Section 10

PACIFIC OCEAN PERCH

by

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Executive Summary

Relative to last year's final BS/AI SAFE report, the following major changes have been made in the current draft of the Pacific ocean perch chapter:

Changes in the Input Data

(1) A model run with the maturity schedule currently used in the Gulf of Alaska POP assessment was made, and the recommended ABC is from this model.

(2) The 1999 harvest levels for Pacific ocean perch have been revised and harvests through September 30, 2000 have been included in the assessment.

(3) Length composition data from the 1996 harvest has been included for the eastern Bering Sea POP, as has length composition data from the 1997-1999 Aleutian Island harvests.

(4) The 2000 Aleutian Island survey biomass estimates and length composition data were used in the assessment, and the 1991, 1994, and 1997 biomass estimates were re-estimated.

(5) The domestic catch from 1982 to 1990 to changed to reflect strictly the Pacific ocean perch catch rather than the catch of the POP complex.

Changes in the Assessment Methodology

(1) The stock synthesis model configuration and assessment methodology remains essentially unchanged from that used in last year's assessment.

Changes in the Assessment Results

(1) A summary of the 2001 ABC's relative to the 2000 recommendations is as follows:

	Eastern Bering Sea		Aleutian Islands	
	2000	2001	2000	2001
ABC	2,600 t	1,727 t	12,300 t	10,213 t
OFL	3,100 t	2,043 t	14,400 t	11,842 t

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INTRODUCTION

Pacific ocean perch (*Sebastes alutus*) inhabit the outer continental shelf and upper slope regions of the North Pacific Ocean and Bering Sea. The management of Pacific ocean perch in these areas has been divided into two geographic units corresponding to the eastern Bering Sea slope and the Aleutian Islands region. The management stock from the Aleutian Islands region is the larger of the two.

Pacific ocean perch, and four other associated species of rockfish (northern rockfish, *S. polyspinis*; rougheye rockfish, *S. aleutianus*; shortraker rockfish, *S. borealis*; and sharpchin rockfish, *S. zacentrus*) were managed as a complex in the two distinct areas from 1979 to 1990. Known as the POP complex, these five species were managed as a single entity with a single TAC (total allowable catch). In 1991, the North Pacific Fishery Management Council enacted new regulations that changed the species composition of the POP complex. For the eastern Bering Sea slope region, the POP complex was divided into two subgroups: 1) Pacific ocean perch, and 2) shortraker, rougheye, sharpchin, and northern rockfishes combined, also known as “other red rockfish.” For the Aleutian Islands region, the POP complex was divided into three subgroups: 1) Pacific ocean perch, 2) shortraker/rougheye rockfishes, and 3) sharpchin/northern rockfishes. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, and rougheye rockfish (the three most valuable commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual TAC.

Of the five species which comprise the POP complex, *S. alutus* has historically been the most abundant rockfish in this region and has contributed most to the commercial rockfish catch. Furthermore, the bulk of the research on rockfish has been concentrated on *S. alutus*; relatively little biological or assessment information is available for the other rockfish species. This chapter discusses strictly Pacific ocean perch; the assessment of other red rockfish is addressed in another chapter.

FISHERY

Pacific ocean perch were highly sought by Japanese and Soviet fisheries and supported a major trawl fishery throughout the 1960s. Catches in the eastern Bering Sea peaked at 47,000 (metric tons, t) in 1961; the peak catch in the Aleutian Islands region occurred in 1965 at 109,100 t. Apparently, these stocks were not productive enough to support such large removals. Catches continued to decline throughout the 1960s and 1970s, reaching their lowest levels in the mid 1980s. With the gradual phase-out of the foreign fishery in the 200-mile U.S. Exclusive Economic Zone (EEZ), a small joint-venture fishery developed but was soon replaced by a domestic fishery by 1990. In 1990 the domestic fishery recorded the highest Pacific ocean perch removals since 1977. The history of *S. alutus* landings since implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) is shown in Table 1. The catches for the domestic fishery from 1982-1990 were changed to reflect strictly the POP catch; data in the earlier assessments represents catch of the POP complex. This was accomplished by applying the species composition of the POP complex observed in the 1990 observer data to the catch in previous years.

Estimates of retained and discarded Pacific ocean perch from the fishery have been available since 1990. Table 2 summarizes this information for *S. alutus* in both regions. The eastern Bering Sea region generally shows a higher discard rate than in the Aleutian Islands region. For the period from 1990 to 1999, the Pacific ocean perch discard rate in the eastern Bering Sea averaged about 24.5%; whereas, in the Aleutian Islands region, the discard rate for the same period averaged about 16.7%.

DATA

Fishery Data

Catch per unit effort (CPUE) data from Japanese trawl fisheries indicate that Pacific ocean perch stock abundance has declined to very low levels in the Aleutian Islands region (Ito 1986). By 1977, CPUE values had dropped by more than 90-95% from those of the early 1960s. Japanese CPUE data after 1977, however, is probably not a good index of stock abundance because most of the fishing effort has been directed to species other than Pacific ocean perch. Standardizing and partitioning total groundfish effort into effort directed solely toward Pacific ocean perch is extremely difficult. Increased quota restrictions, effort shifts to different target species, and rapid improvements in fishing technology undoubtedly affect our estimates of effective fishing effort. Consequently, we included CPUE data primarily to evaluate its consistency with other sources of information. We used nominal CPUE data for class 8 trawlers in the eastern Bering Sea and Aleutian Islands regions from 1968-1979. During this time period these vessels were known to target on Pacific ocean perch (Ito 1982).

Otoliths collected by the NMFS domestic observer program in 1990 were analyzed for age composition estimates. Estimates of catch length frequency data for 1996 were added to the eastern Bering Sea POP assessment, and the catch length frequency from 1997-1999 were added to the Aleutian Islands POP assessment. Although catch length frequency data exist for more recent years in the eastern Bering Sea, the samples sizes were viewed as too small to be used. For example, the total number of POP lengths available in the eastern Bering Sea per year did not exceed 289 in 1995 and from 1998-1999, and was 989 in 1997. Within synthesis, fits to annual length-frequency data from the commercial fishery and surveys were weighted by the square root of sample size.

Survey Data

Biomass estimates of *S. alutus* in the eastern Bering Sea were derived from cooperative U.S.-Japan trawl surveys from 1979 to 1985. These estimates were based almost entirely on data collected by Japanese vessels sampling the continental slope (the area of greatest Pacific ocean perch abundance). In 1988, the U.S. vessel *Miller Freeman* sampled the continental slope for the first time. This vessel was again used to sample the continental slope during the 1991 eastern Bering Sea survey. This complicates the comparison of the 1988 and 1991 estimates with those from earlier years. To solve this problem, the Japanese provided a landbased trawler in 1988 to conduct side-by-side trawling operations with the *Miller Freeman* so that it would be possible to relate the *Miller Freeman* data to that of the Japanese vessels which sampled the slope in the past.

The 1988 and 1991 biomass estimates are not directly comparable with estimates from previous years because the area of the slope sampled by the *Miller Freeman* was less than that sampled by the Japanese vessels in 1979-85. The *Miller Freeman* sampled from 200-800 m whereas the Japanese vessels sampled from 200-1,000 m in previous years. To better evaluate the trend in abundance of *S. alutus* as shown by the 1988 and 1991 trawl data, the biomass estimates for earlier years were recalculated using data only from the 200-800 m depth interval.

Biomass estimates for the 200-1,000 m depth interval in 1988 and 1991 were also calculated. These were derived by using the average of the ratios between the biomass estimates from the 200-800 m and 200-1,000 m depth intervals in 1982 and 1985 which was 0.7810. Applying this average to the 1988 biomass in the 200-800 m depth interval (28,882/0.7810) produced an estimate for the 200-1,000 m depth interval of 36,981 t. For 1991, biomass was estimated at 14,562 t (11,373/0.7810). Biomass estimates of *S. alutus* for the 200-1,000 m depth interval from cooperative U.S.-Japan trawl surveys (1979-1985) and U.S. domestic trawl surveys (1988-1991) are shown in Table 3.

The biomass estimate for the eastern Bering Sea has two surveyed components--the eastern Bering Sea shelf-slope component and the Aleutian Islands component of Bering Sea statistical Area I. The eastern Bering Sea shelf-slope component increased between the 1979-82 and the 1985 surveys, reflecting the variability among the point estimates (Fig. 10-1). For example, there is a sixfold increase from 1982 to 1985 while from 1985 to 1988, biomass appeared to only increase slightly from about 32,400 t in 1994 to approximately 37,000 t three years later in 1988. Then in 1991 biomass dropped by more than half to 14,465 t.

In addition to the 2000 Aleutian Islands survey biomass estimate, the earlier estimates in 1991, 1994, and 1997 were re-estimated with more accurate estimates of survey strata. In all cases, the new estimates were less than the previous estimates, with the percentage decline ranging from 28% to 34% for the Aleutian Islands component of the EBS and 14% for each year in the Aleutian Islands region. There is wide variability among survey estimates from the Aleutian Islands component of the EBS, with the estimated biomass increasing from 1501 t in 1991 to 18, 217 t in 1994; the 2000 estimate is 15,473 t (Table 3). The estimated biomass of Pacific ocean perch in the Aleutian Islands region (long. 170^{o} E to 170^{o} W) appears to be less variable. In this region there has been a steady increase from 1980 to 1997, followed by a decline to the 2000 estimate. The 1991 trawl survey produced a biomass estimate of 349,592 t, representing more than 3.2 times the 1980 point estimate. The 1994 and 1997 trawl surveys produced a biomass estimates of 365,401 and 613,174 t. The most recent trawl survey of the Aleutian Islands region occurred in 2000 and produced an estimate of 492,836 t. We use the Aleutian Islands trawl survey biomass estimates in a relative sense rather than in an absolute sense; specifically, we allow the survey catchability (q) to be estimated in the model rather than fixing q at 1.0. Model fits to the survey biomass estimates were weighted by the inverse of their variances (Fig. 1).

Biological Data

The surveys produce large numbers of samples for age determination, length-weight relationships, sex ratio information, and for estimating the length distribution of the population. The age compositions were determined by constructing age-length keys for each year and using them to convert the observed length frequencies from each year. The length frequency data were corrected to represent the entire catch of the surveys within a year. Because these age data were based on the break and burn method of ageing Pacific ocean perch, they were treated as unbiased but measured with error. Kimura and Lyons (1991) give data on the percent agreement between otolith readers for Pacific ocean perch. The estimate of aging error was identical to that presented in Ianelli and Ito (1991). Stock synthesis uses this information to create a transition matrix to convert the simulated "true" age composition to a form consistent with the observed but imprecise age data.

Assessments of Pacific ocean perch have significantly changed in the past decade because of improved methods of age determination. Previously, Pacific ocean perch age determinations were done using scales and surface readings from otoliths. These gave estimates of natural mortality of about 0.15 and a longevity of about 30 years (Gunderson 1977). Based on the now accepted break and burn method of age determination using otoliths, Chilton and Beamish (1982) determined the maximum age of *S. alutus* to be 90 years. Using similar information, Archibald et al. (1981) concluded that natural mortality for Pacific ocean perch should be on the order of 0.05. The age at 50% recruitment to the fishery is estimated from previous cohort analyses to be about 7.25 yrs or about 28 cm. In the stock synthesis analyses presented below, we re-estimate the fishery selectivity pattern.

The length weight relationship for Pacific ocean perch was estimated using survey data by area from 1983 - 1989. The following equations were used in stock synthesis to model length at age and weight:

Aleutian Islands region:

$$L_{age} = 39.565(1 - e^{-0.1673(age+0.907)})$$
$$W_L = 1.224x10^{-5} L^{3.0297}$$

Eastern Bering Sea region:

$$L_{age} = 39.962(1 - e^{-0.1348(age+1.831)})$$
$$W_L = 1.193x10^{-5} L^{3.037}$$

where L = length in cm, W = weight in grams. Because stock synthesis uses this growth relationship to interpret length frequency data, an estimate of variability in length at age is also required. We used the variance in length at age reported in Ianelli and Ito (1991). Sex ratio information was calculated from the trawl survey samples. The ratio of males to females varied slightly from year to year but was not significantly different from 1:1 (Ianelli and Ito 1991).

Previous assessments of BSAI POP have used the work of Chikuni (1975) to infer the proportion of females mature at a given age, resulting in a length and age at 50% maturity of 28.5 cm and 7 years, respectively. However, these values seem small relative to other studies of POP maturity. For example, Westrheim (1975) found that the length at 50% maturity in several locations in the North Pacific ranged from 28 cm to 35 cm, with the age at 50% maturity ranging from 10 to 15 years. The maturity schedule used in the GOA POP assessment has an age at 50% maturity of 10.5 years, based upon recent field work. This range of results motivated the observation of POP maturity in the 2000 Aleutian Island survey (Figure 2), which produced a relatively large length at 50% maturity of 40.2 cm; this length is larger than the von Bertalanffy length at inifinity above. Thus, both the recent survey data and the data of Chikuni (1975) are inconsistent other observed estimates of maturity. Two models runs were made in this assessment: Model 1 has the maturity schedule of Chikuni (1975), and Model 2 uses the more recent maturity schedule currently used in the GOA assessment.

ANALYTIC APPROACH

Previous stock assessments of Pacific ocean perch in the eastern Bering Sea and Aleutian Islands have relied in part on stock reduction analysis (SRA, Kimura et al. 1984; Kimura 1985, 1988) to provide historical biomass and exploitation trends in the fishery. One limitation of SRA is that the underlying age-structure of the population and other auxiliary information are not directly incorporated into the analysis. The stock synthesis (SS) model (Methot 1989, 1990) is a form of catch-at-age analysis that has been designed to incorporate age composition and a diversity of other information into a single computational framework. The main difference between the two models is that SRA does not keep track of abundance of fish at age. By explicitly tracking age structure, stock synthesis allows information on age and length composition to be used in the estimation process.

Stock synthesis functions by simulating both the dynamics of the population and the processes by which the population is observed. This simulation, which incorporates both imprecision and bias in the observations, is used to predict expected values for the observations. These expected values are then compared to the actual observations (data) from surveys and the fishery. Together, the comparisons between expected values given the simulation conditions and the observations are used to obtain a statistical likelihood value. This likelihood value is maximized via a numerical derivative “hill climbing” algorithm (Methot 1989) to update the simulation model parameters. The model proceeds with this updating process until no further improvements can be made by tuning the simulation.

Model parameters are estimated by maximizing the log likelihood (*l*) of the predicted observations given the data. Data are classified into different components. For example, age composition from a survey and catch per unit effort (CPUE) from a fishery are different components. The total *l* is a sum of the likelihoods for each component. The total *l* may also include a component for a stock-recruitment relationship (Methot 1990) and penalty functions to help stabilize parameter estimates (Ianelli and Ito 1991). The likelihood components may be weighted by an emphasis factor.

Likelihood components

The following table shows the main likelihood components by time period used in the stock synthesis model for Pacific ocean perch in the eastern Bering Sea and Aleutian Islands region:

Component	Eastern Bering Sea	Aleutian Islands
Fishery catch	1960-2000	1962-2000
Fishery age composition	1964-72, 81-82, 90	1964-72, 90
Fishery size composition	1963-78, 90-92, 93, 94, 96	1964-84, 86-99
Fishery CPUE	1968-79	1968-79
Survey age composition	--	1980, 83, 86, 91, 94, 97
Survey size composition	1979, 81, 82, 85, 88, 91	1980, 83, 86, 91, 94, 97, 2000
Survey biomass estimates	1979, 81, 82, 85, 88, 91	1980, 83, 86, 91, 94, 97, 2000
Stock-recruitment relationship	All years	All years

In principle, if all data types and model assumptions are consistent with each other, then the maximum of the sum of likelihood components should fall at or near the maximum of each individual component. In practice this is rarely true. Although stock synthesis accounts for many types of errors with the data it uses, it often remains for the practitioner to assign statistical weights to individual data types. Ideally these terms could be estimated directly, however, as pointed out by Fournier and Archibald (1982), there is typically not enough information in the data to determine the relative accuracies of the different data types.

For this analysis, the emphasis assigned to each likelihood component was based on our subjective interpretation of the relative adequacy of each data component. In several previous assessments, survey biomass was set to an emphasis of 3, the fishery size composition was assigned an emphasis of 2, and the fishery CPUE and biased age compositions were given a factor of 0.5 and 0.3, respectively (Ianelli and Ito 1996). All other likelihood components were set to an emphasis of 1.0. As was done in last year's assessment, all likelihood components were set to an emphasis of 1.0 with the exception of the fishery CPUE and biased age compositions, which remained the same. We made this change because we are no longer confident and have no compelling evidence that the trawl surveys and fishery size composition data sets represent a significantly better information source relative to the other likelihood components.

