Section 12

# ASSESSMENT OF BERING SEA/ALEUTIAN ISLANDS ATKA MACKEREL

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## EXECUTIVE SUMMARY

### Summary of Major Changes

Relative to the November 1998 SAFE report, the following substantive changes have been made in the current draft of the **Atka** mackerel chapter:

Changes in the Input Data
1) The 1999 TAC was used as a proxy for the 1999 catch.

Changes in the Assessment Methodology
1) No substantive changes were made in the assessment model.
2) A stochastic projection model was used to project 2000 biomass and yield **and** to evaluate alternative harvest policies for stocks managed under Tiers 1, 2, or 3 of Amendment 56.

Changes in Assessment Results
1) The mean recruitment from the stochastic projections is 622 million recruits, which gives an estimated $B_{40\%}$ level of 154,300 mt.
2) The projected age 3+ biomass at the beginning of 2000 is estimated at 565,150 mt.
3) The projected female spawning biomass for 2000 is estimated at 162,500 mt.
4) The projected 2000 yields at $F_{40\%}$ and $F_{ABC}$ are 102,700 and 78,500 mt, respectively.
5) **The 2000 recommended ABC is 78,500 mt** corresponding to $F$ = 0.26.
6) The projected 2000 overfishing level at $F_{35\%}$ is 119,300 mt.

### Response to comments by the Scientific and Statistical Committee (SSC)

There were no SSC comments pertaining to the BSAI Atka mackerel assessment from the December 1998 or October 1999 SSC minutes.

## 12.1 INTRODUCTION

Atka mackerel (*Pleurogrammus monopterygius*) are distributed from the east coast of the Kamchatka peninsula, throughout the Komandorskiye and Aleutian Islands, north *to* the Pribilof Islands in the *eastern* Bering Sea, and eastward through the Gulf of Alaska to southeast Alaska. Their center of abundance according to past surveys has been in the Aleutian Islands, particularly from Buldir Island to Seguam Pass (Figure 12. 1).

Atka mackerel are pelagic during much of the year, but migrate annually from the lower edge of the shelf to the shallow coastal waters where they become demersal during spawning (Morris et al. 1983). While spawning, they are distributed in dense aggregations near the bottom. Spawning is reported to peak from June through September in eastern Kamchatkan waters (Musienko 1970; Morris 198 l), and from July to October in Alaskan waters (McDermott and Lowe 1997). Atka mackerel are reported to deposit their eggs in rock crevices or among stones, guarded by brightly colored males until hatching (Gorbunova 1962; Zolotov 1993). The adhesive eggs hatch in 40-45 days (Musienko 1970), releasing planktonic larvae which have been found up to 800 lan from shore. The first in situ observations of spawning habitat in Seguam Pass were recently (August, 1999) documented (Pers. comm. Harold Zenger, AFSC). Nest-guarding males and spawning females were observed. Little is known of the life history of young Atka mackerel prior to their appearance in trawl surveys and the fishery at about age 2-3 years. Adult Atka mackerel in the Aleutians consume a variety of prey, but principally calanoid copepods and euphausiids, and are consumed by a variety of piscivores, including groundfish (e.g., Pacific cod and arrowtooth flounder, Livingston et al. unpubl. manuscr.), marine mammals (e.g., northern fur seals and Steller sea lions, Kajimura 1984, NMFS 1995), andseabirds (e.g., tufted puffins, Byrd et al. 1992).

A morphological and meristic study suggested that there may be separate populations in the Gulf of Alaska and the Aleutian Islands (Levada 1979). This study was based on comparisons ofsamples collected off Kodiak Island in the central Gulf, and the Rat Islands in the Aleutians. Lee (1985) also conducted a morphological study of Atka mackerel from the Bering Sea, Aleutian Islands and Gulf of Alaska. The data showed some differences (although not consistent by area for each characteristic analyzed), suggesting a certain degree of reproductive isolation. However, results from a genetics study comparing Atka mackerel samples from the western Gulf of Alaska with samples from the eastern, central, and western Aleutian Islands showed no evidence of discrete stocks (Lowe et al. 1998). Between-sample variation was extremely low among the four samples indicating that a large amount of gene flow is occurring throughout the range. It is presumed that gene flow is occurring during the larval, pelagic stage, and that the localized aggregations reflect the distribution of surviving, settled larvae and juveniles. Differences in growth rates consistently observed throughout their Alaskan range are phenotypic characteristics reflecting differences in the local environment.

