) all data east of 170° W longitude (All AI survey east of Samalga Pass). As expected the differences in length and weight at age in the Aleutian Islands region is not as distinct as the differences among regions and there are no consistent longitudinal trends in length or weight at age (Fig.13). At age 1 the pollock in the Central Aleutians are approximately 5-6% longer and 10-15% heavier than pollock in any of the other AI areas. The length and weight of age 1 pollock in the other three areas are indistinguishable. By age 6 there is no difference in length or weight among the AI regions (Fig. 14 and Fig. 15). Annual growth rates after the first year are highest in the EBS and East AI regions up to age 5, then are indistinguishable for all regions (Fig. 16). Central and West AI annual growth rates are nearly identical for all years following age 1.

Although there hasn't been many morphometric studies conducted on Aleutian Islands pollock, it should be noted that there are many morphometric studies throughout the range of pollock that conclude stock separation at smaller spatial scales than the spatial range of the Aleutian Islands (See Bailey et al. 1999, Table 2). However the simple length and weight at age analysis within the AI conducted here reveals no distinct patterns after age 1. Tagging models conducted in Japan suggest a model of dispersed feeding and homing migration to distinct and consistent spawning locations (Bailey et al. 1999). The survey data presented above for the AI are from summer survey data when pollock from different spawning sites would be expected to be intermingled. Fishery data are available for AI pollock in different seasons, but maturity data are only available post-2005 when very few otoliths were collected for aging and only from the central AI where the directed fishery was conducted.

Hinckley (1987) used distinct and consistent spawning locations as one metric for discerning pollock stocks. She was able to identify spawning locations in the EBS, GOA, and Aleutian basin, but did not have data for the AI. In 2006 Barbeaux and Fraser (2009) identified distinct areas in the Central AI that contained spawning aggregations of pollock. These areas consistently had pollock in spawning condition for 2006 through 2008 during the Aleutian Islands Cooperative Acoustic surveys study. Further these areas were consistent with areas fished during the domestic fishery in the early to mid 1990s when the fishery was targeting pre-spawning pollock aggregations.

Genetics

Bailey et al. (1999; Table 4) provides an excellent synopsis of genetics studies conducted on pollock up to 1999. At that time only Mulligan et al. (1992) had included samples from the Aleutian Islands. The Mulligan et al. (1992) study showed discernible differences among samples collected in the Aleutian Islands, Gulf of Alaska, and Aleutian Basin using mtDNA and RFLP methods (Fig. 16).

The only other study to include samples from the Aleutian Islands region was conducted by Grant et al. (2010). The study used sequences of mitochondrial DNA cytochrome oxidase subunit I in nine samples (*n* = 433) from Japan to Puget Sound to evaluate genetic population structure. In their study two haplotypes varied clinally across the North Pacific (Fig. 16). They concluded that these clines were likely the result of the isolation of populations in ice-age refugia, secondary post-glacial contact, and restricted long-distance dispersal. Overall, $\Phi_{ST}= 0.030$ ($p< 0.001$), but the greatest partition was attributable to differences between Asian and North American populations ($\Phi_{CT} = 0.058$, $p = 0.036$). Isolation by distance was detected across the North Pacific, but differentiation among populations within regions was minimal ($\Phi_{SC}= 0.007$, $p < 0.092$). Like the earlier morphological studies pollock genetic samples were not collected throughout the AI and therefore discerning differences within the AI was not possible.

Interpretation of the information regarding stock structure

The weight of evidence suggests that pollock in the Aleutian Islands area differ in growth and other morphometric characteristics from pollock of other North Pacific areas. The biophysical barrier at Samalga Pass likely separates Bering Sea, Gulf of Alaska, and Aleutian Islands pollock to some extent. In the two genetic studies conducted which included samples from the AI genetic trends were detected. The analyses suggest a clinal trend across the North Pacific and do not present direct evidence of complete genetic separation of the stocks. These studies therefore do not provide strong evidence for genetic separation and suggest that the biophysical barrier at Samalga Pass is likely porous.

Besides the length and weight at age data presented in this document research on morphological and genetic differences within the AI region is not available. Although some weak biophysical barriers have been identified within the AI region by Logerwell *et al.* (2005), the morphological differences observed among the delineated areas were not substantial. Shifts in local abundance at centennial and decadal scales due to climate variability likely prevent the appearance of genetically discrete stocks in the US EEZ and even more so at the scale of the Aleutian Islands.

Management implications

The results of this analysis suggest that current management practices are adequate to address concerns of stock delineation for the AI pollock within the North Pacific and within the Aleutian Islands. There are morphological differences, but these differences are likely due to latitudinal trends and the effects of differences in temperature and food availability on growth and not due to inherent genetic differences. The greatest difference in growth between AI pollock and other stocks was up to age 1. This difference disappeared in following age classes. Local temperatures are likely highly significant factor in growth in the first year when pollock cannot emigrate out of local poor conditions, but is mediated later when the larger, more mobile pollock can seek favorable temperatures and feeding areas. Given initial differences in growth and clinal genetic trends, separation of the AI pollock from the AI Basin, GOA, EBS pollock is warranted. Although there isn't a strict separation of stocks, the biophysical break at Samalga Pass appears to be a logical location for separation of these four stocks. Currently there isn't sufficient evidence to suggest any further separation of stocks within the AI, however little research has been conducted on AI pollock stock delineation in this area. It should be noted that genetic and morphological studies conducted in the western Pacific have concluded stock structure exists for some pollock populations at spatial resolutions much smaller than the extent of the Aleutian Islands area (Bailey *et al.* 1999).

Since 2011 there has been no directed fishery for AI pollock, all catch has come as bycatch in other fisheries. Pollock catch in the AI has been well below ABC since 1998, with an annual fishing mortality rate across all ages below 0.02 for the past 15 years. Without substantial changes to current regulations concerning bycatch in this fishery, the resurgence of a larger directed AI pollock fishery is highly unlikely.

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Tables

Table 1. Summary of available data on stock identification for Aleutian Islands pollock

HARVEST AND TRENDS	
Factor and criterion	Justification
Fishing mortality (5-year average percent of F_{max})	Fishing mortality rate (F) and catch/biomass rate averaged 0.096 and 0.0058, respectively, over the last five years.
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	No directed fishery since 2011, very small fishery concentrated in the central and Eastern AI in 2005-2011. Most catch is bycatch in other fisheries. Catch is mostly concentrated outside of SSL Exclusion zones in areas of highest abundance in the Atka mackerel, Pacific cod, and recently the arrowtooth flounder fisheries.
Population trends (Different areas show different trend directions)	Recently stable to increasing population size characterized by highly variable recruitment.
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	Generation time is < 10 years
Physical limitations (Clear physical inhibitors to movement)	Some possibly porous biophysical barriers within the North Pacific, for AI pollock specifically at Samalga Pass. No strong evidence for other barriers for AI pollock. Dispersal potential during larval phase is very high.
Growth differences (Significantly different LAA, WAA, or LW parameters)	Apparently higher growth rates in Aleutian Islands in the first years stabilizing or slowing afterwards.
Age/size-structure (Significantly different size/age compositions)	Larger fish at age in AI up to age 6. Some synchronous large recruitment events for AI, GOA, and EBS.
Spawning time differences (Significantly different mean time of spawning)	Timing of spawning differs between AI, GOA, EBS and AI Basin stocks, not evidence of differences within AI
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Unknown
Morphometrics (Field identifiable characters)	Two studies identified morphometric differences from other stocks (Serobaba 1978, Dawson 1994), Unkown for within AI differences.
Meristics (Minimally overlapping differences in counts)	Meristic characteristics have a latitudinal trend with some non-statistically significant differences observed (Serobaba 1978). Low sample sized did not allow for good comparisons. No studies conducted within AI region.
Behavior & movement	
Spawning site fidelity (Spawning	Yes