Catch data used in the stock synthesis model were from 1960 to 2000 for the eastern Bering Sea stock and from 1962 to 2000 for the Aleutian Islands stock. Catch data for the last ten years were adjusted to include discards. Discards were based on detailed catch information published by the NMFS Alaska Regional Office. Recent estimates of the retained catch and discards are provided in Table 2. Catch data prior to 1990 were assumed to include discards in the total.

The stock synthesis model configuration used in this year's assessment is essentially the same as that used in last year's asssessment (Ito and Ianelli 1998). Biomass estimates from NMFS trawl surveys were used in the model, but in different ways depending on the region. For the eastern Bering Sea (EBS) model configuration, we collapsed the trawl survey biomass estimates into a single point. This was done to address some of the concerns regarding the perceived uninformative nature of the eastern Bering Sea survey biomass time series. There was concern by the review panel that the trawl surveys in this region may not adequately capture the population trends, especially given the large CV's often associated with the survey estimates. A single point biomass estimate was determined by summing the mean of the biomass estimates from the 1979-91 EBS slope surveys and the mean of the biomass estimates from that portion of the EBS region (Area I) covered during the 1980-2000 Aleutian Islands surveys (Table 3). This resulted in a single point estimate of 45,906 t which was then used as the 1989 (1979-2000 midpoint) "tuning" point for all subsequent EBS stock synthesis runs.

For the Aleutian Islands model configuration, the individual biomass estimates from the 1980-2000 trawl surveys were used. But rather than use these estimates as absolute, we chose to use them as relative indices of abundance. We believe that the trawl surveys probably do a fairly good job of describing the general population trend of Pacific ocean perch in the Aleutian Islands region. It is still questionable, however, whether these surveys adequately estimate the absolute abundance of rockfish populations (e.g., Krieger and Sigler 1996). As such, we attempt to estimate the survey catchability coefficient (q) rather than keeping it fixed at 1.0. The sampling variance of survey biomass estimates was used to appropriately weight the individual survey observations.

Full-Selection Fishing Mortality Rates

In this report, full selection instantaneous fishing mortality rates (F) are used to calculate yield (Y) for given year as :

$$Y = \sum_{a=1}^{nages} W_a N_a F S_a \left(\frac{1 - e^{-Z_a}}{Z_a} \right)$$

$$Z_a = FS_a + M$$

where S_a is the selectivity at age, M is natural mortality, W_a is the mean weight at age, and N_a is the number at age *a* in the beginning of the year. It is important to understand that other forms of reported F, e.g., the knife-edged selectivity version for the standard Baranov catch equation dealing with numbers of fish, are *not* identical to the above. Furthermore, a constant F fishing strategy does not imply a constant fraction of biomass removals; year-class variability will cause the biomass fraction of removals to vary.

The exploitation rate, reported here as the fraction of the exploitable biomass to be harvested, is calculated based on the ratio of the yield for a given (full-selection) F level. Two such reference F-levels will be used in this assessment: $F_{40\%}$ and $F_{35\%}$. These rates are estimated to be the fishing mortality at which the spawning biomass per recruit (SBPR) is reduced to 40% and 35% of the unfished level. Note that the actual value of F for these calculations is independent of any stock-recruitment relationship and depends solely on the schedules of age-specific weights, maturity, natural mortality, and fishery selectivity.

RESULTS

Model Selection

The use of the maturity schedule currently used in the Gulf of Alaska POP assessment lowered the fishing mortality reference points such that F35% rate under the Chikuni (1975) maturity schedule (Model 1) was similar to the F40% under the GOA schedule (Model 2; Table 4). The overall model fits were similar in the Aleutian Island POP, but the eastern Bering Sea POP showed a higher likelihood and lower biomass under the Model 2. Because Model 2 is more consistent with recent information on POP maturity, it is recommended for use here; this leads to more conservative management recommendations. The text below refer to the Model 2 results.

Biomass Trends

Figure 3 shows the trend in survey biomass as estimated by the stock synthesis modeling process. The trajectory of survey biomass estimated by stock synthesis shows that in 1962 the survey biomass in the Aleutian Islands region was over 1,077,000 tons, then declined to about 103,000 tons through the late 1970s and has rebuilt to the current level which is estimated to be around 435,000 tons. The reader should bear in mind that the survey point estimates are used in a relative sense rather than in an absolute sense, with a survey catchability estimated at 2.06 rather than fixed at 1.0. In the eastern Bering Sea, the trajectory of the survey biomass begins at about 247,000 tons in 1960, declines to around 20,000 tons in 1981, and has increased to about 42,000 tons in recent years. The estimated time series of total biomass, spawning biomass, and recruitment are given in Table 5. The estimated numbers at age for the eastern Bering Sea and Aleutian Islands region are provided in Tables 6 and 7, respectively.

Selectivity

Survey abundance estimates are highly dependent on the type of selectivity exhibited by the surveys. For example, absolute abundance can be much larger than the estimated abundance from the surveys if older fish are not selected or available to the gear. In this assessment, we chose to use an asymptotic selectivity function for the surveys. This assumption is based on the objective sampling design of the surveys which cover several depth strata. Survey abundance therefore reflects the abundance of fish old enough to be selected by the survey gear.

The AI Pacific ocean perch appear to be available at earlier ages in the surveys than the early fishery (Fig. 4). This may be due to the fact that the surveys are carried out over a shallower range of depths than the fishery and Pacific ocean perch have been known to aggregate at certain depths at different ages (Ito 1982). For the recent fishery, the model predicts a decrease in selectivity with age. In a previous assessment (Ianelli and Ito 1992), an asymptotic selectivity pattern for the fishery was evaluated and was found to be inadequate in describing the observed data. The estimated current fishery selectivity-at-age values for the eastern Bering Sea and Aleutian Islands region are given in Table 8.

Fishing Mortality

The estimates for instantaneous fishing mortality on POP range from highs during the 1970’s to low levels in the 1980’s (Fig. 5). Relative to the estimated $F_{35\%}$ level, the stocks in both the eastern Bering Sea and Aleutian Islands were overfished during considerable portions of this period (Table 9). Fishing mortality rates since the early 1980's, however, have moderated considerably due to the phase out of the foreign fleets and quota limitations imposed by the North Pacific Fishery Management Council.

Recruitment

For both the eastern Bering Sea and Aleutian Islands, year class strength varies widely (Fig. 6; Table 5). The relationship between spawning stock and recruitment also displays a high degree of variability (Fig. 7). This variability reflects the most fundamental difference between the stock synthesis approach and stock reduction analysis (SRA). Under SRA, the large removals of Pacific ocean perch in the 1960s was implicitly comprised of mostly old (>25yr) fish. Using explicit age structured information in stock synthesis has shown that the catches evidently comprised removals of relatively young fish representing strong year-classes.

PROJECTIONS AND HARVEST ALTERNATIVES

A constant age-structured exploitation rate strategy was employed to obtain an acceptable biological catch (ABC) for Pacific ocean perch, *S. alutus*. Several spawning-biomass per recruit (SBPR) fishing mortality rates were calculated based on the current age-structured estimates of fishery selectivity, individual weights, and proportion mature. The corresponding fishing mortality rates for *S. alutus* in 2001 are:

Quantity	**Eastern Bering Sea**	**Aleutian Islands**
F35%	0.0577	0.0729
F40%	0.0485	0.0624

Projected Catch and Abundance

This year, a standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2000 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2001 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2000. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2001, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2001 recommended in the assessment to the *max* F_{ABC} for 2000. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1995-1999 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and five-year projections of the mean spawning stock biomass, fishing mortality rate, and harvest for the remaining four scenarios are shown in Tables 10 and 11.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Alaska plaice stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2001, then the stock is not overfished.)

Scenario 7: In 2001 and 2002, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2003 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the neither the Aleutian Islands or eastern Bering Sea Pacific ocean perch stock is overfished or approaching an overfished condition. With regard to assessing the current stock level, the expected AI stock size in the year 2001 of scenario 6 is 1.09 times its $B_{35\%}$ value of 78,005 t. With regard to whether the Aleutian island stock is likely to be overfished in the future, the expected stock size in 2003 of scenario 7 is 1.03 times the $B_{35\%}$ value. For the eastern Bering Sea POP, the expected stock size in 2001 is 18,097 t, which is between $B_{35\%}$ and $B_{35\%}$ / 2. In this case, the stock is not considered overfished because the projected stock biomass in 2011 is 18,967 t, which is 137 t above the $B_{35\%}$ level of 18,831 t. With regard to whether the eastern Bering Sea POP are aproaching an overfished condition, the projected stock size 2013 of scenario 7 is 19,338 t, or 1.03 times the $B_{35\%}$ level. While the eastern Bering Sea POP are not defined as overfished, their low sizes relative to $B_{35\%}$ may be a concern in future years.

Acceptable Biological Catch

The results of our assessment for the Aleutian Islands stock indicate that current spawning biomass is about 4,280 t below its long-term average under an $F_{40\%}$ (=0.062) harvest strategy. Our estimate of the year 2001 spawning biomass for this stock (SPB_{2001}) is about 84,869 t; whereas, the long-term equilibrium spawning biomass ($SPB_{40\%}$) is about 89,149 t. Similar to the guidelines established under tier 3b of Amendment 56, we calculate the F_{ABC} as $\{F_{40\%}$ x $(SPB_{2000}/SPB_{40\%}$ - 0.05)/(1-0.05)$\}$. **This procedure produces an F_{ABC} of 0.059 and an ABC estimate for the Aleutian Islands region of approximately 10,213 t**. This ABC estimate represents about a 2,100 t decrease over last year's recommendation of 12,300 t.

For the eastern Bering Sea stock, the estimate of current spawning biomass is also below its long-term average. The current estimate of spawning biomass for this stock is at about 18,130 t and its long-term equilibrium spawning biomass is 21,521 t. We apply the same adjustment procedure to the eastern Bering Sea $F_{40\%}$ that was used to calculate the F_{ABC} for the Aleutian Islands stock. **This procedure produces and F_{ABC} of 0.040 and an ABC estimate for the eastern Bering Sea region of approximately 1,727 t**. This ABC estimate represents about a 900 t decrease over last year's recommendation of 2,600 t.

Overfishing Definitions

Prevention of growth overfishing requires that fishing mortality, either intentional or incidental, be directed at fish that have reached ages where increases in biomass due to individual body growth is offset by mortality in the population. Typically, management measures to prevent growth overfishing require implementation of mesh-size regulations or area closures. For Pacific ocean perch, growth in weight occurs relatively quickly; they reach about 80% of their maximum weight by age 12. As recruitment to the fishery is approximately 50% by age 8, the Pacific ocean perch does not appear to be in danger of growth overfishing. Should recruitment to the fishery begin at early ages, then area closures in shallow waters might be appropriate given that younger fish appear to reside at shallower depths (Heifetz and Clausen 1991).

Prevention of recruitment overfishing from a harvest management perspective requires information on the level of spawning biomass required to prevent recruitment failure. For Pacific ocean perch, low recruitment appears to have happened regularly, even before fishery removals became significant (Figures 10-5, 10-6). This suggests that environmental conditions and perhaps biological interactions may play an important role in the success of a year class. These characteristics plague estimation of recruitment productivity because of the large amount of process error driving inter-annual recruitment variability.

For both the eastern Bering Sea and Aleutian Islands stocks, the current SPB is below $SPB_{40\%}$. Under the guidelines established in the new overfishing definition, F_{OFL} is to be calculated as $F_{35\%}$ x ($SPB_{2000}/SPB_{40\%}$ - 0.05) / (1-0.05). The estimates of F_{OFL} for the Aleutian Islands stock is 0.069 and 0.048 for the eastern Bering Sea stock. These mortality levels translate to overfishing harvest levels of 11,842 t and 2,043 mt, respectively.

OTHER CONSIDERATIONS

To distribute fishing effort throughout the Aleutian Islands region we recommend that the ABC be apportioned based on the apparent distribution of the biomass. The four most recent trawl surveys (1991, 1994, 1997,and 2000; Table 12), indicate that the average POP biomass was distributed in the Aleutian Islands region as follows:

Biomass (%)	
Eastern subarea (541):	28.4%
Central subarea (542):	25.1%
Western subarea (543):	46.5%
Total	100%

Under these proportions, the recommended ABC is 2,900 t for area 541, 2,563 t for area 542, and 4,749 t for area 543.

The biomass trends produced by the stock synthesis model are highly dependent on the survey biomass estimates. The current trawl survey methods to assess rockfish absolute biomass, especially for the deeper water species such as shortraker and rougheye rockfish, have not been calibrated. Additionally, the effect of the fisheries on the ecosystem is not well understood. These concerns have prompted the Alaska Fisheries Science Center to develop a comprehensive working plan to improve stock assessments for rockfish stocks in waters off Alaska and to better understand the habitat in which they live. Research studies have been initiated and are currently ongoing to improve our understanding of rockfish biology and distribution. Many of these studies hope to improve survey designs for the major rockfish species.

The catch of Pacific ocean perch taken in research surveys will be included in catch totals in future assessments; these catch levels are shown from 1977-2000 in Table 13.

FUTURE RESEARCH OBJECTIVES

Several avenues for future work became apparent with this years assessment. First, the somewhat unrealistic drastic decline in fishery selectivity implies a very large group of large fish that is not observed in the fishery. This is related to an equilibrium population assumption in the first year of the model, which puts a very large portion of the population in the age 25+ group. Second, age and size composition information are often used in the same year, particularly in the Aleutian Islands model, and inconsistencies with the age-length transition matrix may cause poor model fits. Third, the length distributions group all fish above 39 cm (36 cm in the Aleutian Islands model) in a single bin, and this size group often has more fish than any other group. Thus, it may be difficult to infer the presence of strong cohorts unless they are observed prior to entering the terminal length group. The observed and estimated age and length compositions are shown in the Appendix. In future assessments, a number of alternatives will be evaluated, including estimating the first year age distribution (rather than using an equilibrium assumption), updating the growth functions and transition matrices, using either the size or age composition from a given year, and evaluating length bins with greater resolution.

SUMMARY

The management parameters for Pacific ocean perch as presented in this assessment are summarized as follows:

	Eastern Bering Sea	Aleutian Islands
M	0.05	0.05
Approximate recruitment age	7 yrs	7 yrs
$F_{35\%}$	0.0577	0.0729
$F_{40\%}$	0.0485	0.0624
Equil. spawner biomass ($F_{40\%}$)	21,522	89,149
2000 spawner biomass	18,130	84,869
$F_{abc\ (adjusted)}$	0.0404	0.0593
ABC (adjusted $F_{40\%}$)	**1,727**	**10,213**
$F_{overfishing}$ (adjusted $F_{30\%}$)	0.048	0.069
Overfishing Level	**2,043**	**11,842**

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Table 1. Estimated removals (t) of Pacific ocean perch (*S. alutus*, t) since implementation of the Magnuson Fishery Conservation and Management Act of 1976.

	Eastern Bering Sea				Aleutian Islands			
Year	Foreign	JVP	DAP	Total	Foreign	JVP	DAP	Total
1977	2,654	--	--	2,654	8,080	--	--	8,080
1978	2,221	--	--	2,221	5,286	--	--	5,286
1979	1,723	--	--	1,723	5,487	--	--	5,487
1980	1,050	47	--	1,097	4,700	Tr	--	4,700
1981	1,221	1	--	1,222	3,618	4	--	3,622
1982	212	3	8	223	1,012	2	--	1,014
1983	116	97	7	220	272	8	--	280
1984	156	134	1,122	1,412	356	273	2	631
1985	35	32	629	696	Tr	215	72	287
1986	16	117	375	508	Tr	160	98	258
1987	5	50	768	823	0	500	391	891
1988	0	51	874	925	0	1,513	362	1,875
1989	0	31	2,570	2,601	0	Tr	2,101	2,101
1990	0	0	6,344	6,344	0	0	11,838	11,838
1991	0	0	5,339	5,339	0	0	2,831	2,831
1992	0	0	3,309	3,309	0	0	10,278	10,278
1993	0	0	3,746	3,746	0	0	13,330	13,330
1994	0	0	1,687	1,687	0	0	10,865	10,865
1995	0	0	1,207	1,207	0	0	10,303	10,303
1996	0	0	2,855	2,855	0	0	12,827	12,827
1997	0	0	817	817	0	0	12,648	12,648
1998	0	0	1,017	1,017	0	0	9,051	9,051
1999	0	0	381	381	0	0	11,880	11,880
2000*	0	0	451	451	0	0	8,576	8,576

Tr = trace, JVP = Joint Venture Processing, DAP = Domestic Annual Processing.
Source: PacFIN, NMFS Observer Program, and NMFS Alaska Regional Office.
* Estimated removals through September 30, 2000.