While genetic information suggests that the Aleutian Island (AI) and Gulf of Alaska (GOA) populations of Atka mackerel could be managed as a unit stock, there are significant differences in population size, distribution, recruitment patterns, and resilience to fishing that suggest otherwise. Bottom trawl surveys and fishery data suggest that the Atka mackerel population in the GOA is smaller and much more patchily distributed than that in the Al, and composed almost entirely of fish > 30 cm in length. There are also more areas of moderate Atka mackerel density in the AI than in the GOA. The lack of small fish in the GOA suggests that Atka mackerel recruit to that region differently than in the AI, perhaps as juveniles moving east from the larger population in the Al rather than from larval settlement in the area. This might also explain the greater sensitivity to fishing depletion in the GOA as reflected by the history of the GOA fishery since the early 1970s. Catches of Atka mackerel from the GOA peaked in 1975 at about 27,000 mt. Recruitment to the AI population was low from 1980-1985, and catches in the GOA declined to 0 in 1986. Only after a series of large year classes recruited to the AI region in the late 1980s, did the population and fishery reestablish in the GOA beginning in the early 1990s. After passage of these year classes through the population, the GOA population, as sampled in the 1996 and 1999 GOA bottom trawl surveys, has declined and is very patchy in its distribution. These differences in population resilience, size, distribution, and recruitment argue for separate assessments and management of the GOA and AI stocks despite their genetic similarities.

## 12.2 FISHERY

### 12.2.1 Catch History

Annual catches of Atka mackerel in the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions increased during the 1970s reaching an initial peak of over 24,000 mt in 1978 (see SAFE Table 3). Atka mackerel became a reported species group in the BSAI Fishery Management Plan in 1978. Catches (including discards) by region and corresponding Total Allowable Catches (TAC) set by the North Pacific Fishery Management Council (Council) from 1978 to the present are given in Table 12.1. This year, scientific research catches are reported in the SAFE reports. Table 12.2 documents annual research catches ( 1977 - 1998) from NMFS trawl surveys.

From 1970-1979, Atkamackerel were landed off Alaska exclusively by the distant water fleets of the U.S.S.R., Japan and the Republic of Korea. U.S. joint venture fisheries began in 1980 and dominated the landings of Atka mackerel from 1982 through 1988. The last joint venture allocation of Atka mackerel off Alaska was in 1989, and since 1990, all Atka mackerel landings have been made by U.S. fishermen. Total landings declined from 1980- 1983 primarily due to changes in target species and allocations to various nations rather than changes in stock abundance. From 1985- 1987, Atka mackerel catches were some of the highest on record, averaging 34,000 mt annually. Beginning in 1992, TACs increased steadily in response to evidence of a large exploitable biomass, particularly in the central and western Aleutian Islands.

### 12.2.2 Description of the Directed Fishery

The patterns of the Atka mackerel fishery generally reflect the behavior of the species: ( 1) the fishery is highly localized and usually occurs in the same few locations each year; (2) the schooling semi-pelagic nature of the species makes it particularly susceptible to trawl gear fished on the bottom; and (3) trawling *occurs* almost exclusively at depths less than 200 m. In the early 1970s, most Atka mackerel catches were made in the western Aleutian Islands (west of 180°W longitude). In the late 1970s and through the 1980s, fishing effort moved eastward, with the majority of landings occurring near Seguam and Amlia Islands. In 1984 and 1985 the majority of landings came from a single 1/2° latitude by 1° longitude block bounded by 52°30'N, 53°N, 172°W, and 173°W in Seguam Pass (73% in 1984, 52% in 1985). Areas fished by the Atkamackerel fishery from 1977 to 1992 are displayed in Fritz (1993). Areas utilized by the 1998 and 1999 fisheries are shown in Figures 12.2a and 12.2.b.

### 12.2.3 Management History

In 1993, an initial Atka mackerel TAC of 32,000 mt was caught by March 11, almost entirely south of Seguam Island (Seguam Bank). This initial TAC release represented the amount of Atka mackerel which the Council thought could be appropriately harvested in the eastern portion of the Aleutian Islands subarea (based on the assessment for 1993 ; Lowe 1992) since there was no mechanism in place at the time to spatially allocate TACs in the Aleutians to minimize the likelihood of localized depletions. In mid- 1993, however, Amendment 28 to the Bering Sea/Aleutian Islands Fishery Management Plan became effective, dividing the Aleutian subarea into three districts at 177°W and 177°E longitudes for the purposes of spatially apportioning TACs (Figure 12.2). On August 11, 1993, an additional 32,000 mt of Atka mackerel TAC was released to the Central (27,000 mt) and Western (5,000 mt) districts. The fishery in the Central area (542) was closed on October 29, 1993 after harvest levels reached 26,560 mt. Only 2,285 mt were landed in the Western area (543) in all of 1993; annual landings for 1993 in the eastern area (541) and the EBS totaled 36,892 mt. Since 1994, the BSAI Atka mackerel TAC has been allocated to the three regions based on the average of the two most recent Aleutian Island bottom trawl surveys.