individuals occur in same location consistently)	
Mark-recapture data (Tagging data may show limited movement)	None.
Natural tags (Acquired tags may show movement smaller than management areas)	Some limited data on parasites show no difference between AI and EBS pollock (Serobaba 1978), no data for within AI region.
Genetics	
Isolation by distance (Significant regression)	Apparent weak IBD structure from Asia to North America using microsatellites. No data for within the AI.
Dispersal distance (<<Management areas)	No dispersal distances estimated.
Pairwise genetic differences (Significant differences between geographically distinct collections)	Consistent pairwise genetic differences between geographically discrete samples using microsatellite markers from Asia to North America. Shifts in local abundance at centennial and decadal scales due to climate variability likely prevent the appearance of genetically discrete stocks in the US EEZ and even more so at the scale of the Aleutian Islands. No data to compare population structure within AI region.

Figures

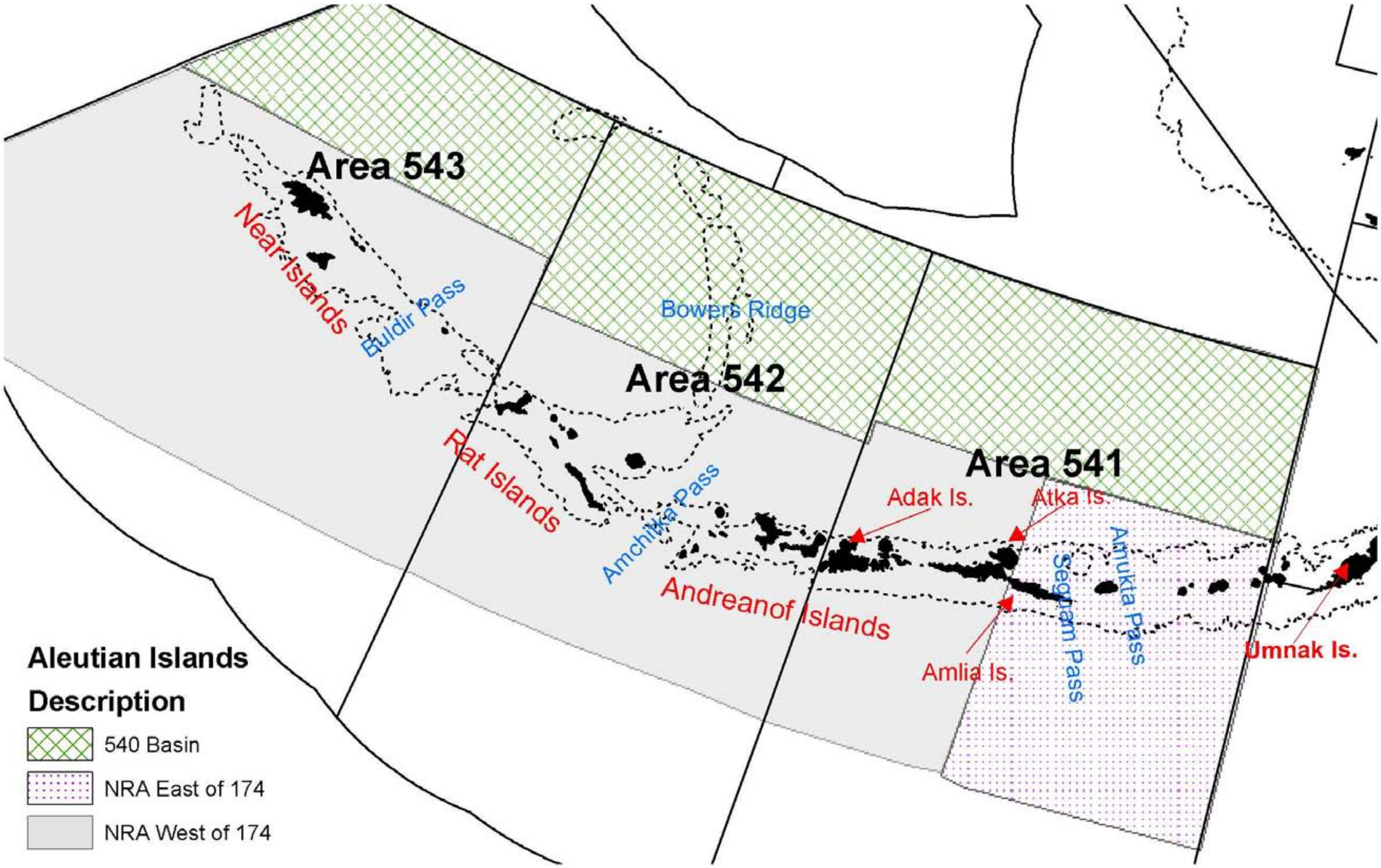


Figure 1. Aleutian Islands areas as defined in the Aleutian Islands walleye pollock stock assessment (Barbeaux et al. 2012).

Figure 2. Fishing mortality rates in the Aleutian Islands area for 1978- 2012.