Table 2. Estimated retained, discarded, and percent discarded of Pacific ocean perch from the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions.

Area	Year	Catch Retained (t)	Discard (t)	Total (t)	Discard Percentage
EBS	1990	5,069	1,275	6,394	20.1%
	1991	4,112	1,227	5,339	23.0%
	1992	2,784	525	3,309	15.9%
	1993	2,602	1,144	3,746	30.5%
	1994	1,281	406	1,687	24.1%
	1995	839	368	1,207	30.5%
	1996	2,522	333	2,855	11.7%
	1997	539	278	817	34.0%
	1998	821	201	1,022	19.7%
	1999	247	134	381	35.2%
	2000*	237	215	452	47.6%
AI	1990	10,288	1,551	11,838	13.1%
	1991	1,851	980	2,831	34.6%
	1992	8,686	1,592	10,278	15.5%
	1993	11,438	1,892	13,330	14.2%
	1994	9,491	1,374	10,865	12.6%
	1995	8,603	1,700	10,303	16.5%
	1996	9,832	2,995	12,827	23.3%
	1997	10,855	1,793	12,648	14.2%
	1998	8,030	940	8,970	10.5%
	1999	10,406	1,473	11,879	12.4%
	2000*	7,850	726	8576	8.5%

* Estimated removals through September 30, 2000.
Source: NMFS Alaska Regional Office

Table 3. Pacific ocean perch estimated biomass in metric tons from the NMFS bottom trawl surveys, and a comparison with data used in the 1999 assessment.

Year	(EBS) Shelf and Slope	Aleutian Islands portion of EBS Area I		Aleutian Islands Region	
		1999	2000	1999	2000
1979	4,459	--	--	--	--
1980	--	6,003	6,003	109,022	109,022
1981	9,821	--	--	--	--
1982	5,505	--	--	--	--
1983	--	97,478	97,478	144,080	144,080
1984	--	--	--	--	--
1985	32,393	--	--	--	--
1986	--	49,562	49,562	220,614	220,614
1987	--	--	--	--	--
1988	36,981	--	--	--	--
1989	--	--	--	--	--
1990	--	--	--	--	--
1991	14,562	2,274	1,501	405,366	349,592
1992	--	--	--	--	--
1993	--	--	--	--	--
1994	--	25,147	18,217	423,045	365,401
1995	--	--	--	--	--
1996	--	--	--	--	--
1997	--	17,972	12,099	713,841	613,174
1998	--	--	--	--	--
1999	--	--	--	--	--
2000		--	15,473	--	492,836

Table 4. Comparison of selected model results under with the maturity schedule of Chikuni (1975) (Model 1) and the maturity schedule use in the GOA POP assessment (Model 2).

	AI		EBS	
	Model 1	Model 2	Model 1	Model 2
Log likelihood	-494.04	-493.93	-537.70	-533.86
Total Biomass (2000)	232,354	232,572	61,043	53,315
F35%	0.073	0.062	0.057	0.048
F40%	0.086	0.073	0.069	0.058
ABC (2001)	12,295	10,213	2,744	1,727

Table 5. Estimated time series of POP total biomass (t), spawner biomass (t), and recruitment (thousands) for each region.

	Total	Biomass	Spawner Biomass		Recruitment (age 3)	
Year	AI	EBS	AI	EBS	AI	EBS
1960	--	287643	--	114660	--	24876
1961	--	282975	--	107827	--	20601
1962	562571	236439	200529	91828	93350	22347
1963	572313	217389	205110	83495	27891	19352
1964	558636	194964	198101	73789	31779	33957
1965	495500	172713	168313	64671	299753	44542
1966	401595	158576	132967	57751	53166	19433
1967	329525	140762	104466	49920	27271	15244
1968	286418	125226	85282	41039	21459	33183
1969	251527	97086	75400	31683	20531	22853
1970	222725	85240	64809	27355	53330	8416
1971	161597	77915	51638	24482	34599	9349
1972	145290	70858	45104	22402	20027	14216
1973	116771	67524	37411	21618	21608	9122
1974	109693	65578	33833	20459	17305	3554
1975	91354	52348	28414	17255	20862	2309
1976	78168	44249	24218	14195	14488	2243
1977	67329	29419	21006	10684	14174	3286
1978	63357	27711	19311	9927	23579	10196
1979	65754	28588	18407	9330	56776	30533
1980	69122	33083	17598	8911	47309	52726
1981	76622	37130	17125	8646	66190	20763
1982	82916	41225	17345	8526	14904	16092
1983	94156	46523	18987	9055	41860	14758
1984	113365	51105	21434	10204	112538	5825
1985	128017	54088	25013	11457	23525	6095
1986	149620	57240	29084	13352	100774	4530
1987	171466	60430	34243	15773	72333	8211
1988	191278	62672	41031	18360	43831	5523
1989	212432	64339	47481	20716	75303	5218
1990	230886	63805	54487	21852	41011	4816
1991	239900	58991	60078	21433	62772	4686
1992	254289	54896	67400	20859	22460	4783
1993	258220	52647	72962	20418	17041	4681
1994	256024	49923	77366	19777	12640	6226
1995	255262	49718	82261	19661	28600	11397
1996	253571	50147	85836	19361	28600	11298
1997	248119	49058	87529	18690	28600	11149
1998	242020	50314	88316	18632	28600	11121
1999	238796	51428	88728	18601	28600	11049
2000	232572	53315	87539	18844	28600	10882

Table 6. Estimated numbers (thousands) of Pacific ocean perch at age in the Eastern Bering Sea region

Eastern Bering Sea

Age

Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1960	24876	28479	28149	31557	43515	18359	17464	16612	15802	15031	14298	13601	12937	12306	11706	11135	10592	10076	9584	9117	8672	8249	160894
1961	20601	23659	27075	26728	29856	40820	17013	16035	15190	14428	13719	13048	12411	11806	11230	10682	10161	9666	9194	8746	8319	7913	159363
1962	22347	19568	22398	25355	24237	25109	30815	11839	10759	10065	9523	9044	8599	8179	7779	7400	7039	6696	6369	6058	5763	5482	146517
1963	19352	21241	18568	21136	23537	21653	21231	24998	9428	8513	7948	7516	7137	6785	6453	6138	5838	5554	5283	5025	4780	4547	138796
1964	33957	18389	20136	17466	19429	20502	17459	16152	18528	6925	6236	5817	5500	5222	4964	4721	4491	4272	4063	3865	3677	3497	128884
1965	44542	32259	17417	18886	15912	16537	15829	12525	11212	12716	4736	4260	3973	3756	3566	3390	3224	3067	2917	2775	2639	2511	117450
1966	19433	42328	30584	16389	17380	13901	13408	12132	9361	8307	9397	3497	3145	2933	2772	2632	2502	2380	2264	2153	2048	1948	108279
1967	15244	18459	40076	28652	14879	14662	10555	9404	8212	6259	5533	6252	2326	2091	1950	1843	1750	1664	1583	1505	1432	1362	97472
1968	33183	14476	17463	37442	25796	12285	10692	7009	5989	5155	3911	3453	3900	1451	1304	1216	1150	1092	1038	987	939	893	86371
1969	22853	31451	13605	15968	31563	17981	6520	4621	2763	2287	1949	1475	1301	1469	546	491	458	433	411	391	372	354	69140
1970	8416	21691	29702	12640	14131	24933	12069	3871	2596	1523	1254	1067	806	711	803	299	269	250	237	225	214	203	59346
1971	9349	7993	20526	27775	11411	11751	18427	8161	2515	1664	972	799	680	514	453	512	190	171	160	151	143	136	52411
1972	14216	8878	7563	19184	25036	9451	8619	12335	5243	1593	1050	612	503	428	323	285	322	120	108	100	95	90	46153
1973	9122	13510	8419	7120	17686	21970	7727	6682	9336	3936	1193	785	458	376	320	242	213	241	90	81	75	71	41995
1974	3554	8673	12827	7959	6648	16032	19092	6505	5545	7710	3246	983	647	378	310	264	199	176	199	74	66	62	38923
1975	2309	3373	8188	11904	7021	5206	10589	11090	3567	2981	4120	1731	524	345	201	165	141	106	94	106	39	35	33170
1976	2243	2193	3190	7643	10691	5759	3751	6918	6935	2197	1828	2522	1059	321	211	123	101	86	65	57	65	24	29018
1977	3286	2125	2056	2894	6288	7000	2718	1383	2284	2204	690	572	789	331	100	66	38	32	27	20	18	20	22313
1978	10196	3122	2014	1933	2659	5469	5628	2059	1021	1670	1607	503	417	574	241	73	48	28	23	20	15	13	20181
1979	30533	9691	2961	1897	1786	2345	4514	4419	1581	778	1269	1221	382	316	436	183	55	36	21	17	15	11	18396
1980	52726	29024	9197	2796	1763	1600	1994	3690	3548	1262	619	1011	972	304	252	347	146	44	29	17	14	12	16921
1981	20763	50132	27567	8706	2620	1614	1417	1721	3149	3016	1072	526	858	825	258	214	295	124	37	25	14	12	15758
1982	16092	19741	47610	26085	8148	2391	1420	1213	1455	2651	2536	901	442	721	693	217	180	248	104	31	21	12	14648
1983	14758	15306	18773	45250	24749	7700	2246	1328	1132	1357	2472	2365	840	412	672	646	202	167	231	97	29	19	13892
1984	5825	14038	14557	17846	42960	23426	7257	2110	1246	1061	1272	2318	2217	787	386	630	606	189	157	216	91	28	13196
1985	6095	5540	13341	13807	16828	39955	21361	6519	1883	1110	944	1132	2061	1972	700	344	560	539	168	140	192	81	12416
1986	4530	5797	5268	12678	13092	15878	37432	19905	6060	1749	1030	877	1051	1914	1831	650	319	520	500	156	130	179	11831
1987	8211	4308	5513	5008	12037	12396	14972	35186	18685	5686	1641	967	822	986	1796	1718	610	299	488	469	147	122	11392
1988	5523	7810	4097	5240	4752	11376	11648	14009	32860	17438	5306	1531	902	767	920	1675	1603	569	279	455	438	137	10910
1989	5218	5252	7424	3889	4956	4472	10667	10905	13108	30744	16316	4964	1432	844	718	861	1568	1500	533	261	426	410	10346
1990	4816	4960	4986	7019	3642	4579	4089	9710	9913	11912	27940	14830	4513	1302	768	653	783	1427	1366	485	238	388	9801
1991	4686	4574	4695	4670	6417	3216	3939	3479	8231	8396	10091	23681	12576	3829	1106	652	555	666	1214	1162	413	203	8692
1992	4783	4451	4331	4404	4286	5706	2793	3386	2980	7047	7190	8645	20296	10783	3285	949	560	477	572	1044	1000	356	7665
1993	4681	4546	4221	4083	4091	3900	5113	2486	3007	2646	6257	6385	7679	18035	9585	2921	844	498	425	510	930	891	7150
1994	6226	4448	4309	3972	3776	3692	3455	4493	2179	2635	2318	5484	5599	6736	15825	8414	2565	742	438	373	448	818	7080
1995	11397	5920	4224	4077	3729	3504	3397	3167	4113	1994	2412	2122	5021	5127	6170	14498	7710	2351	680	401	342	411	7246
1996	11298	10837	5624	4003	3842	3484	3253	3145	2930	3805	1845	2231	1964	4646	4745	5711	13420	7138	2177	629	372	317	7095
1997	11149	10737	10278	5301	3720	3498	3124	2898	2795	2603	3381	1639	1983	1746	4133	4222	5083	11950	6358	1939	561	331	6612
1998	11121	10602	10205	9753	5012	3498	3276	2920	2708	2612	2432	3159	1532	1853	1632	3863	3947	4752	11172	5945	1814	525	6495
1999	11049	10575	10074	9675	9199	4692	3256	3042	2710	2512	2423	2257	2932	1422	1721	1515	3587	3665	4413	10377	5522	1685	6523
2000	10882	10509	10055	9571	9175	8700	4428	3071	2868	2555	2368	2284	2127	2764	1341	1622	1429	3382	3456	4162	9786	5208	7741

Table 7. Estimated numbers (thousands) of Pacific ocean perch by age in the Aleutian Islands region.

	Aleutian Islands																						
	Age																						
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1962	93350	50424	27740	33827	69172	1E+05	1E+05	26922	25609	24357	23153	21995	20892	19844	18848	17902	17004	16151	15340	14570	13839	13145	252910
1963	27891	88798	47965	26386	32169	65766	1E+05	1E+05	25595	24347	23156	22012	20911	19862	18865	17919	17020	16166	15354	14584	13852	13157	253043
1964	31779	26529	84414	45394	24444	29090	59125	1E+05	1E+05	22991	21869	20800	19772	18783	17841	16946	16096	15288	14521	13792	13100	12447	249513
1965	3E+05	30219	25157	78307	37901	18120	20951	42425	76137	81035	16489	15685	14918	14181	13471	12796	12154	11544	10965	10414	9893	9413	231939
1966	53166	3E+05	28604	22994	60536	24249	11073	12728	25756	46218	49190	10010	9521	9056	8608	8178	7767	7378	7007	6656	6323	6023	205396
1967	27271	50541	3E+05	26026	17363	37030	14094	6394	7344	14860	26665	28380	5775	5493	5225	4966	4718	4481	4256	4043	3841	3660	178218
1968	21459	25926	47842	2E+05	20162	11154	22731	8601	3899	4478	9061	16260	17306	3522	3350	3186	3028	2877	2733	2596	2466	2349	155690
1969	20531	20402	24559	43990	2E+05	13688	7282	14766	5584	2531	2907	5883	10556	11235	2286	2175	2068	1966	1868	1774	1685	1605	137454
1970	53330	19522	19340	22711	36140	1E+05	9524	5046	10227	3867	1753	2013	4074	7310	7780	1583	1506	1432	1362	1293	1229	1169	122861
1971	34599	50685	18428	17290	15652	18563	67571	4513	2389	4841	1831	830	953	1928	3460	3683	749	713	678	644	612	584	100427
1972	20027	32899	48049	17053	14253	11323	13010	47164	3149	1666	3377	1277	579	665	1345	2414	2569	523	497	473	450	428	89490
1973	21608	19036	31088	43322	12280	7962	5947	6779	24553	1639	867	1758	665	301	346	700	1257	1337	272	259	246	235	74527
1974	17305	20548	18057	28918	36689	9354	5911	4400	5014	18160	1212	642	1300	492	223	256	518	929	989	201	191	182	67154
1975	20862	16450	19436	16413	21720	22214	5375	3374	2510	2859	10356	691	366	741	280	127	146	295	530	564	115	110	57017
1976	14488	19834	15571	17758	12663	13843	13516	3251	2039	1517	1728	6259	418	221	448	169	77	88	179	320	341	70	49024
1977	14174	13774	18772	14223	13685	8054	8403	8156	1960	1229	915	1042	3774	252	133	270	102	46	53	108	193	206	42113
1978	23579	13478	13060	17397	11814	10044	5736	5962	5784	1390	872	649	739	2676	179	95	192	72	33	38	76	137	37640
1979	56776	22424	12793	12211	15134	9472	7896	4498	4673	4534	1090	683	508	579	2098	140	74	150	57	26	30	60	34382
1980	47309	53994	21284	11959	10609	12105	7426	6174	3516	3653	3544	852	534	397	453	1640	109	58	117	44	20	23	31335
1981	66190	44992	51268	19951	10540	8722	9784	5989	4979	2835	2946	2858	687	431	320	365	1322	88	47	95	36	16	28733
1982	14904	62953	42743	48261	17975	9037	7389	8277	5066	4210	2398	2491	2417	581	364	271	309	1118	75	40	80	30	26630
1983	41860	14177	59865	40563	45353	16707	8377	6847	7669	4694	3901	2222	2308	2239	538	338	251	286	1036	69	37	74	25209
1984	1E+05	39819	13485	56919	38489	42937	15808	7926	6478	7256	4441	3691	2102	2184	2119	509	319	238	271	980	65	35	24021
1985	23525	1E+05	37873	12816	53910	36312	40470	14898	7469	6105	6838	4185	3479	1981	2058	1997	480	301	224	255	924	62	22834
1986	1E+05	22378	1E+05	36015	12172	51124	34423	38363	14122	7080	5787	6482	3967	3297	1878	1951	1893	455	285	212	242	876	21762
1987	72333	95859	21286	96834	34216	11551	48502	32657	36394	13397	6717	5490	6149	3763	3128	1781	1851	1796	432	271	201	229	21519
1988	43831	68805	91176	20233	91782	32325	10904	45780	30824	34351	12645	6340	5182	5804	3552	2953	1681	1747	1695	407	255	190	20650
1989	75303	41688	65421	86612	19175	86614	30379	10225	42893	28872	32173	11843	5938	4853	5436	3327	2765	1575	1636	1587	381	239	19753
1990	41011	71621	39638	62149	82092	18101	81441	28504	9585	40201	27058	30151	11099	5564	4548	5094	3118	2591	1476	1533	1487	358	18951
1991	62772	38986	67984	37458	58057	75139	16241	72289	25197	8462	35475	23874	26602	9792	4909	4012	4494	2751	2286	1302	1353	1313	18041
1992	22460	59702	37067	64576	35492	54767	70576	15219	67679	23583	7919	33199	22342	24895	9164	4594	3755	4206	2574	2140	1218	1266	18330
1993	17041	21355	56703	35092	60628	32833	49941	63856	13729	60994	21248	7135	29908	20127	22427	8255	4139	3383	3789	2319	1928	1098	18371
1994	12640	16200	20275	53620	32843	55712	29638	44645	56874	12214	54240	18893	6344	26592	17895	19940	7340	3680	3008	3369	2062	1715	18196
1995	28600	12018	15387	19196	50355	30400	50847	26843	40318	51313	11016	48918	17038	5721	23982	16139	17983	6619	3319	2712	3038	1860	18658
1996	28600	27193	11416	14573	18045	46705	27831	46221	24335	36519	46466	9975	44292	15427	5180	21714	14612	16282	5993	3005	2456	2752	19247
1997	28600	27190	25822	10801	13660	16635	42364	25023	41418	21783	32678	41574	8924	39628	13802	4634	19427	13073	14567	5362	2688	2198	20538
1998	28600	27190	25819	24431	10122	12588	15081	38067	22409	37052	19480	29220	37173	7980	35433	12341	4144	17370	11689	13025	4795	2405	21246
1999	28600	27194	25830	24460	22979	9401	11547	13741	34596	20349	33636	17683	26524	33743	7243	32163	11202	3761	15767	10611	11823	4353	22194
2000	28600	27190	25823	24438	22923	21177	8523	10376	12306	30950	18198	30078	15812	23717	30172	6477	28759	10017	3363	14099	9488	10576	24743