In June 1998, the Council passed a fishery regulatory amendment which proposed a four-year timetable to temporally and spatially disperse and reduce the level of Atka mackerel fishing within Steller sea lion critical habitat in the Bering Sea/Aleutian Islands. The temporal dispersion is accomplished by dividing the BSAI Atka mackerel TAC into two equal seasonal allowances. The first allowance is made available for directed fishing from January 1 to April 15 (A season), and the second seasonal allowance is made available from September 1 to November 1 (B season). The spatial dispersion is accomplished through maximum catch percentages of each seasonal allowance that can be caught within sea lion critical habitat (CH) as specified for the Central and Western Aleutian Islands. No critical habitat closures are established for the Eastern subarea, but the 20 nm trawl exclusion zones around Seguam and Agligadak rookeries that have been in place only for the pollock A-season, are in effect year-round. These regulations implementing these management changes became effective January 22, 1999. The four-year timetable for spatial dispersion outside of critical habitat is:

## Aleutian Island District

| | Area 541 | | Area 542 | | Area 543 | |
|---|---|---|---|---|---|---|
| *Year(s)* | *Inside CH* | *Outside CH* | *Inside CH* | *Outside CH* | *Inside CH* | *Outside CH* |
| 1999 | | | 80% | 20% | 65% | 35% |
| 2000 | | | 67% | 33% | 57% | 43% |
| 200 1 | | | 54% | 46% | 49% | 51% |
| 2002 | | | 40% | 60% | 40% | 60% |

The seasonal and spatial apportionments (including the CDQ reserve) of the 1999 BSAI Atka mackerel TAC were:

| 1999 Atka Mackerel Temporal-Spatial Quotas | | | | A Season | | B Season | |
|---|---|---|---|---|---|---|---|
| | TAC | CDQ Reserve | ITAC | Total | CH Limit | Total | CH Limit |
| Western (543) | 27,000 | 2,025 | 24,975 | 12,487 | 8,117 | 12,487 | 8,117 |
| Central (542) | 22,400 | 1,680 | 20,720 | 10,360 | 8,288 | 10,360 | 8,228 |
| Eastern (541) | 17,000 | 1,275 | 15,725<br>15,568[1] | 7,784 | ------- | 7,784 | ------ |
| Total | 66,400 | 4,980 | 61,420 | 30,631 | - - - | 30,631 | ------- |

1/ Up to 2% of the Eastern Al ITAC may be allocated to the jig gear fleet. The Council allocated 1% (157 mt) for 1999. The remaining ITAC is 15,568 mt which is apportioned by season; the jig gear allocation is not apportioned by season.

Preliminary estimated catches from inside critical habitat (CH) from the 1999 fishery were calculated by applying the actual observed catch percentage taken inside CH, to the total blend data catches for each management area. These catches (summarized below; all catches in mt) indicate that, except for the A-season within 542, the fishery fished more outside of critical habitat (CH) than it was required to do. For instance, in the 542 B-season, the fishery could have taken 8,288 mt of Atka mackerel from inside CH, but only took 2,190 mt. The preliminary estimate of the percentage removals from within CH in 1999, 52%, is the lowest since 1992-93.

Preliminary Temporal and Spatial Distribution of 1999 Atka mackerel fishery catches

| **A-season** Area | Total Catch | Estimated Catch Inside CH | % Inside | CH Limit | Difference |
|---|---|---|---|---|---|
| 541&EBS | 7,923 | 2,307 | 29% | - | |
| 542 | 11,660 | 8,965 | 77% | 8,288 | 677 |
| 543 | 5.614 | 4.396 | 78% | 8.117 | (3.72 1) |
| **B-season** Area | | | | | |
| 541&EBS | 7.967 | 2,658 | 33% | ▪ | |
| 542 | 9,797 | 2,190 | 22% | 8,288 | (6,098) |
| 543* | 4.902 | =4.013 | 82% | 8,117 | (4.104) |
| **CDQ** Area | | | | Quota | |
| 541&EBS* | 962 | 639 | | 1,275 | |
| 542* | 821 | 821 | | 1,680 | |
| 543* | 600 | 48 | | 2,025 | |
| **TOTAL** Area | | | | | |
| 541&EBS* | 16,852 | 5,604 | 33% | | |
| 542* | 22,278 | 11,976 | 54% | | |
| 543* | 11,116 | 8,457 | 76% | | |
| **ALL*** | **50.246** | **26.036** | **52%** | | |

* Incomplete data for this time/area cell because the TAC (quota) had not been reached.