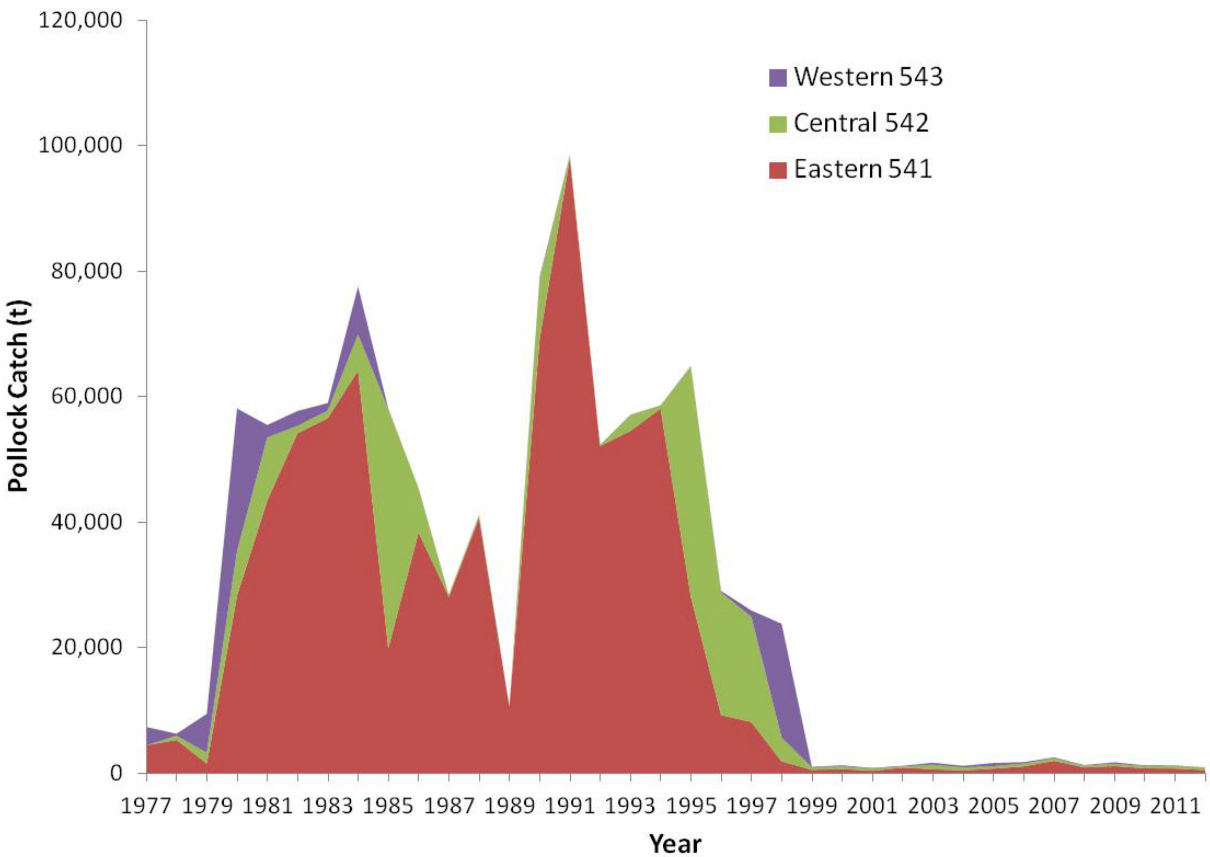


Figure 3. Pollock catch (t) in the Aleutian Islands area by year and by management area.

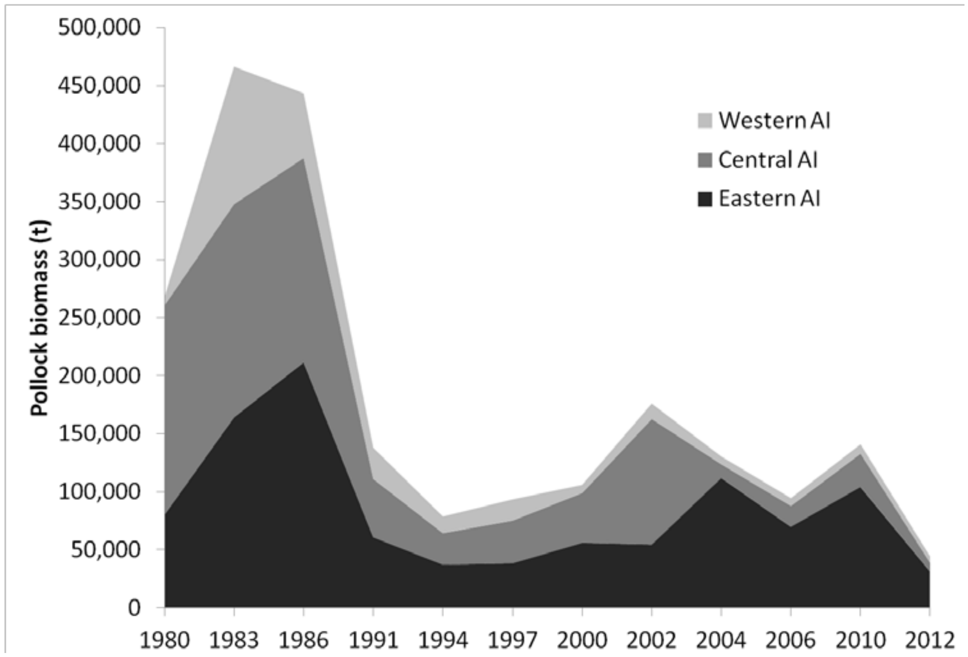


Figure 4. Total pollock biomass (t) in the Aleutian Islands bottom trawl survey by year and management region; Western = 543, Central = 542, and Eastern = 541.

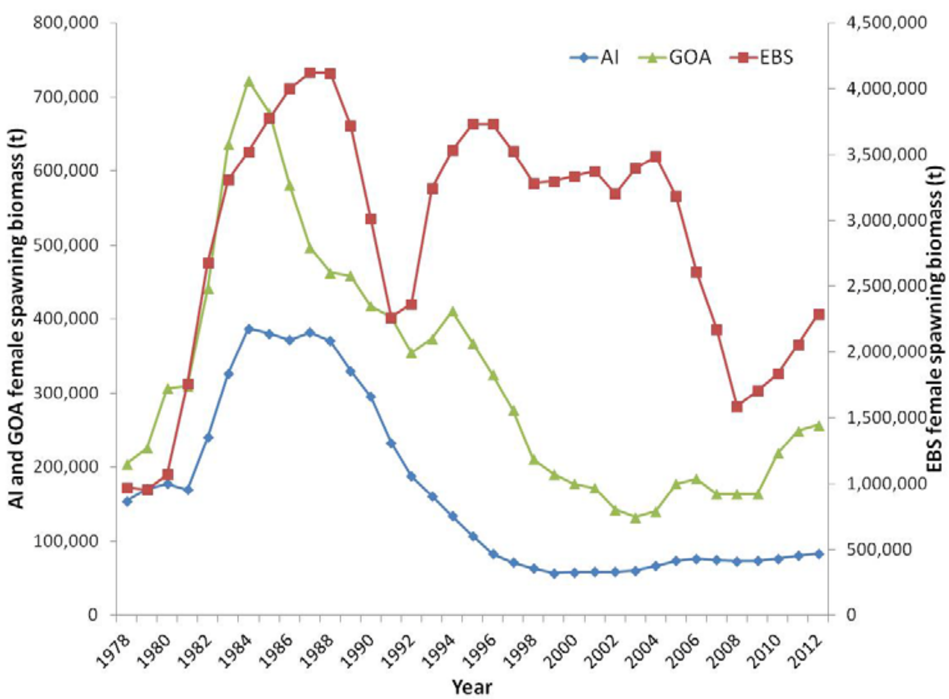


Figure 5. Female spawning biomass for the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands pollock from the 2012 stock assessments (Barbeaux et al. 2012, Dorn et al. 2012, and Ianelli et al. 2012).

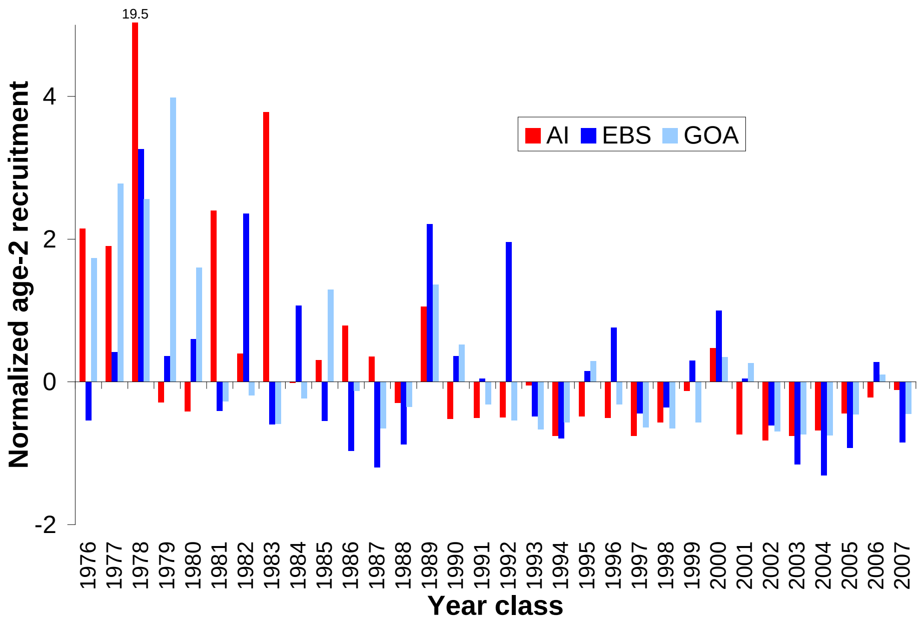


Figure 6. Normalized pollock recruitment at age 2 from the Aleutian Islands (AI),eastern Bering Sea (EBS), and Gulf of Alaska(GOA) stock assessments. Data were normalized to 1978-2008 numbers, AI numbers are from the 20120 reference model while the EBS and GOA are from the 2009 reference models.