Table 8. Current trawl fishery selectivity values by area and age.

Age	Eastern Bering Sea Region	Aleutian Islands Region
3	0.01	0.01
4	0.04	0.03
5	0.13	0.09
6	0.34	0.24
7	0.64	0.51
8	0.87	0.78
9	0.96	0.92
10	0.99	0.97
11	1.00	0.99
12	1.00	1.00
13	0.99	1.00
14	0.99	1.00
15	0.99	1.00
16	0.98	1.00
17	0.98	1.00
18	0.97	1.00
19	0.97	1.00
20	0.96	1.00
21	0.96	1.00
22	0.95	1.00
23	0.95	0.99
24	0.94	0.87
25+	0.94	0.23

Table 9. Estimated full selection fishing mortality rate (F) for Pacific ocean perch by region 1960-2000.

Year	Eastern Bering Sea Region	Aleutian Islands Region
1960	0.042	- -
1961	0.367	- -
1962	0.187	0.001
1963	0.262	0.057
1964	0.331	0.282
1965	0.254	0.449
1966	0.358	0.500
1967	0.422	0.445
1968	0.927	0.382
1969	0.554	0.317
1970	0.401	0.698
1971	0.413	0.310
1972	0.240	0.603
1973	0.144	0.252
1974	0.579	0.512
1975	0.441	0.454
1976	1.113	0.456
1977	0.267	0.294
1978	0.225	0.194
1979	0.178	0.196
1980	0.114	0.165
1981	0.124	0.118
1982	0.020	0.026
1983	0.015	0.005
1984	0.067	0.009
1985	0.024	0.004
1986	0.014	0.003
1987	0.019	0.008
1988	0.017	0.016
1989	0.046	0.015
1990	0.116	0.075
1991	0.105	0.016
1992	0.069	0.054
1993	0.082	0.068
1994	0.039	0.053
1995	0.028	0.049
1996	0.066	0.061
1997	0.018	0.062
1998	0.025	0.047
1999	0.009	0.062
2000	0.010	0.046

Table 10. Projections of eastern Bering Sea spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 21,522 t and 18,831 t, respectively.

Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2000	18617.6	18617.6	18617.6	18617.6	18617.6	18617.6	18617.6
2001	18129.7	18129.7	18217.2	18176.5	18305.3	18097.1	18129.7
2002	18033.6	18033.6	18468.4	18264.9	18917.6	17874.5	18033.6
2003	18048.8	18048.8	18824.9	18461.6	19657.7	17771.8	18016.4
2004	18182.6	18182.6	19300.6	18780.9	20547.4	17793.6	18021.2
2005	18393.9	18393.9	19856.3	19186.7	21552.1	17897.6	18109.2
2006	18655.6	18655.6	20464.2	19654.2	22645.3	18056.5	18251.4
2007	18939.3	18939.3	21092.7	20155.7	23793.7	18242.7	18420.2
2008	19222.6	19222.6	21717.1	20668.1	24966.9	18434.7	18596
2009	19498.7	19498.7	22333	21183.3	26151.4	18626.1	18767.1
2010	19756.1	19756.1	22931.5	21687.7	27328	18805.1	18928.8
2011	19989.7	19989.7	23506	22173.2	28482.5	18966.5	19079
2012	20210.1	20210.1	24065.4	22647.8	29621.7	19119.7	19212.9
2013	20405.2	20405.2	24594.3	23095.9	30725.8	19251.7	19337.6
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2000	0.06112	0.06112	0.06112	18617.6	0.06112	0.06112	0.06112
2001	0.04044	0.04044	0.02022	18176.5	0	0.04801	0.04044
2002	0.04022	0.04022	0.02052	18264.9	0	0.04738	0.04022
2003	0.04025	0.04025	0.02093	18461.6	0	0.04709	0.04778
2004	0.04057	0.04057	0.02149	18780.9	0	0.04715	0.0478
2005	0.04107	0.04107	0.02214	19186.7	0	0.04745	0.04804
2006	0.04169	0.04169	0.02286	19654.2	0	0.0479	0.04845
2007	0.04236	0.04236	0.02357	20155.7	0	0.04842	0.04892
2008	0.04304	0.04304	0.02405	20668.1	0	0.04896	0.04942
2009	0.04367	0.04367	0.02419	21183.3	0	0.0495	0.04988
2010	0.04423	0.04423	0.02422	21687.7	0	0.04999	0.0503
2011	0.04467	0.04467	0.02423	22173.2	0	0.0504	0.05067
2012	0.04503	0.04503	0.02423	22647.8	0	0.05078	0.05099
2013	0.0453	0.0453	0.02424	23095.9	0	0.05109	0.05127
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2000	2600.12	2600.12	2600.24	2600.08	2600.07	2600.12	2600.2
2001	1727.49	1727.49	871.758	1272.29	0	2043.61	1727.47
2002	1744.77	1744.77	914.576	1304.72	0	2035.17	1744.73
2003	1774.29	1774.29	964.086	1337.66	0	2042.93	2098.88
2004	1816.71	1816.71	1021.2	1370.82	0	2067.04	2118.99
2005	1867.53	1867.53	1083.84	1403.78	0	2101.93	2150.4
2006	1923.91	1923.91	1150.54	1436.44	0	2144.18	2189.47
2007	1982.93	1982.93	1218.13	1468.81	0	2190.44	2232.61
2008	2041.82	2041.82	1273.22	1500.65	0	2237.63	2276.4
2009	2098.11	2098.11	1310.07	1531.59	0	2284.09	2317.63
2010	2148.43	2148.43	1339.76	1561.15	0	2326.53	2354.8
2011	2191.24	2191.24	1367.14	1589.37	0	2363.69	2388.63
2012	2227.95	2227.95	1393.08	1616.39	0	2397.73	2417.84
2013	2259.07	2259.07	1417.71	1642.05	0	2426.35	2444.03

Table 11. Projections of Aleutian Island spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 89,149 t and 78,005 t, respectively.

Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2000	87130.8	87130.8	87130.8	87130.8	87130.8	87130.8	87130.8
2001	84869.3	84869.3	85417.8	84925.4	85970	84689.6	84869.5
2002	82687.7	82687.7	85343.2	82930.5	88122.1	81838.7	82687.9
2003	80623.8	80623.8	85140.8	80929.5	90114.2	79225.4	80472.2
2004	78790.8	78790.8	84953.1	79057.4	92082.5	76940	78292
2005	77365	77365	84999.3	77513.6	94263.9	75136	76545.3
2006	76494.5	76494.5	85435.7	76475.9	96785.2	73950	75464.8
2007	76059.2	76059.2	86145.1	75852.3	99496.7	73254.6	74903
2008	76110.4	76110.4	87260.1	75709.5	102618	73076.1	74878.7
2009	76628	76628	88761.8	76051.2	106083	73391.1	75274.1
2010	77497.4	77497.4	90603.2	76776.7	109911	74069.8	75946.4
2011	78565.8	78565.8	92657.1	77745.4	113977	74954.1	76779.3
2012	79786.6	79786.6	94890.7	78918.4	118233	75993.9	77663.7
2013	80993	80993	97148.8	80132.8	122532	77020.6	78547.4

F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2000	0.06727	0.06727	0.06726	87130.8	0.06726	0.06727	0.06726
2001	0.05928	0.05928	0.02964	84925.4	0	0.06904	0.05928
2002	0.05767	0.05767	0.02962	82930.5	0	0.06659	0.05767
2003	0.05615	0.05615	0.02955	80929.5	0	0.06434	0.06541
2004	0.0548	0.0548	0.02948	79057.4	0	0.06237	0.06353
2005	0.05375	0.05375	0.0295	77513.6	0	0.06082	0.06203
2006	0.0531	0.0531	0.02967	76475.9	0	0.0598	0.0611
2007	0.05278	0.05278	0.02992	75852.3	0	0.0592	0.06062
2008	0.05282	0.05282	0.03026	75709.5	0	0.05905	0.0606
2009	0.0532	0.0532	0.03057	76051.2	0	0.05932	0.06093
2010	0.05383	0.05383	0.0308	76776.7	0	0.0599	0.06149
2011	0.05457	0.05457	0.03095	77745.4	0	0.06065	0.06218
2012	0.0554	0.0554	0.03104	78918.4	0	0.06151	0.06289
2013	0.05617	0.05617	0.0311	80132.8	0	0.06235	0.0636

Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2000	12300.8	12300.8	12300.4	12300.5	12300.3	12300.8	12301.1
2001	10213.2	10213.2	5176.91	9703.44	0	11842	10216.6
2002	9469.35	9469.35	5060.7	9266.25	0	10793	9482.85
2003	8801.07	8801.07	4933.57	8849.77	0	9883.46	10261.9
2004	8450.77	8450.77	4942.31	8699.18	0	9370.1	9803.66
2005	8092.19	8092.19	4909.62	8474.97	0	8878.77	9363.21
2006	7722.42	7722.42	4828.25	8160.65	0	8404.85	8912.83
2007	7754.6	7754.6	4969.2	8215.54	0	8385.61	8908.3
2008	7636.39	7636.39	4974.14	8054.25	0	8220.45	8738.32
2009	7722.68	7722.68	5068.45	8059.14	0	8284.18	8786.15
2010	7933.3	7933.3	5206.26	8160.99	0	8487.74	8961.68
2011	8076.98	8076.98	5266.51	8182.89	0	8629.47	9066.79
2012	8339.96	8339.96	5394.52	8319.37	0	8898.21	9290.77
2013	8539.52	8539.52	5477.35	8407.15	0	9108	9456.44

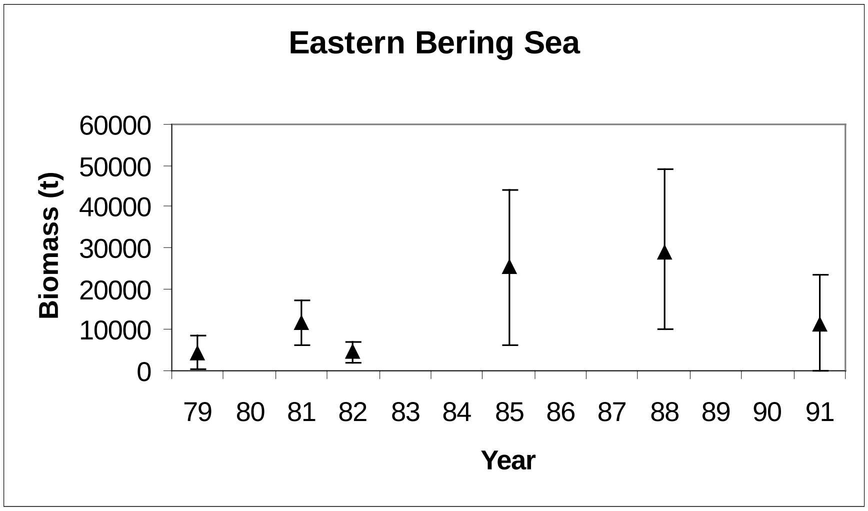
Table 12. Pacific ocean perch biomass estimates (t) from the 1991, 1994, 1997, and 2000 triennial trawl surveys broken out by the three management sub-areas in the Aleutian Islands region.

	Aleutian Islands Management Sub-Areas			
	Western	Central	Eastern	Total
1991	214,137	79,911	55,545	349,592
1994	184,005	80,811	100,585	365,401
1997	225,725	166,816	220,633	613,174
2000	222,584	129,740	140,512	492,836
Average	222,584	114,319	129,319	455,251
	(46.5%)	(25.1%)	(28.4%)	(100.0%)

Table 13. Catches of Pacific ocean perch (t) in trawl and hydroacoustic surveys in the eastern Bering Sea and Aleutian Islands.

Year	AI Trawl Survey	EBS Trawl Survey	EBS Hydroacoustic Survey
1977		0.01	
1978		0.13	0.01
1979		3.08	
1980	71.47	0.00	
1981		13.98	
1982	0.24	12.09	
1983	133.30	0.16	
1984		0.00	
1985		98.57	
1986	164.54	0.00	
1987		0.01	
1988		10.43	
1989		0.00	
1990		0.02	0.01
1991	73.57	2.76	0.00
1992		0.38	0.00
1993		0.01	0.00
1994	112.79	0.00	0.02
1995		0.01	0.01
1996		1.18	0.00
1997	177.94	0.73	0.15
1998		0.01	0.00
1999		0.19	0.00
2000		0.01	0.01

Figure 1. Estimated biomass and 95% confidence intervals by year and region.