12.2.4 Fishing Seasons. 1994-present

**The TACs and** catches by area, and dates when the directed fishery was open in each region are listed in the table below. For 1998 and later, the Community Development Quota (CDQ) catches are Listed separately. The CDQ TAC is 7.5% of the T'AC.

| | | Aleutian Subarea | | | Total |
|---|---|---|---|---|---|
| **Year** | | **541 & EBS** | 542 | 543 | |
| | TAC (mt) | 13,475 | 44,525 | 10,000 | 68,000 |
| 1994 | Catch (mt) | 15,433 | 41,004 | 8,923 | 65,360 |
| | Dates Open | l/20-2/13 | 1/20-6/7;7/4-7/28 | l/20-6/30 | |
| | TAC (mt) | 13,500 | 50,000 | 16,500 | 80,000 |
| 1995 | Catch (mt) | 14,200 | 50,387 | 16,967 | 81,554 |
| | Dates Open | 1/20-2/2 | l/20-4/25; 7/1-7/17 | 1/20-5/15 | |
| | TAC (mt) | 26,700 = | 33,600 | 45,857 | 106,157 |
| 1996 | Catch (mt) | 28,173 | 33,524 | 42,246 | 103,943 |
| | Dates Open | 1/20-2/14; 7/2-7; 8/1- | l/20-4/14; 7/2-12; 8/1-4 | 1/20-9/7# | |
| | TAC (mt) | 15,000 | 19,500 | 32,200 | 66,700 |
| 1997 | Catch (mt) | 16,318 | 19,990 | 29,537 | 65,845 |
| | Dates Open | 1/20-2/4 | 1/20-3/15 | 1/20-4/20& | |
| | ITAC* | 13,783 | 20,720 | 24,975 | 59,478 |
| | Catch (mt) | 11,685 | 20,028 | 24,248 | 55,961 |
| 1998 | Dates Open | 1/20-2/2, 1 1/18-11/19 | 1/20-3/31 | 1/20-11/4 | |
| | CDQ catch | 666 | 181 | 369 | 1,216 |
| | ITAC* | 15,725 | 20,720 | 24,975 | 61,420 |
| | Catch** | 15,890 | 21,457 | 10,516 | 47,863 |
| 1999 | Dates Open | l/20-1/29; 9/1-9/7 | 1/20-3/1, 3/7-4/5; 9/1- | 1/20-4/15,9/1- | |
| | CDQ catch* * | 962 | 821 | 600 | 2,383 |

* Initial TAC in 1998 and 1999 is for the open-access fishery only; (7.5% of actual TAC is allocated to the CDQ fishery).

** 1999 open access catch as of 10/14/99 from NMFS Alaska Region Home Page; Allocations by season are given above. 1999 CDQ catch as of 10/21/99 from NMFS Alaska Region Home Page.

\# In 1996, area 543 was closed to trawling on 9/7 to prevent further retention of sharpchin and northern rockfish, catches of which had exceeded the Aleutian-wide overfishing level.

& In 1997, area 543 was closed to trawling on 4/20 to prevent further retention of shortraker and rougheye rockfish, catches of which were near the Aleutian-wide overfishing level.

12.2.5 Bycatch and Discards

Atka mackerel are not commonly caught as bycatch in other directed fisheries. The largest amounts of discards of Atka mackerel, which are likely under-size fish, occur in the directed Atka mackerel trawl fisheries. Atka mackerel are also caught as bycatch in the trawl Pacific cod and rockfish fisheries. The directed Atka mackerel fishery has had low bycatch rates of rockfish (1-5% of the total Atka mackerel catch) and slightly higher bycatch rates of cod (3-15%).

Discard data have been available for the groundfish fishery since 1990. Total discards of Atka mackerel were calculated for 1990-98 by applying the observed discard rate (Atka mackerel discarded per ton of retained target species catch) by each target species fishery and gear, and within each subarea to the blend target species catches. These figures were summed with blend data for retained Atka mackerel for all fisheries yielding estimates of the amounts of Atka mackerel discarded and retained for each fishery (see below; values differ slightly from those above due to differences in data sets employed):