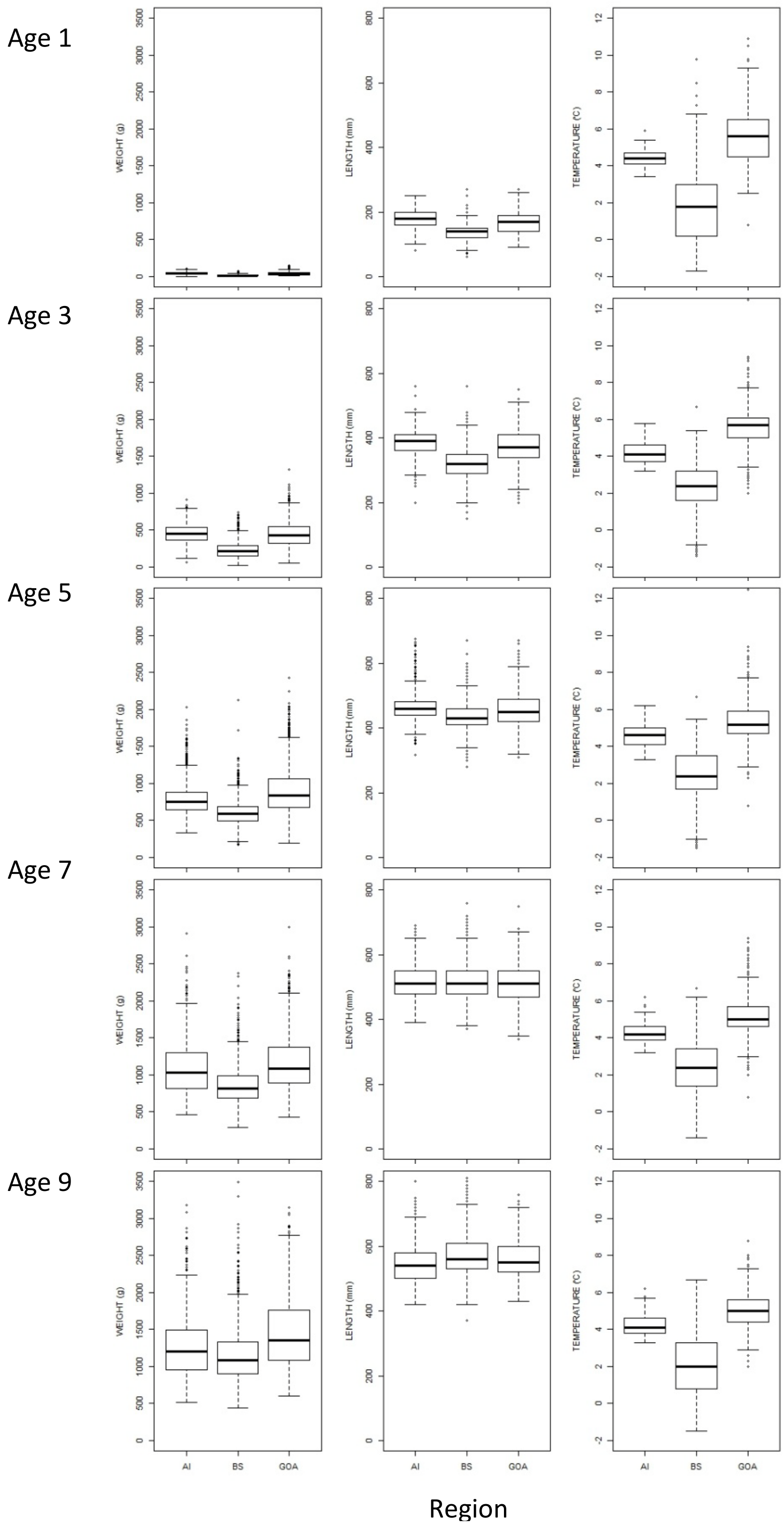


Figure 7. Walleye pollock mean weight, fork length, and bottom temperature for the Aleutian Islands (AI), Bering Sea (BS), and Gulf of Alaska (GOA) summer bottom trawl surveys 1980-2012.

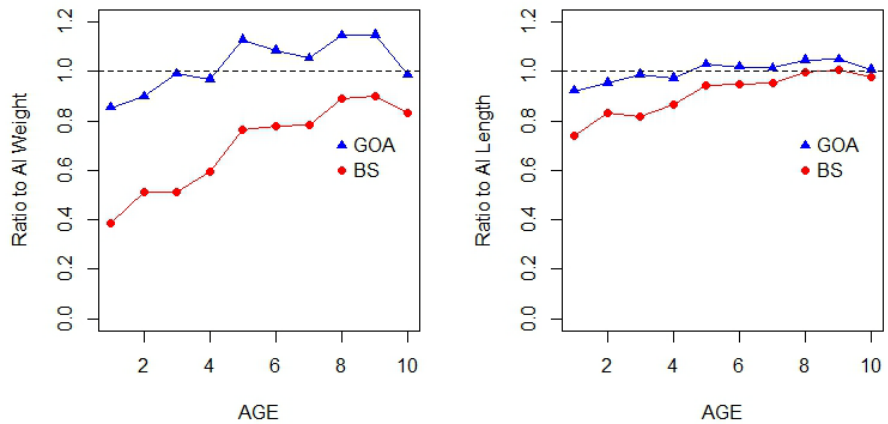


Figure 8. Pollock weight and length by age as a ratio of the Aleutian Islands pollock at age from the Aleutian Islands (AI), Bering Sea (BS), and Gulf of Alaska(GOA) summer bottom trawl surveys for 1980-2012.