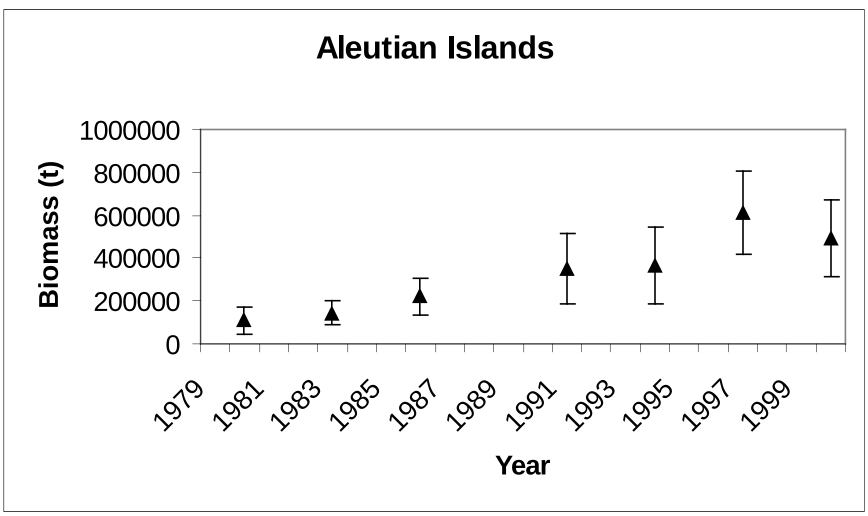
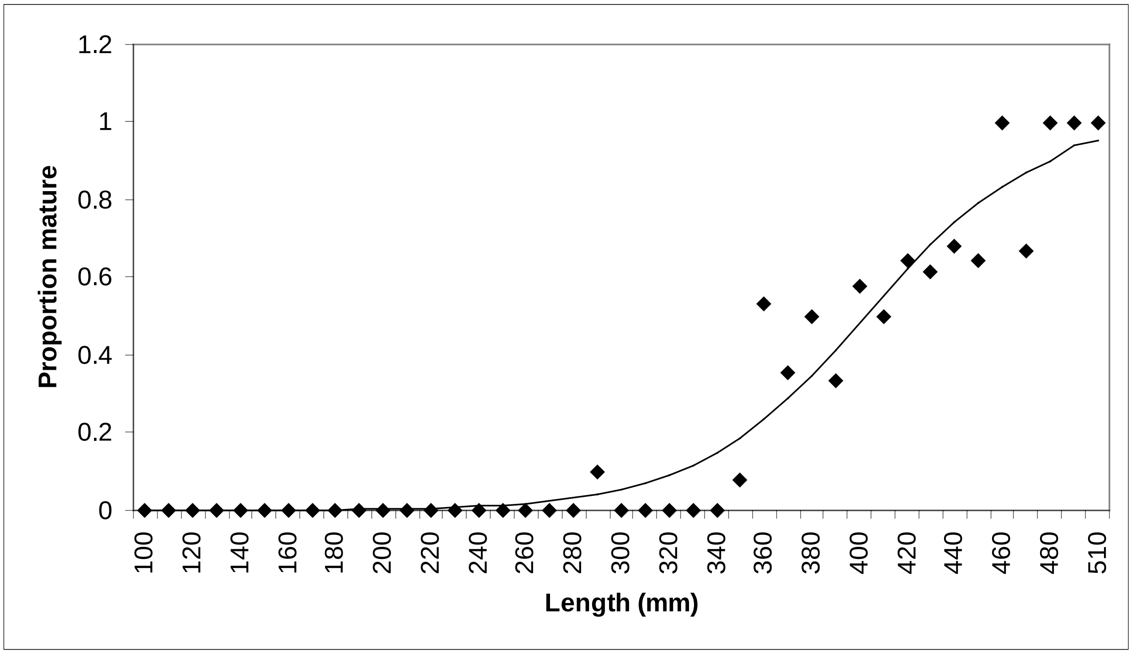


Figure 2. Estimated maturity, by length, from the 2000 Aleutian Island survey (top panel), and the maturity curves obtained from Chikuni (1975) and from the GOA POP assessment. (lower panel).



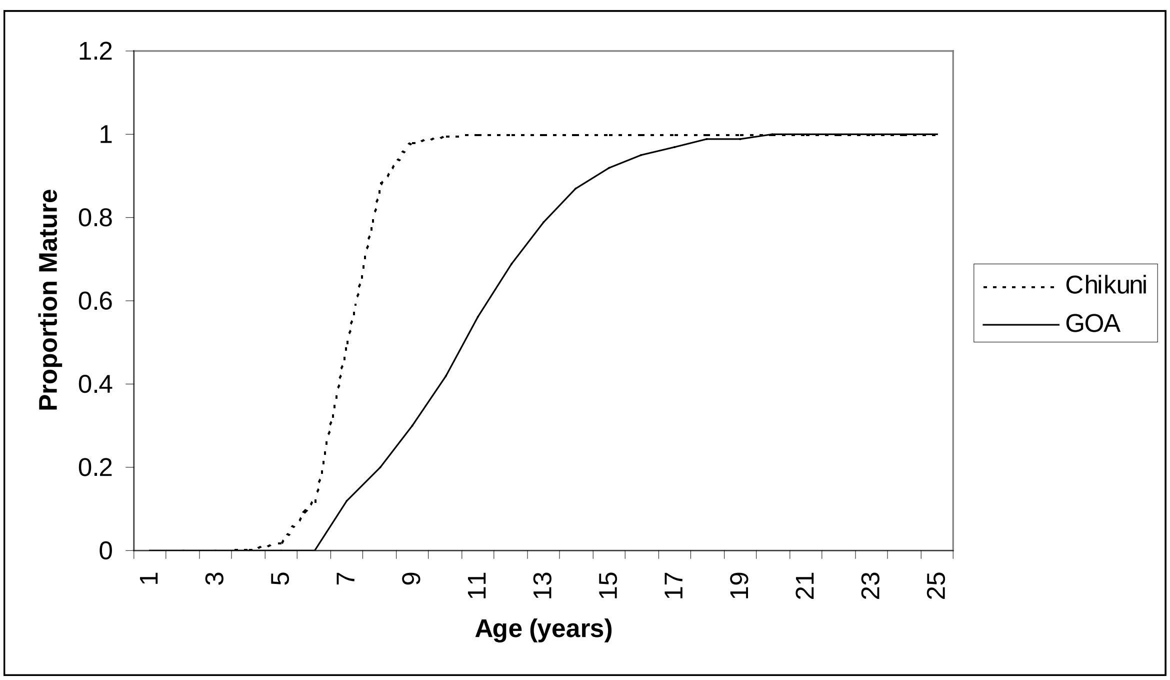
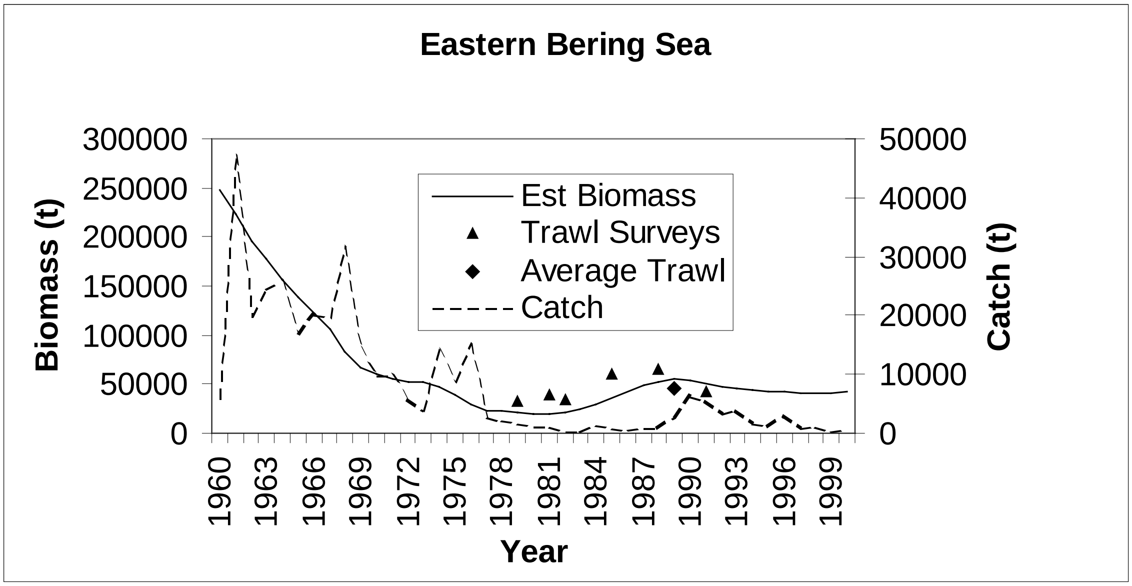


Figure 3. Estimated total removals and predicted and observed survey biomass trends for the eastern Bering Sea and Aleutian Islands region.



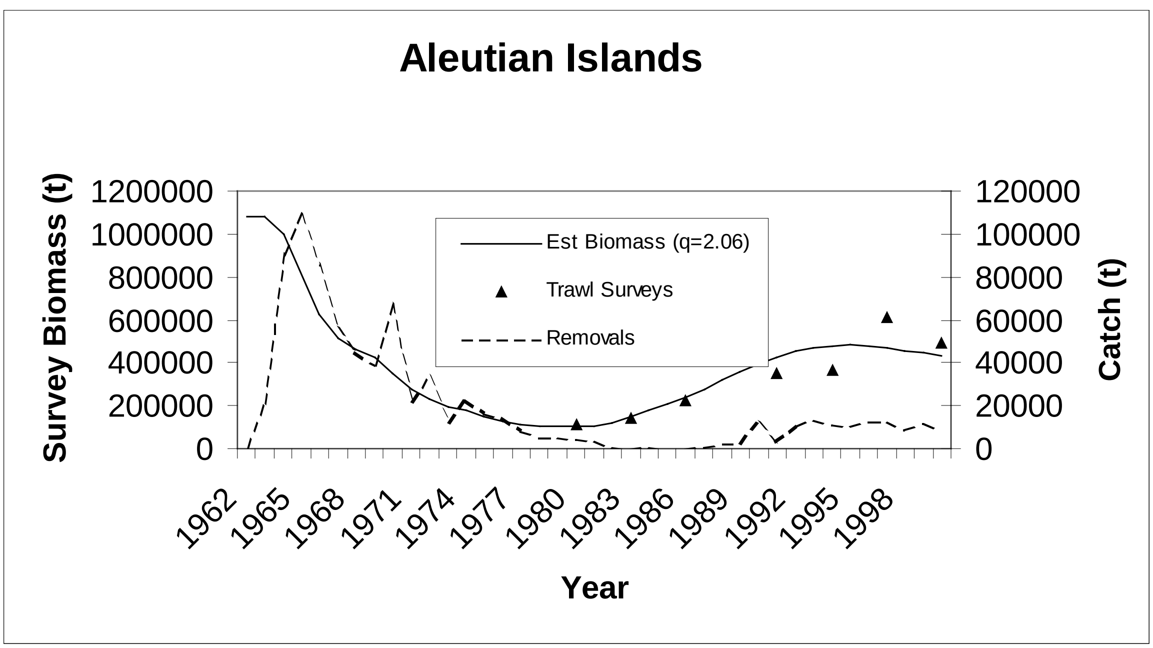
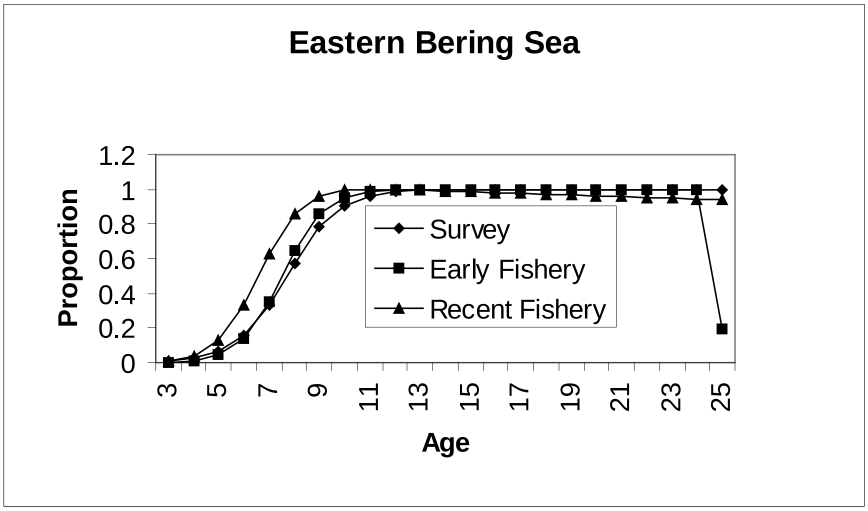


Figure 4. Selectivity patterns for the eastern Bering Sea and Aleutian Islands region for two different fishery periods and the surveys.



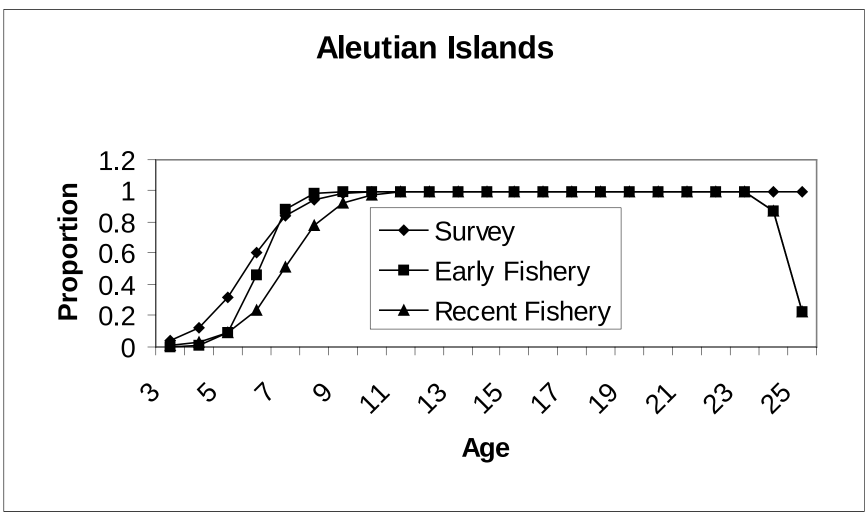
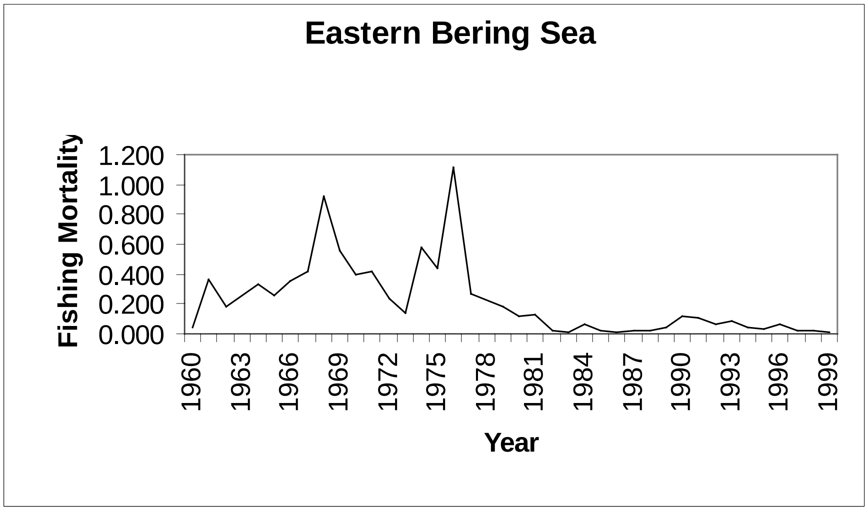


Figure 5. Estimated trajectory of full-selection fishing mortality rates for eastern Bering Sea and Aleutian Islands region.



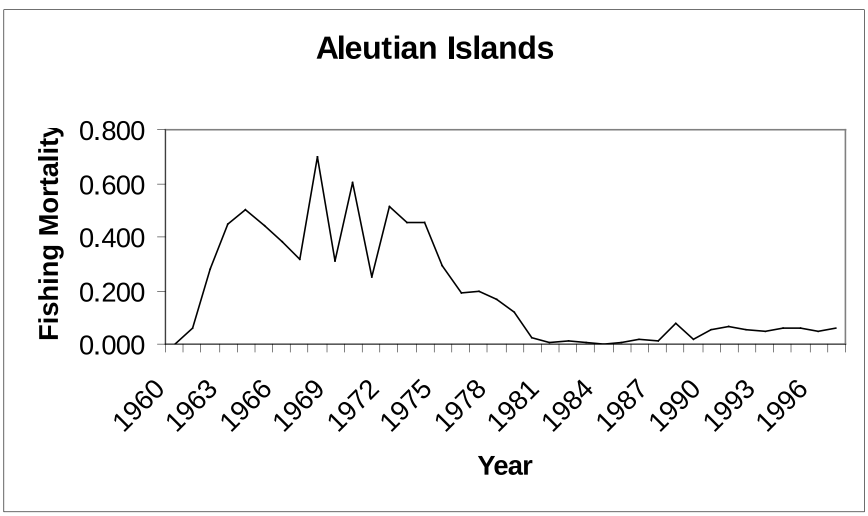
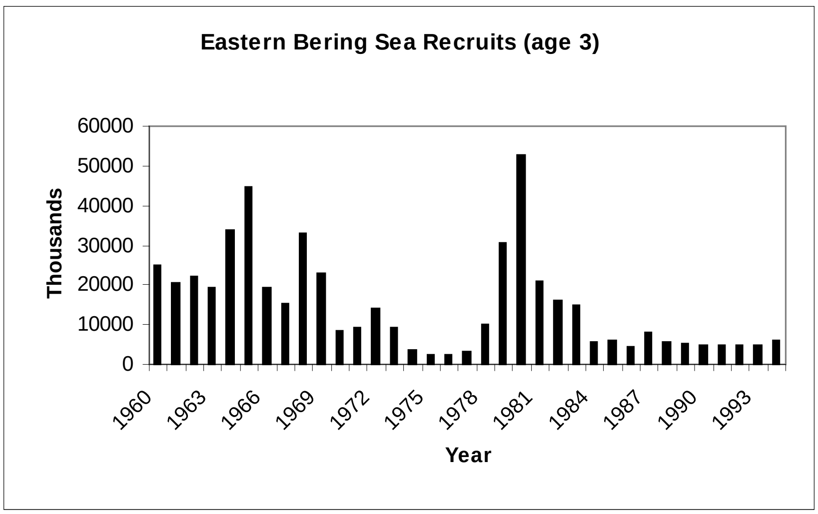


Figure 6. Estimated recruitment time series for the eastern Bering Sea and Aleutian Islands regions.