| Year | Fishery | Discarded (mt) | Retained (mt) | Total (mt) | Discard Rate (%) |
|---|---|---|---|---|---|
| 1990 | Atka mackerel | 2,247 | 18,900 | 21,147 | 10.6 |
| | All others | 1,354 | 1,399 | 2,753 | |
| | All | 3,601 | 20,299 | 23,900 | |
| 1991 | Atka mackerel | 3,693 | 23,060 | 25,753 | 14.3 |
| | All others | 2,099 | 428 | 2,527 | |
| | All | 4,792 | 23,487 | 28,280 | |
| 1992 | Atka mackerel | 7,326 | 37,972 | 45,208 | 16.2 |
| | All others | 3,595 | 2,352 | 5,947 | |
| | All | 10,831 | 40,324 | 51,155 | |
| 1993 | Atka mackerel | 12,517 | 48,164 | 60,682 | 20.6 |
| | All others | 4,184 | 2,084 | 6,268 | |
| | All | 16,702 | 50,248 | 66,950 | |
| 1994 | Atka mackerel | 9,597 | 58,224 | 67,821 | 14.1 |
| | All others | 754 | 1,016 | 1,770 | |
| | All | 10,351 | 59,240 | 69,590 | |
| 1995 | Atka mackerel | 13,669 | 66,153 | 79,823 | 17.1 |
| | All others | 1,230 | 501 | 1,731 | |
| | All | 14,899 | 66,654 | 8 1,554 | |
| 1996 | Atka mackerel | 15,441 | 86,225 | 101,666 | 15.2 |
| | All others | 2,050 | 1,813 | 3,863 | |
| | All | 17,491 | 88,038 | 105,529 | |
| 1997 | Atka mackerel | 5,829 | 57,850 | 63,680 | 9.1 |
| | All others | 752 | 1,410 | 2,162 | |
| | All | 6,582 | 59,260 | 65,842 | |
| 1998" | Atka mackerel | 4,597 | 50,380 | 54,977 | 8.4 |
| | All others | 1,072 | 1,047 | 2,119 | |
| | All | 5,669 | 5 1,427 | 57,096 | |

* 1998 data includes CDQ catch

The discard rate of Atka mackerel by the directed fishery increased from 11% in 1990 and 199 1 to 2 1% in 1993. Reasons for this increase are not known, but may be related to larger than expected catches of small Atka mackerel in 1992 and 1993. Small Atka mackerel were also encountered in large numbers in 1995. Some of the recent increase in small Atka mackerel catches and discards may be due to the spatial allocation of the TAC among the three Aleutian subareas. Growth rates are slower in the western and central Aleutian districts than in the east, where most of the catch was taken prior to 1993. Increases in amounts of Atka mackerel discarded by other fisheries through 1993 (primarily trawl fisheries for Pacific cod and rockfish) may be related to earlier closures of the directed Atka mackerel fisheries in 199 l-93 than in 1990 as well as greater numbers of small Atka mackerel encountered. In 1998, the directed Atka mackerel fishery had the lowest observed discard rate (8.4%) since data collection began.

Discard rates of Atka mackerel by the target fishery have generally been greatest in the western AI (543) and lowest in the east (541), except for 1998:

| | Aleutian Islands Subarea | | |
|---|---|---|---|
| | 541 | 542 | 543 |
| 1994 | | | |
| Retained (mt) | 13,165 | 36,949 | 8,082 |
| Discarded (mt) | 1,709 | 5,909 | 1,959 |
| Rate | 11% | 14% | 19% |
| 1995 | | | |
| Retained (mt) | 11,791 | 40,832 | 13,530 |
| Discarded (mt) | 1,371 | 9,005 | 3,294 |
| Rate | 10% | 18% | 20% |
| 1996 | | | |
| Retained (mt) | 22,685 | 28,096 | 34,055 |
| Discarded (mt) | 3,919 | 4,910 | 6,525 |
| Rate | 15% | 15% | 16% |
| 1997 | | | |
| Retained (mt) | 14,528 | 18,060 | 25,262 |
| Discarded (mt) | 969 | 1,562 | 3,298 |
| Rate | 6% | 8% | 12% |
| 1998 | | | |
| Retained (mt) | 9,385 | 17,311 | 23,488 |
| Discarded (mt) | 1,287 | 2,593 | 705 |
| Rate | 12% | 13% | 3% |

### 12.2.5 Fisher-v Length Frequencies

From 1977 to 1988, commercial catches were sampled for length and age structures by the NMFS foreign fisheries observer program. There was no JV allocation of Atka mackerel in 1989, when the fishery became fully domestic. Since the domestic observer program was not in full operation until 1990, there was Little opportunity to collect age and length data in 1989. Also, the 1980 and 198 1 foreign observer samples were small, so these data were supplemented with length samples taken by R.O.K. fisheries personnel from their commercial landings. Data from the foreign fisheries show an increase in the size of fish in the commercial fishery reflecting the recruitment of the 1977 and 1984 year classes to the fishery (Lowe and Fritz 1995).