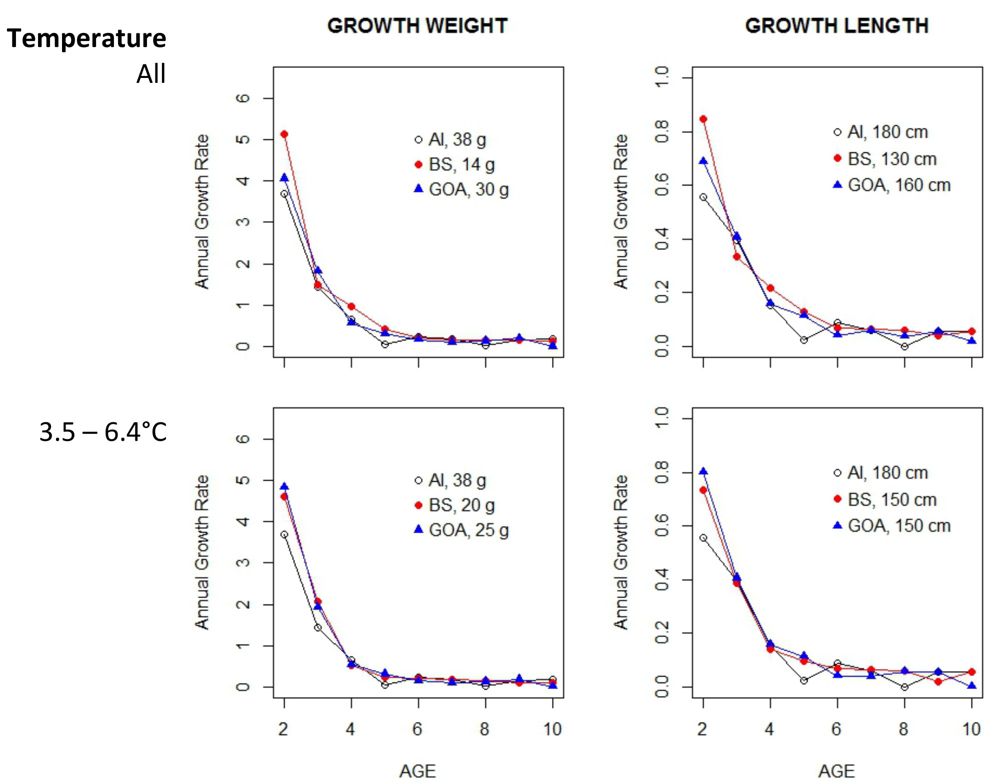


Figure 9. Annual growth rate as a proportion of the previous year’s weight or length for pollock from the Aleutian Islands (AI), Bering Sea (BS), and Gulf of Alaska(GOA) summer bottom trawl surveys for 1980-2012 for all temperatures (top) and between 3.5° and 6.4° C (bottom). Numbers next to the caption are the mean weight or length for age 1 pollock.

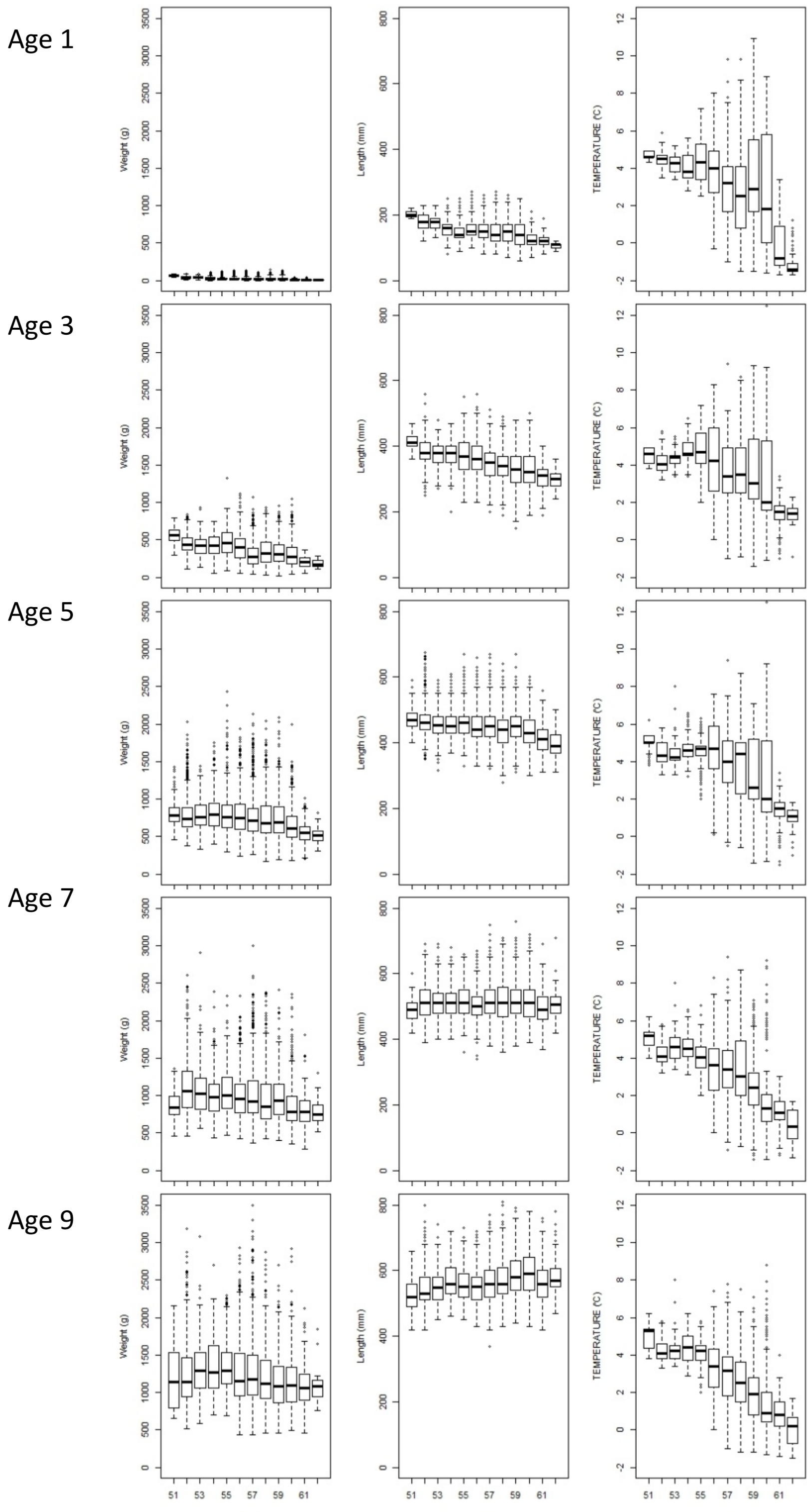


Figure 10. Walleye pollock mean weight, fork length, and bottom temperature for the Aleutian Islands, Bering Sea, and Gulf of Alaska summer bottom trawl surveys 1980-2012 by latitude.