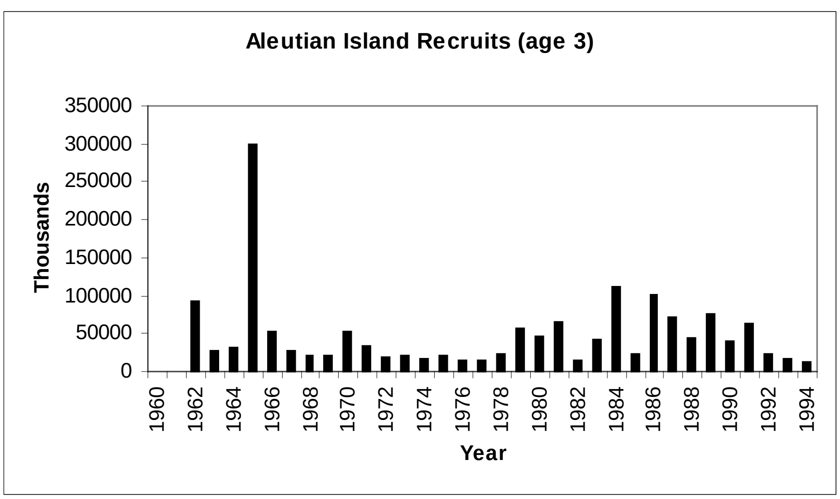
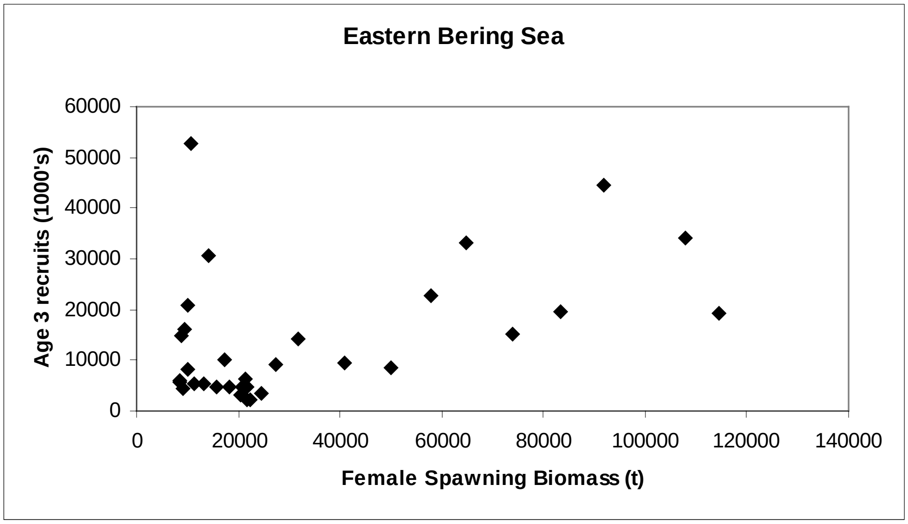
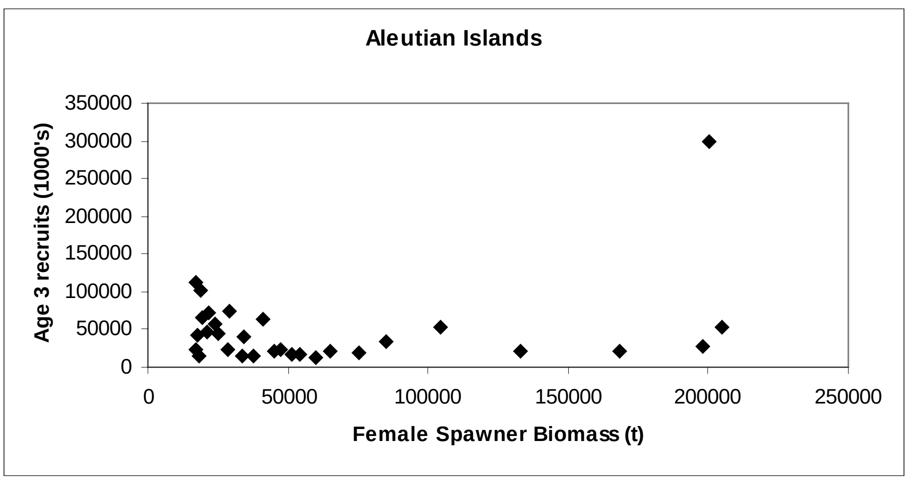


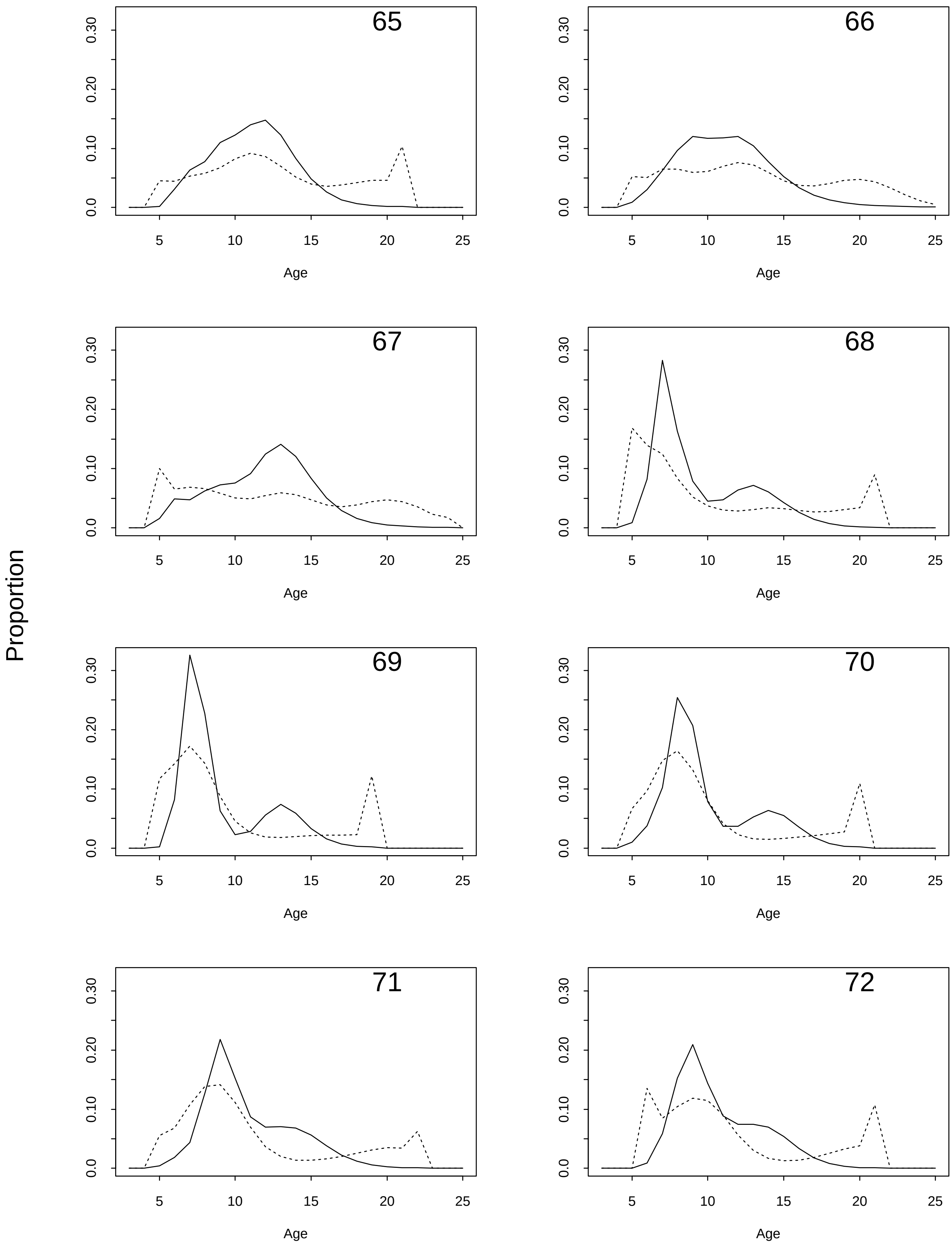
Figure 7. Estimated spawner-recruitment data for the eastern Bering Sea and Aleutian islands region.



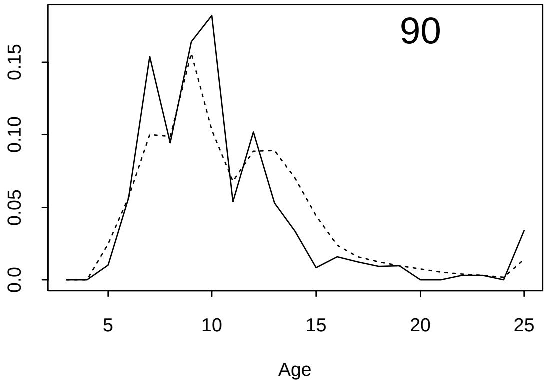


Appendix

Figures showing the observed and estimated age and length compostion for the Aleutian Island (AI) and eastern Bering Sea (EBS) Pacific ocean perch.

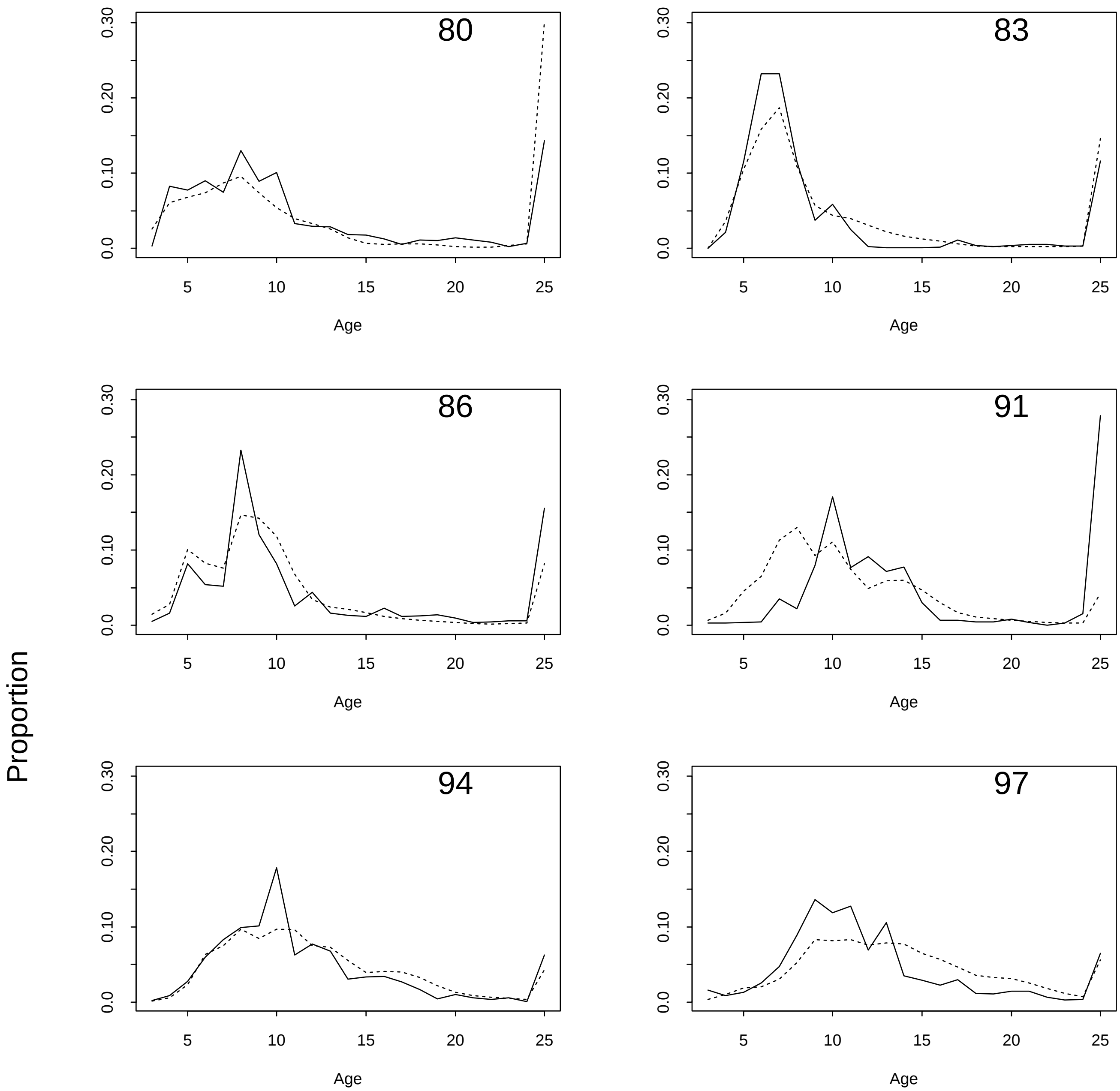


AI Fishery age (biased) composition by year (solid line = observed, dotted line = predicted)