Atka mackerel length distributions from the domestic 1996-98 fisheries by location and management area are shown in Figures 12.3-12.6; 1996 data include lengths collected in the western Gulf of Alaska and in the southern Bering Sea for comparison (see Figures 12.2a and 12.2b for locations fished). The differences in modal length from west to east could be due partially to differences in the mix of year classes composing the mode, but also results from continued faster growth rates after maturity in the east than the west. The 1996 length-frequency data collected in the Aleutian Islands management areas 54 l-543 (Tahoma-Buldir to Seguam in Figure 12.3; also Figure 12.6a) exhibits two modes. The smaller mode is principally composed of 4-year-old fish from the 1992 year class which were all approximately the same size throughout the Aleutian Islands. The larger mode is a mixture of older year-classes, but is composed principally of the dominant 1988 year class. In 1997, length-frequencies at each fished location (Figure 12.4) and in each management area (Figure 12.6b) were predominantly unimodal; the 1992 year class dominated at each location. In 1998, length-frequencies of Atka mackerel caught by the fishery in areas west of 180” from Attu to Amchitka Islands (top 4 panels in Figure 12.5) were similar. Each length-frequency plot was dominated by a single mode centered at approximately 38 cm. To the east, there were relatively more smaller fish (mode centered at 30 cm) caught at Seguam Bank than at any other location. The presence of the modes between 28-30 cm suggests that the magnitude of the 1995 year class of Atka mackerel may be above average.

Length frequency distributions from the 1999 fishery by area fished are shown in Figure 12.7. The 1998 (Figure 12.5) and 1999 distributions from area 543 are nearly identical ranging from about 32 to 42 cm with a mode at about 38 cm. In the 1998 541 length distribution (Figures 12.5 and 12.6c), there was a mode of small fish centered around 30 cm representing the 1995 year class (3 year-olds) and another mode centered at 42 cm of older fish. The mode centered around 37 cm in the January/May 1999 54 1 distribution is primarily 4 year-old fish from the 1995 year class. By September, this mode was centered at 41 cm and the bimodal distribution had disappeared. This series of length-frequency distributions may reflect recruitment of the 1995 year class which showed up strongly in area 541 in 1998 and 1999 (Figures 12.5 and 12.6c).

The 1998 and 1999 distributions from 542 ranged from about 30 to 45 cm, however, the 1999 distribution showed a greater proportion of fish less than 37 cm (Figure 12.7). Small fish were caught at Petrel Bank during the A-season (February and March). The 1999 A season length frequency distribution from Petrel Bank is notably different from the 1996 fishery at this location (Figure 12.3). In 1996, the range in lengths was from about 30 to 44 cm, with a mode at 40 cm, and was similar to the distributions from Amchitka and the Delarofs, also within 542 (Figure 12.3). The 1999 A-season distribution from Petrel Bank ranged from about 25 to 40 cm, with a mode at 33 cm; few fish larger than 37 cm were caught at Petrel Bank (Figure 12.7). Fish 33 cm in length from 542 are likely 4 year-old fish of the 1995 year class. This year class was also noted in area 54 1 in both 1998 and 1999. The data are too preliminary to judge the strength of the 1995 year class, but it does seem to show uneven recruitment or perhaps an east to west cline in recruitment in the Aleutians. Slightly larger fish (mode of 35-36 cm) were caught at Petrel Bank during the B-season (September; Figure 12.7).

### 12.2.6 Steller Sea Lions. Atka mackerel. and the Fisherv

The western stock of Steller sea lions (defined as west of 144°W at Cape Suckling) is currently listed as endangered under the Endangered Species Act, and had been listed as threatened since 1990. In 199 l-92, 10 nm year-round trawl exclusion zones were established around all rookeries west of 150°W; in 1992-93, 20 nm trawl exclusion zones were established around 6 rookeries in the eastern Aleutian Islands that are operational only during the BSAI pollock A-season. Two of the 20 nm zones are located within the Aleutian 541 management district, those around Seguam and Agligadak Islands (Figure 12.2). In 1993, NMFS designated

Steller sea lion critical habitat, which includes a 20 nm aquatic zone around all rookeries and major haulouts west of 144°W, and three foraging areas, one of which is located around Seguam Pass. Sea lion food habits data collected in the Aleutian Islands revealed that Atka mackerel was the most common food item of adults and juveniles in summer (NMFS 1995) and winter (Beth Sinclair, pers. comm., AFSC, National Marine Mammal Laboratory).