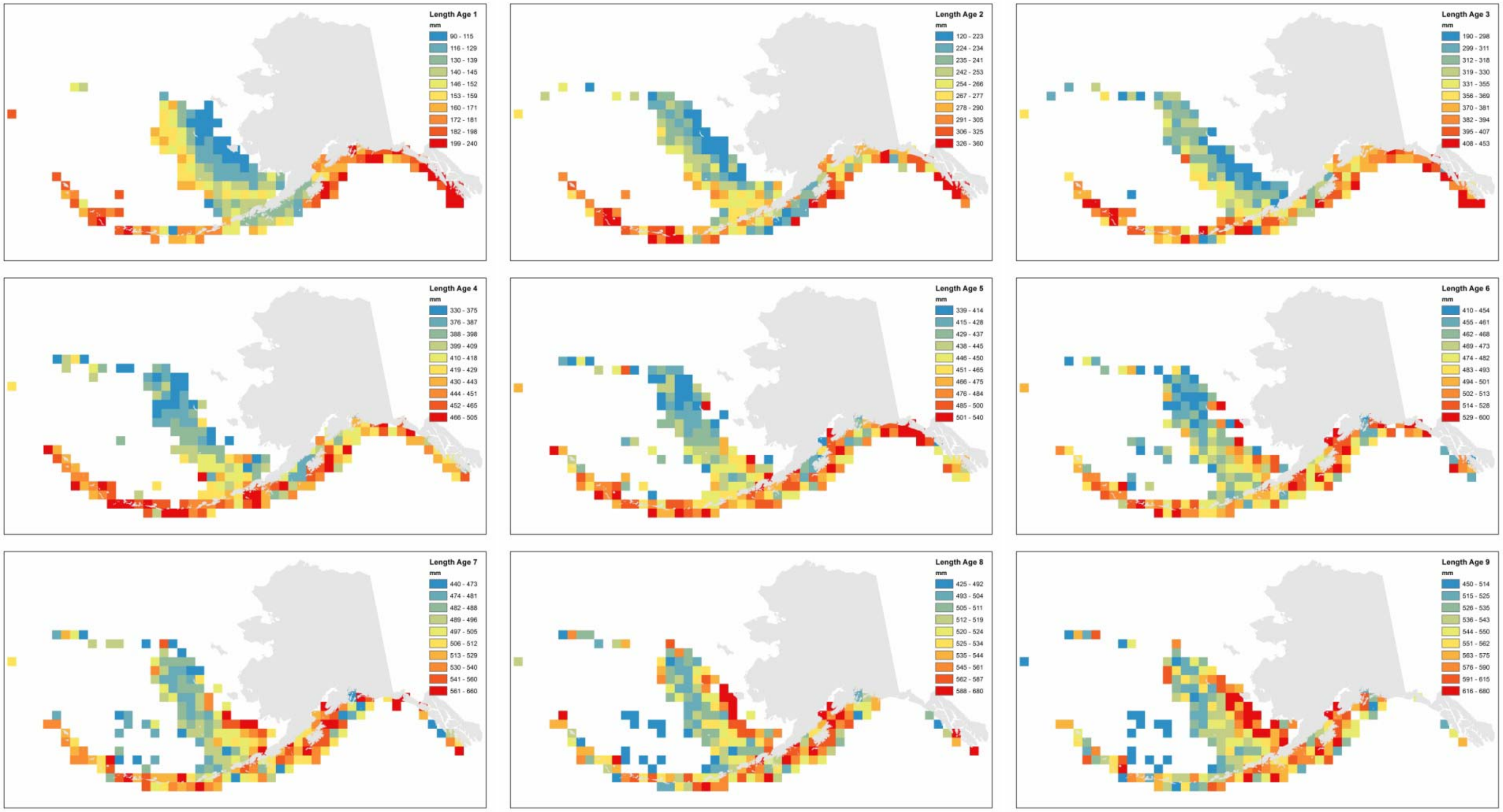


Figure 11. Maps of mean length at age (cm) for all summer bottom trawl surveys 1980-2012 for ages 1 through 9. The analysis was conducted on a grid of 6,000km^2 cells. Color scheme is in deciles of weight with red being the longest 10% at age and dark blue being the shortest 10% at age.

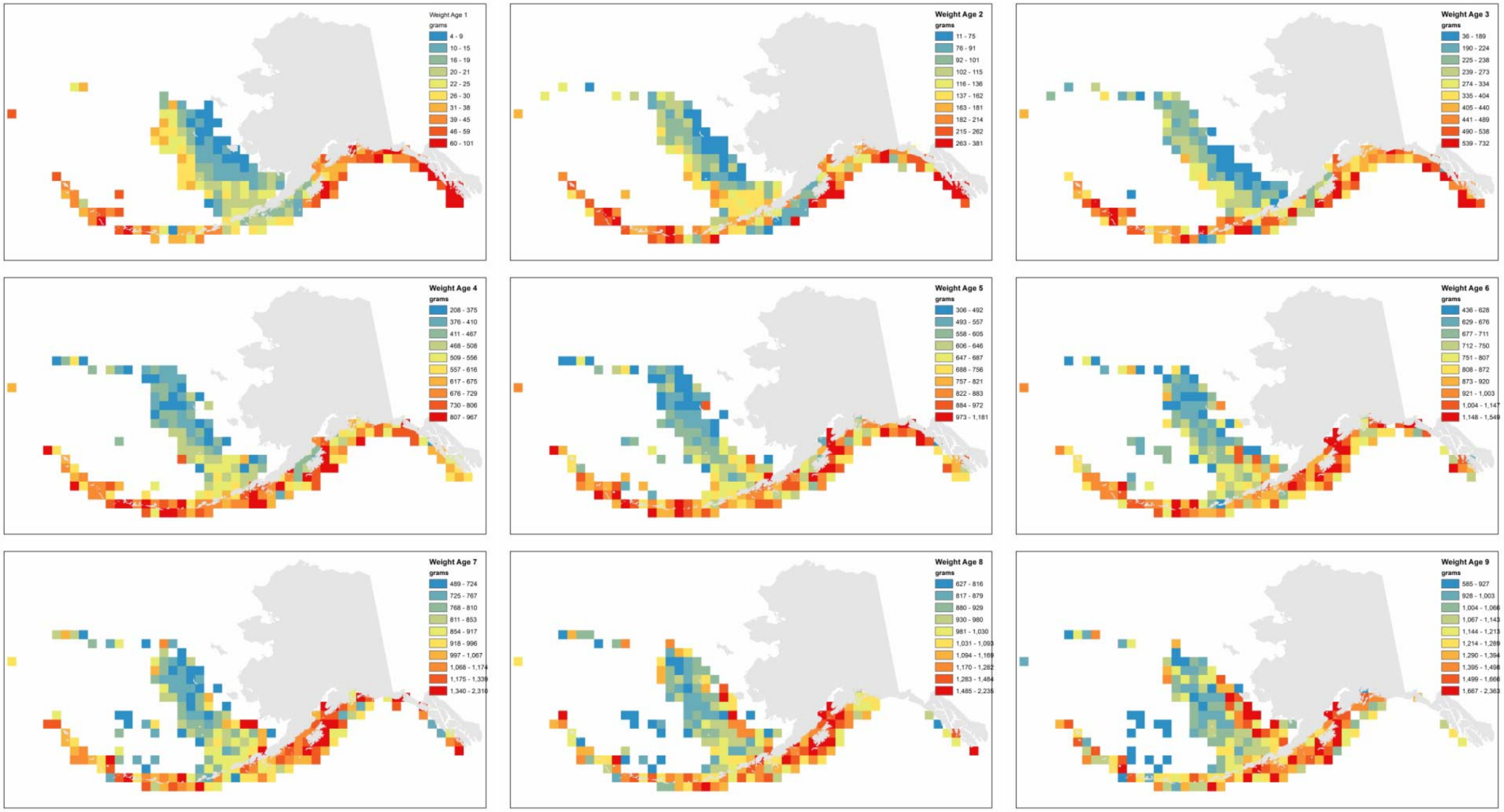


Figure 12. Maps of mean weight at age (g) for all summer bottom trawl surveys 1980-2012 for ages 1 through 9. The analysis was conducted on a grid of 6,000km^2 cells. Color scheme is in deciles of weight with red being the heaviest 10% at age and dark blue being the lightest 10% at age.