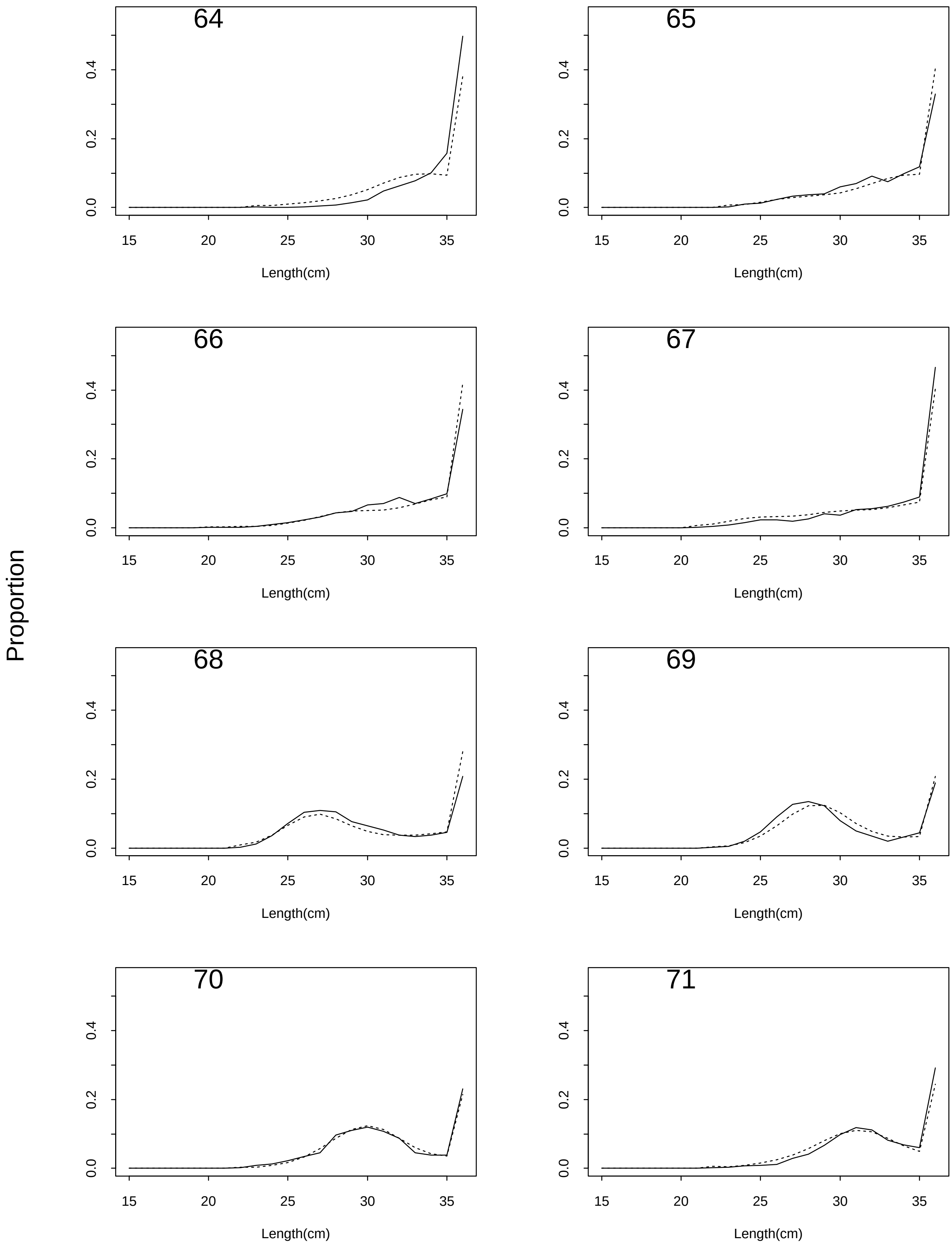


Proportion

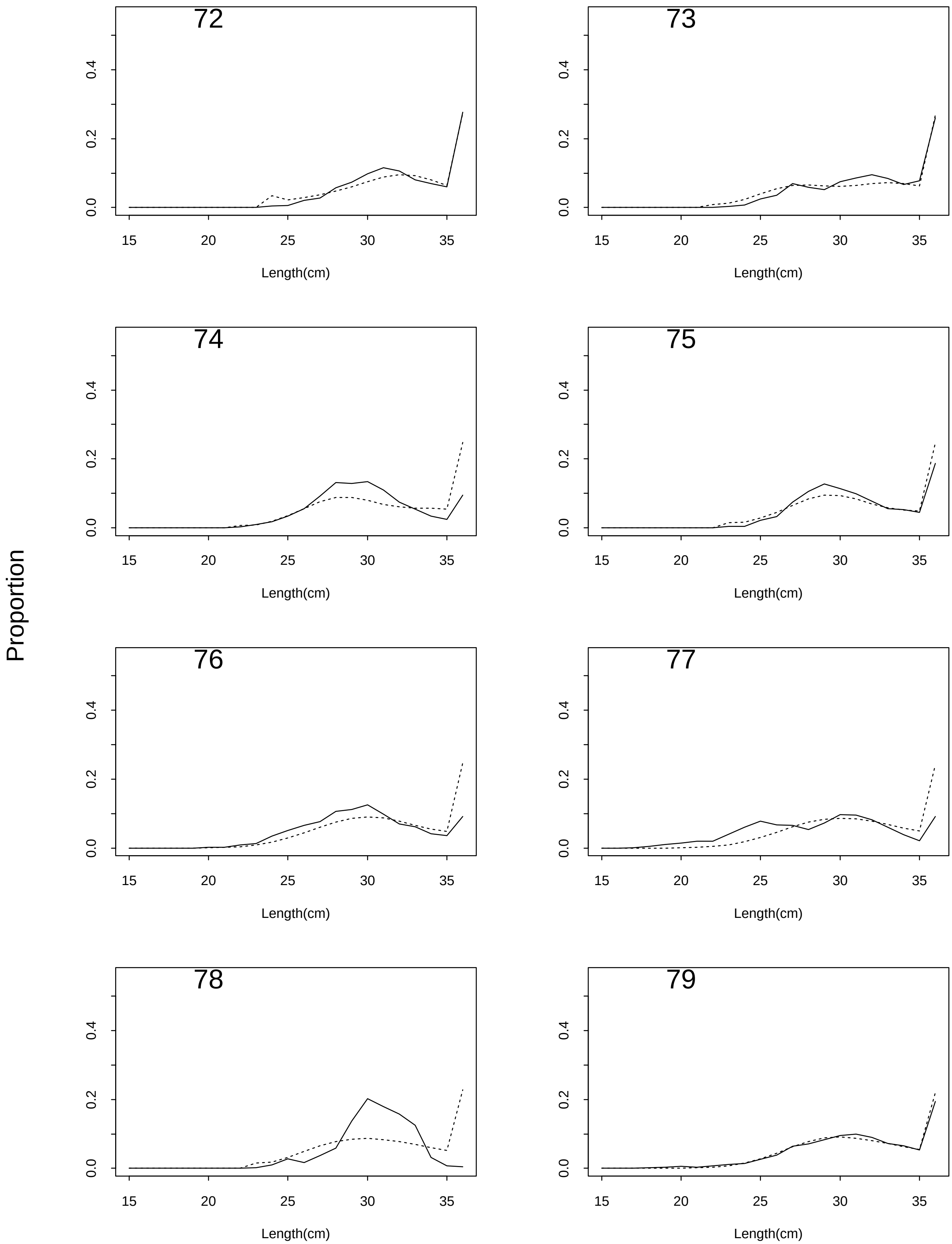
AI Fishery age (unbiased) composition by year (solid line = observed, dotted line = predicted)



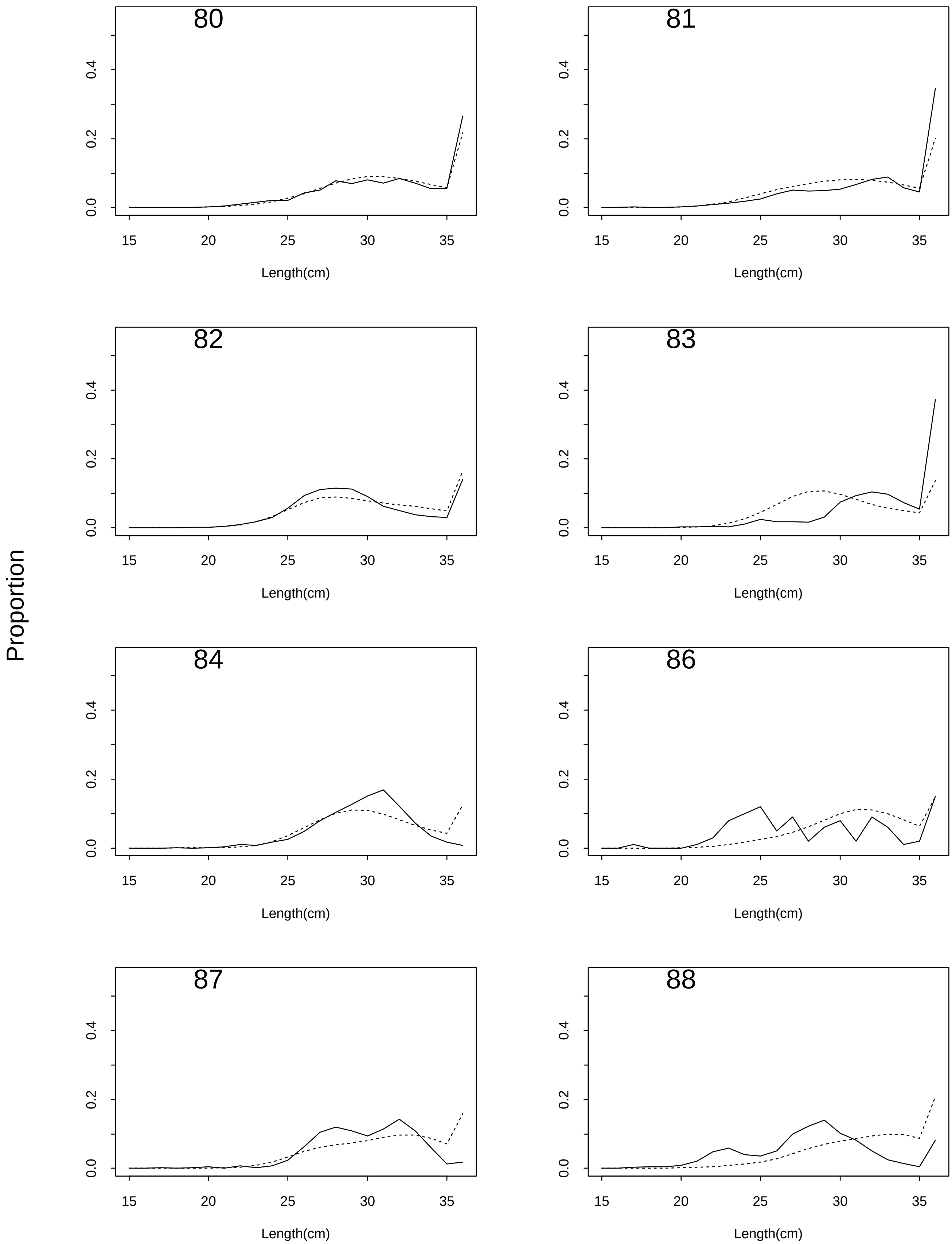
AI Survey age (unbiased) composition by year (solid line = observed, dotted line = predicted)



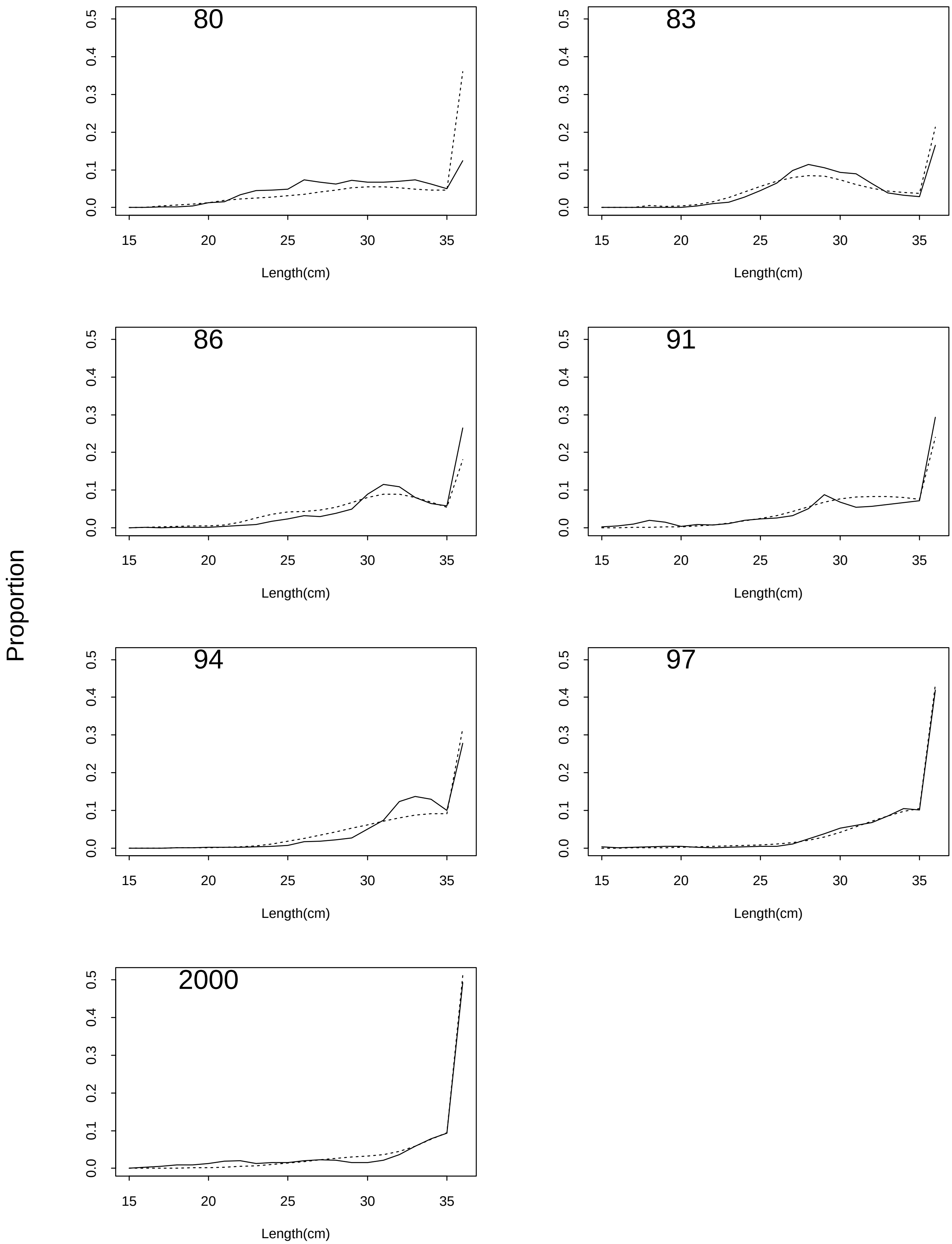
AI Fishery length composition by year (solid line = observed,
dotted line = predicted)



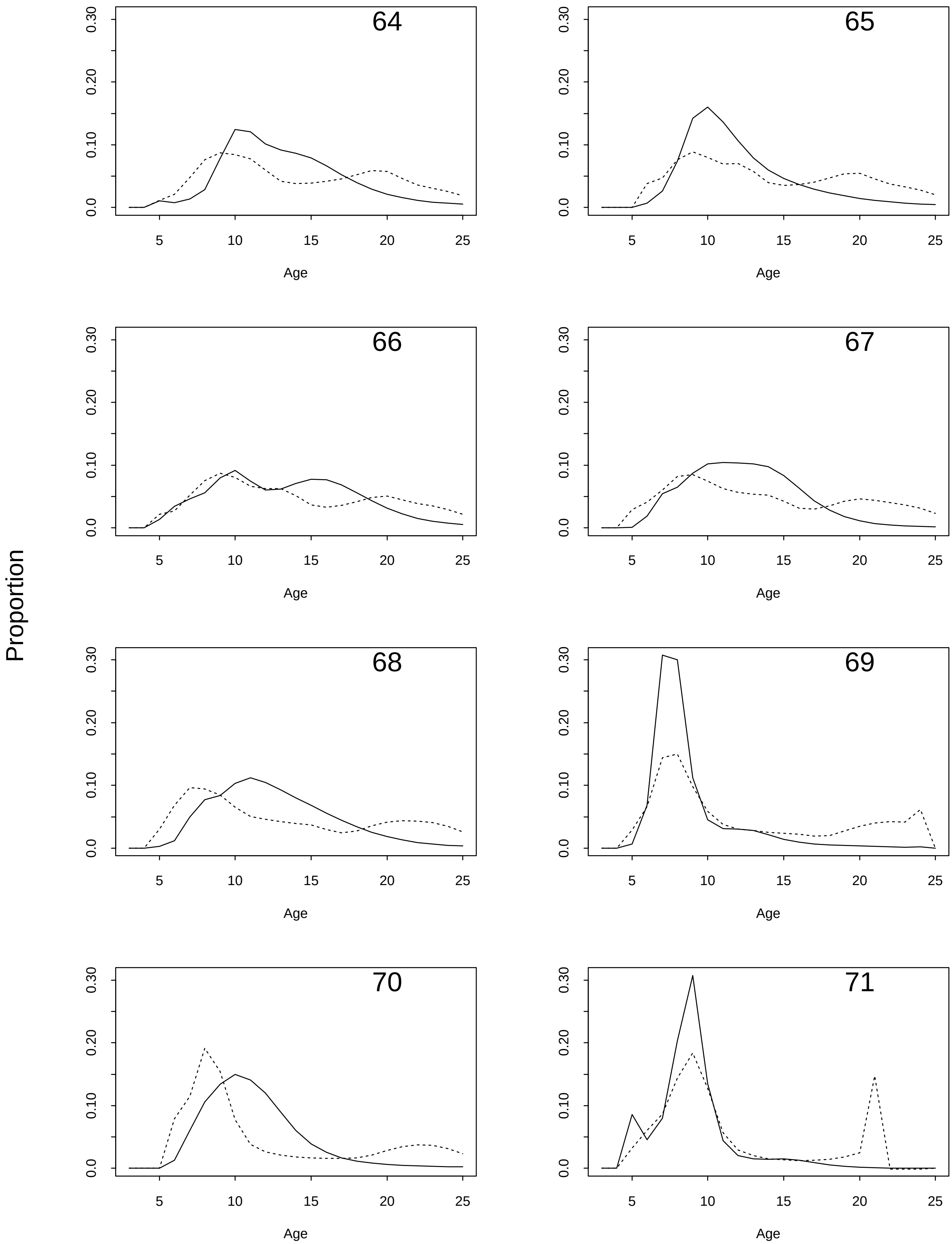
AI Fishery length composition by year (solid line = observed, dotted line = predicted)