Since 1979, the Atka mackerel fishery has occurred largely within areas designated as Steller sea lion critical habitat. While total removals from critical habitat may be small in relation to estimates of total Atka mackerel biomass in the Aleutian region, fishery harvest rates in localized areas may have been high enough to affect prey availability of Steller sea lions (Section 12.2.2 of Lowe and Fritz 1997). The localized pattern of fishing for Atka mackerel apparently does not affect fishing success from one year to the next since local populations in the Aleutian Islands appear to be replenished by immigration and recruitment. However, this pattern could create temporary reductions in the size and density of localized Atka mackerel populations which could affect Steller sea lion foraging success during the time the fishery is operating and for a period of unknown duration after the fishery is closed.

To address the possibility that the fishery creates localized depletions of Atka mackerel and adversely modifies Steller sea lion critical habitat by disproportionately removing prey, the Council passed the fishery management regulatory amendment described in Section 12.2.3 in June 1998. As a result of this NMFS/Council action, the U.S. District Court, Western District agreed with NMFS' conclusion that the Atka mackerel fishery, as modified by this regulatory amendment, was not likely to jeopardize the continued existence of the Steller sea lion nor adversely modify its critical habitat.

NMFS is investigating the efficacy of trawl exclusion zones as a fishery-Steller sea lion management tool. In August 1999, the AFSC conducted a pilot survey to explore the variance in survey catches of Atka mackerel and the feasibility of tagging as methods to determine small-scale changes in abundance and distribution (Appendix 1). This work was conducted in anticipation of paired surveys before and after the fishery to detect differences in distribution and abundance of Atka mackerel.

## 12.3 DATA

### 12.3.1 Fishery Data

Fishery data consist of total catch biomass from 1977 to 1998 and the 1999 TAC (Table 12. I), and the age composition of the catch from 1977-1998 (Table 12.3). Catch-at-age (in numbers) was estimated using the length frequencies described above and age-length keys. The formulas used are described by Kimura (1989). As with the length frequencies, the age data for 1980-198 1, 1989, 1992-1993, and 1997 presented problems. The commercial catches in 1980 and 198 1 were not sampled for age structures, and there were too few age structures collected in 1992 ,1993, and 1997 to construct age-length keys. Therefore, the 1980 survey age-length key was used to estimate the 1980 commercial catch age distribution, and these data were further used to estimate the 198 1 commercial catch age distribution using a mixture model (Kimura and Chikuni 1987). However, this method did not provide satisfactory results for the more recent (1992 & 1993) catch data. Thus, the 1992, 1993 and 1997 fishery length frequency data were used directly in stock synthesis and fitted simultaneously with the time series of catch-age data. Length frequency data were converted to ages within the model using a transition matrix. The transition matrix for length data was defined from a von Bertalanffy growth function of the form:

$$L_t = L_\infty + (L_1 - L_\infty) * \exp(-K(t - 1))$$

Where $L_\infty$ is the asymptotic length, $L_1$ is the mean size at age 1, and $K$ is the growth parameter. Parameters for this equation were estimated from the 1986, 199 1 and 1994 age-length data collected from the surveys.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bin | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Length (cm) | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bin | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| Length (cm) | 35 | 36 | 37 | 38 | 39 | 40 | 41-45 | 46-50 | 51-55 | 56-64 |

The most salient features of the estimated catch-at-age (Table 12.3) are the strong 1975 and 1977 year classes, and the appearance of a large number of 4-year-olds in 1988, 1992, 1995 and most recently in 1996 representing the 1984, 1988, 1991, and the 1992 year classes, respectively. The 1975 year class appeared strong as 3 and 4-year-olds in 1978 and 1979. It is unclear why this year class did not continue to show up strongly after age 4. The 1977 year class appeared strong through 1987, after entering the fishery as 3-year-olds in 1980. The 1988 fishery was basically supported by the 1984 year class which showed up strongly as 4-year-olds. The length frequency data from the 1988 foreign fishery, correspondingly showed a large drop in the mean length as the 1984 year class appeared in large numbers. This year class did not continue to show up strongly after 1988 in the domestic fisheries. The 1988 year class has persisted in large numbers in the 1992-l 996 commercial catches, and also dominated the catch in the 1994 survey. The 1996-1998 catch data are dominated by the strong 1992 year class (Table 12.3)

It is interesting to note that before 1984, catches consisted of fish less than 7 years old. Since 1984, 7+ year-old fish have made up a significant portion of the catches. It is not known if there has been an increase in the numbers of older fish, or if they were previously unavailable to the fishery.