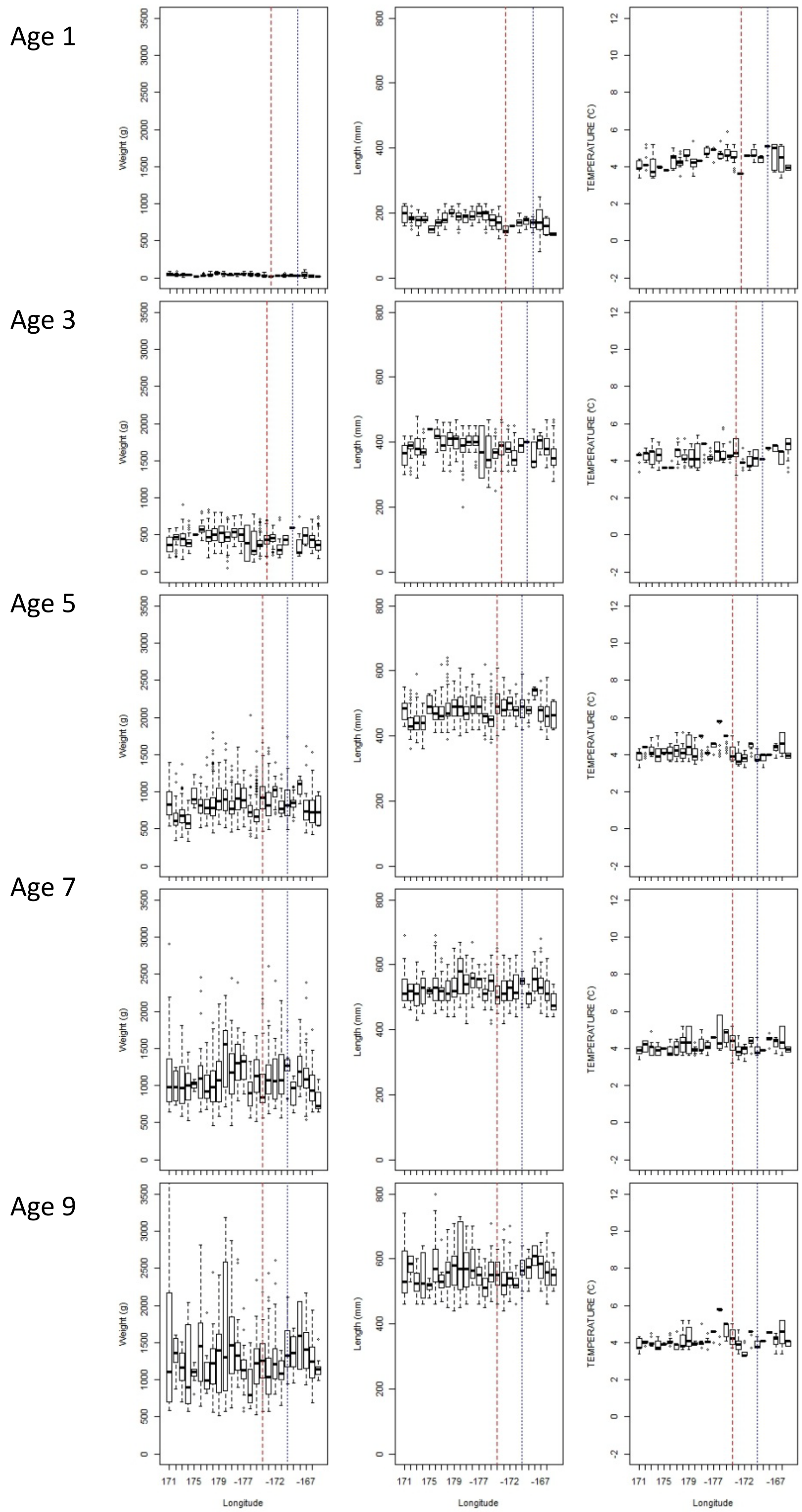


Figure 13. Walleye pollock mean weight, fork length, and bottom temperature at age for the Aleutian Islands summer bottom trawl surveys 1980-2012 by longitude. Red dashed line is at 174° W longitude and the black dotted line is at 170° W longitude.

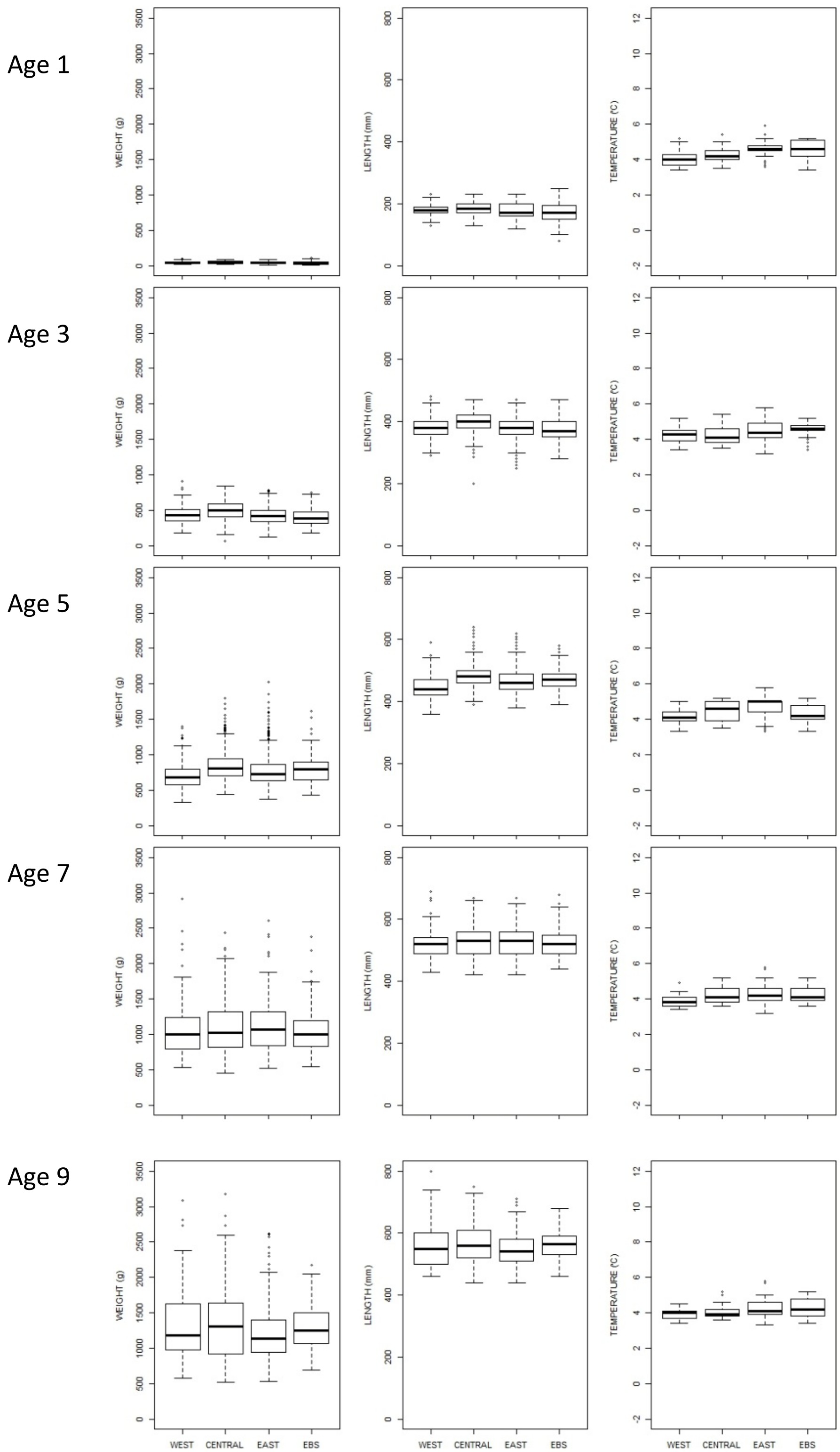


Figure 14. Walleye pollock mean weight, fork length, and bottom temperature at age for the Aleutian Islands summer bottom trawl surveys 1980-2012 by Aleutian Islands regions.