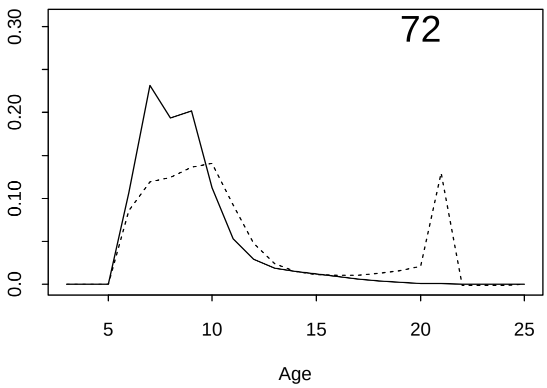
AI Fishery length composition by year (solid line = observed, dotted line = predicted)



AI Survey length composition by year (solid line = observed,
dotted line = predicted)

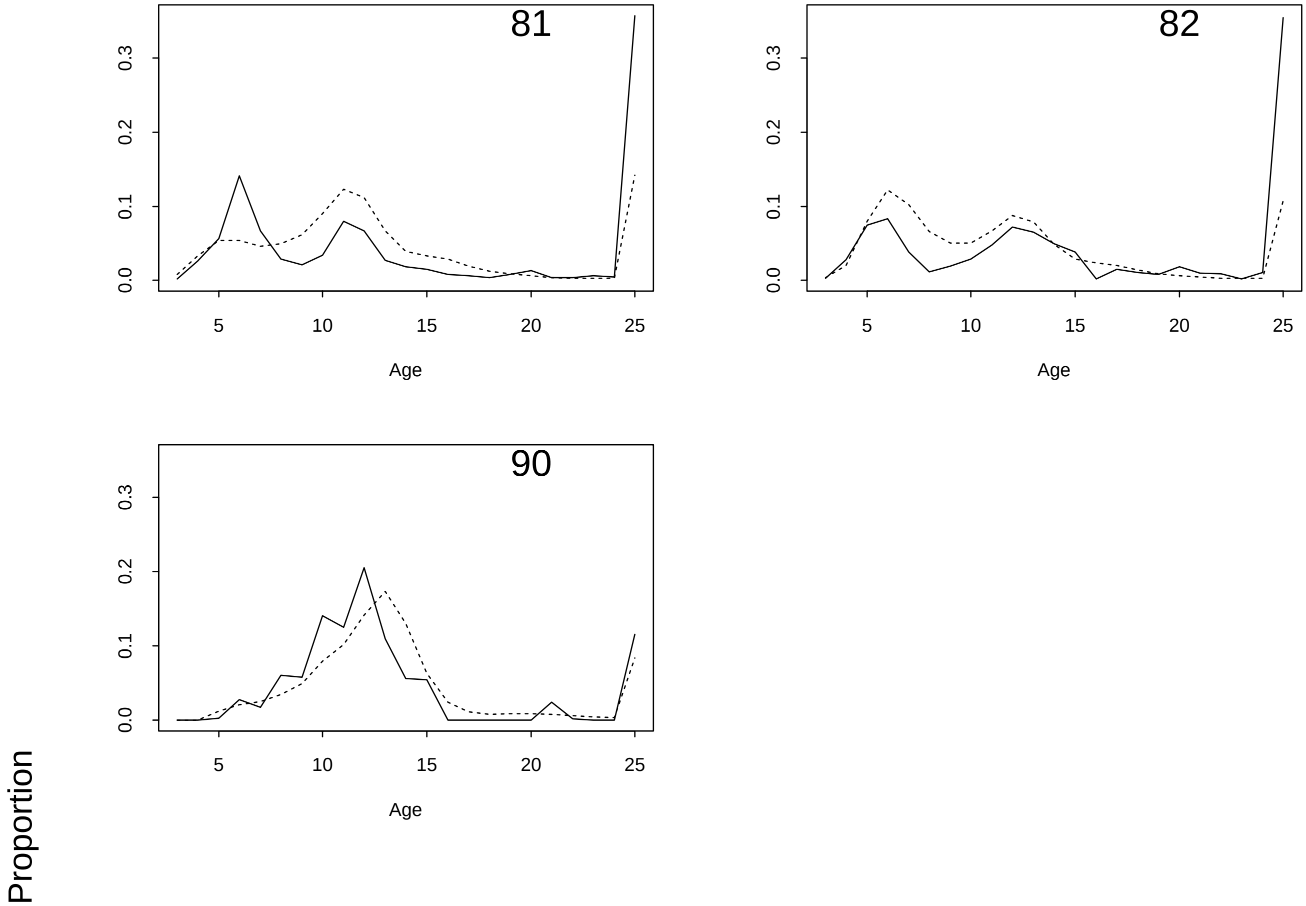


EBS Fishery age (biased) composition by year (solid line = observed, dotted line = predicted)

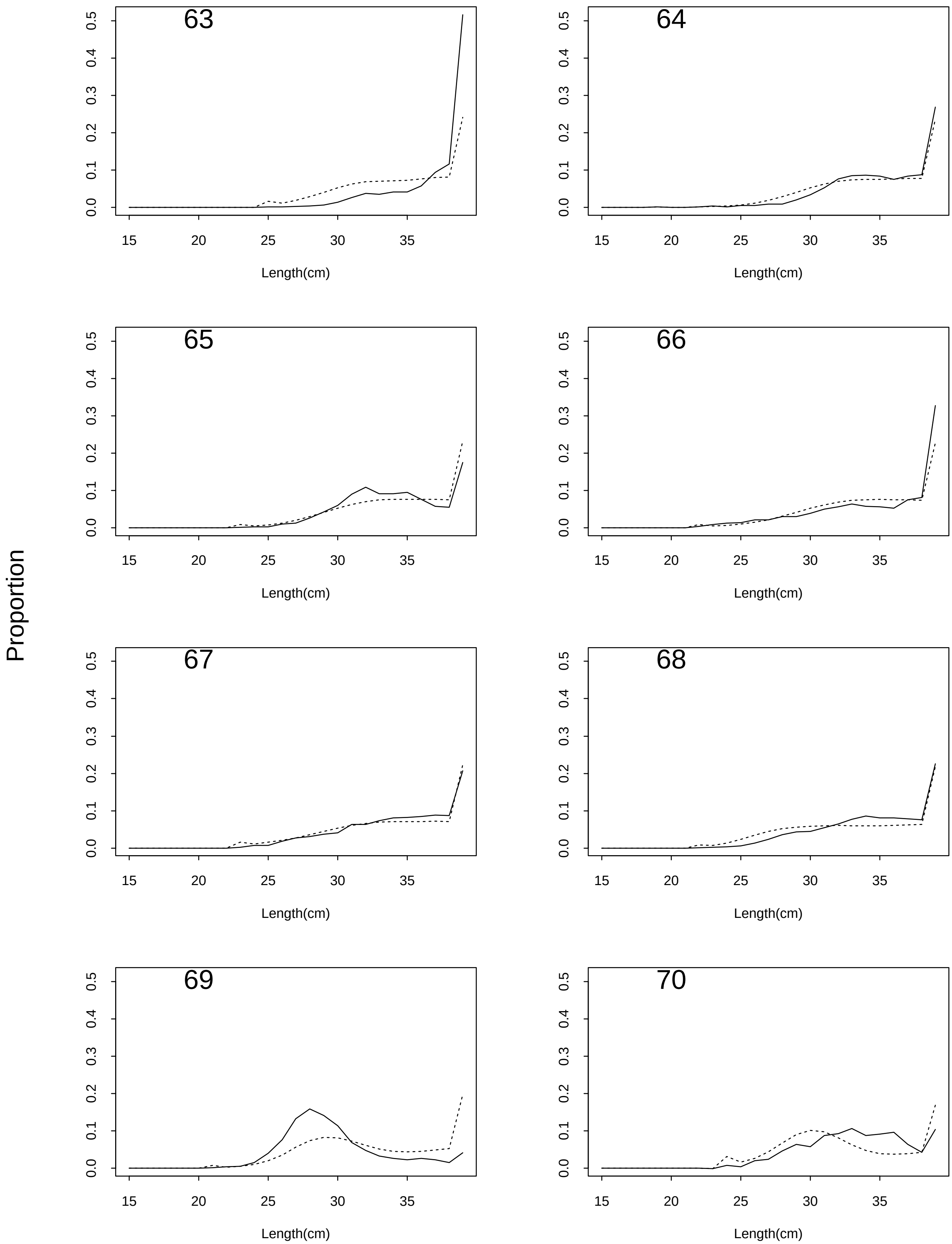


Proportion

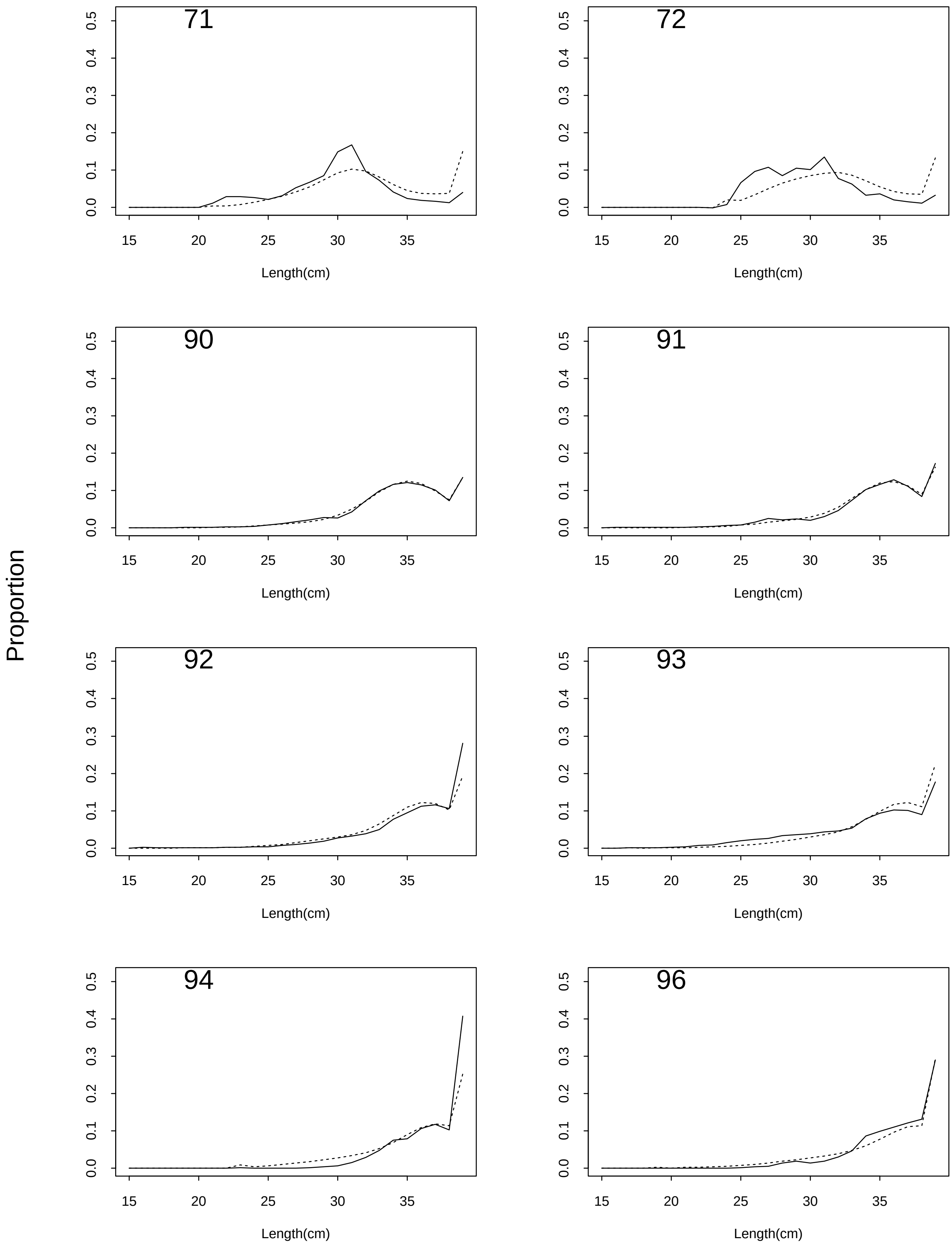
EBS Fishery age (biased) composition by year (solid line = observed, dotted line = predicted)



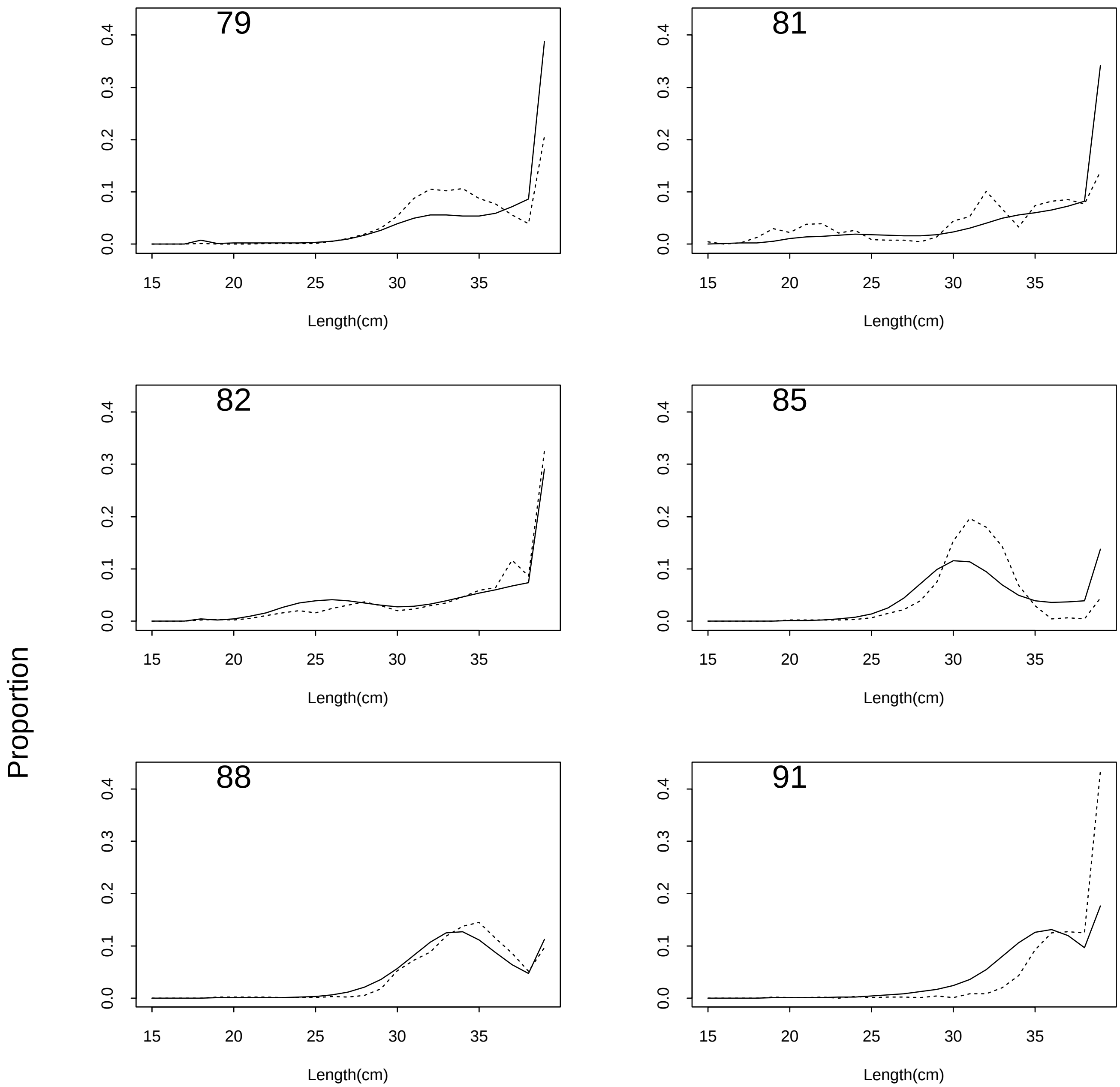
EBS Fishery age (unbiased) composition by year (solid line = observed, dotted line = predicted)



EBS Fishery length composition by year (solid line = observed,
dotted line = predicted)



EBS Fishery length composition by year (solid line = observed,
dotted line = predicted)



EBS Survey length composition by year (solid line = observed, dotted line = predicted)