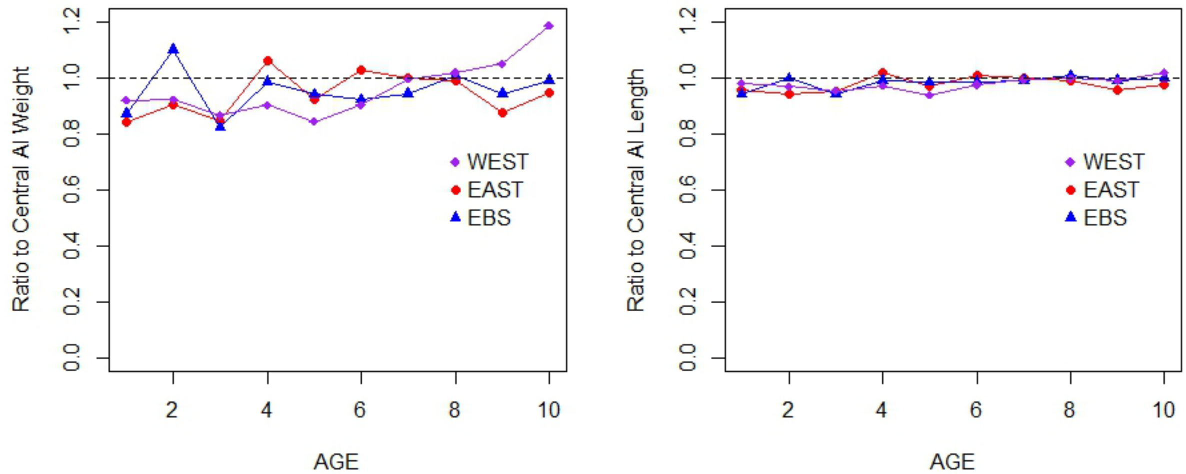


Figure 15. Mean pollock weight and length by age as a ratio of the mean Central Aleutian Islands pollock weight and length at age for all AI regions from the Aleutian Islands summer bottom trawl surveys for 1980-2012.

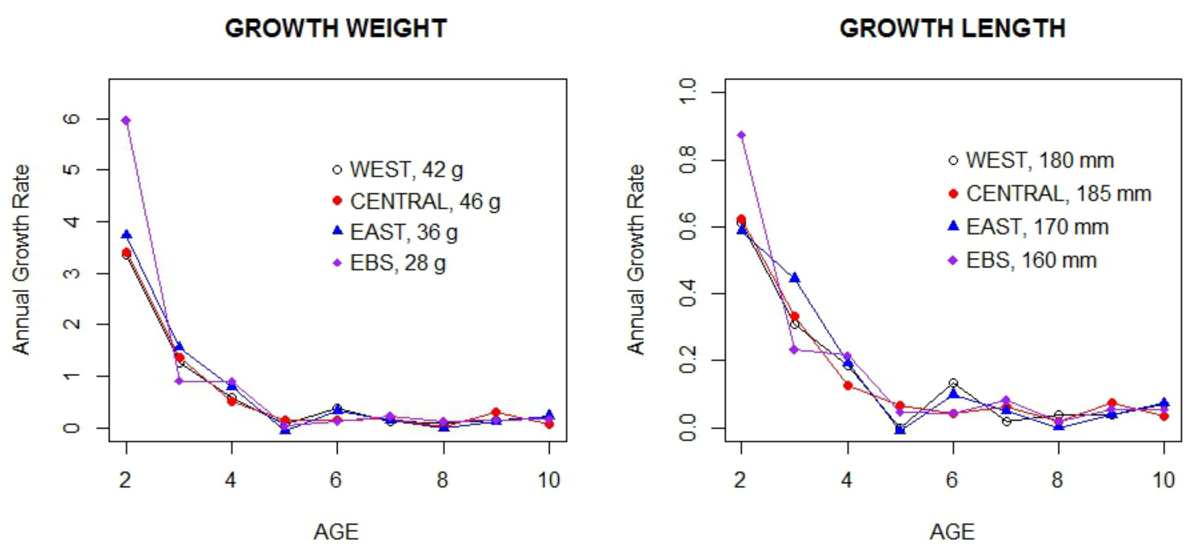
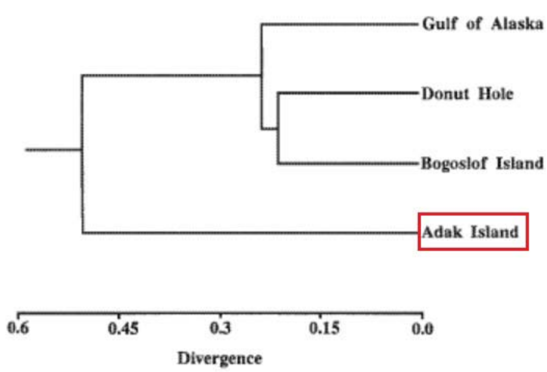


Figure 16. Annual growth rate as a proportion of the previous year's weight or length for pollock in different regions of the Aleutian Islands from the Aleutian Islands summer bottom trawl surveys for 1980-2012. Numbers next to the caption are the mean weight or length for age 1 pollock.



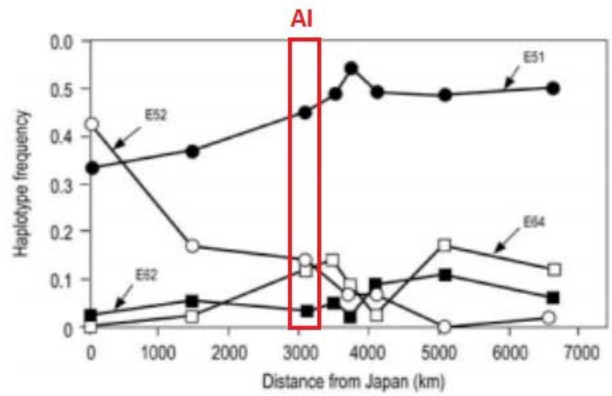


Figure 16. (Left) UPGMA clustering of genetic distances among walleye pollock stocks in the eastern Bering Sea and Chelikof Strait from mt-DNA RFLP data (from Mulligan *et al*. 1992) and (Right) frequencies of four haplotypes in samples of walleye pollock across the North Pacific and Bering Sea(from Grant *et al*. 2010). Samples analyzed from the Aleutian Islands are highlighted in red.