### 12.3.2 Survey Data

Atka mackerel are a difficult species to survey because: (1) they do not have a swim bladder, making them poor targets for hydroacoustic surveys; (2) they prefer hard, rough and rocky bottom which makes sampling with survey bottom trawl gear difficult; and (3) their schooling behavior and patchy distribution result in survey estimates with large variances. Despite these shortcomings, the U.S.-Japan cooperative trawl surveys conducted in 1980, 1983, 1986, and the 1991, 1994, and 1997 domestic surveys, provide the only direct estimates of population biomass from throughout the Aleutian Islands region. Major concentrations of Atka mackerel located by the surveys are shown in Figure 12.1.

Trawl survey biomass estimates of Atka mackerel varied from 197,529 mt in 1980 to 306,780 mt in 1983, and 544,754 mt in 1986 (Table 12.4). However, the high value for 1986 is not directly comparable to previous estimates. During the 1980 survey no successful sampling occurred in shallow waters (< 100 m) around Kiska and Amchitka Islands, and during the 1983 survey very few shallow water stations were successfully trawled. However, during the 1986 survey, several stations were successfully trawled in waters less than 100 m, and some produced extremely large catches of Atka mackerel. In 1986, the biomass estimate from this one depth interval alone totaled 4 18,000 mt in the Southwest Aleutians (Table 12.3), or 77% of the total biomass of Atka mackerel in the Aleutian Islands. This was a 403,000 mt increase over the 1983 biomass estimate for the same stratum-depth interval. The 1986 biomass estimate is associated with a large coefficient of variation (0.63). Due to differences in areal and depth coverage of the surveys, it is not clear how this biomass estimate compares to earlier years.

The most recent biomass estimate from the 1997 Aleutian Islands bottom trawl survey is 348,007 mt, down about 50% relative to the 1991 and 1994 survey estimates (Table 12.5). The breakdown of the Aleutian biomass estimates by area corresponds to the management districts (541-Eastern, 542-Central, and 543-

Western). Relative to the 1994 survey, the 1997 biomass estimates are down 68% in the Western area, up 122% in the Central area, and down 80% in the Eastern area. The 95% confidence intervals about the mean total 1991, 1994, and 1997 Aleutian biomass estimates are 299,202-1,077,276 and 142,215-1,105,438 mt, and 153,055-542,960 mt, respectively. The coefficient of variation (*CV*) of the 1997 mean Aleutian biomass is 28%, consistent with the *CVs* from the 199 1 and 1994 surveys, as are the *CVs* by area for these three surveys (Table 12.4).

The distribution of biomass in the Western, Central, and Eastern Aleutians, and the southern Bering Sea shifted between each of the 1991, 1994, and 1997 surveys. In both 1991 and 1994, the Western area contributed approximately half of the total estimated Aleutian biomass, but dropped to 32% in 1997. In 1994, 14% of the Aleutian biomass was found in the Central area compared to 45% in 199 1 and up to 56% most recently. The contribution of Eastern area biomass from the 1997 survey (12%) is down relative to 1994 (34%), but consistent with the 199 1 distribution (1 1%). In 1994 for the first time since the initiation of the Aleutian triennial surveys, a significant concentration of biomass was detected in the southern Bering Sea area (93,26 1 mt) and again in 1997 (128,000 mt, Table 12.5). This was attributed to a large catch from a single haul encountered north of Akun Island in 1994 and in 1997. Virtually all (>99%) of the Atka mackerel biomass in the trawl surveys has been encountered in the l-200 m depth strata, however, the proportions in the I- 100 m and 100-200 m strata differ among years. In 199 1 Atka mackerel biomass was about the same in both shallow ( 1- 100 m) and deep ( 10 l-200 m) strata, while in 1994, there was about 4 times as much in the deep than shallow strata. In 1997, 42% of the biomass was found in I-100 m, and 58% in 101-200 m. Reasons for biomass shifts by area and depth from year to year are not known. Areas with large catches of Atka mackerel during the 1994 survey included south of Buldir Island, north of Akun Island, Seguam Pass, southwest of Atka Island, Stalemate Bank and south of Amchitka Island. In the 1997 survey, areas with large catches were located north of Akun Island, southwest of Tanaga Island, west of Rat Island, Buldir Island, and Stalemate Bank.

There is greater confidence in Atka mackerel biomass estimates from bottom trawl surveys of the groundfish community of the Aleutian Islands (AI) than the Gulf of Alaska (GOA). First, the coefficients of variation of the mean Atka mackerel biomass estimates have been considerably smaller from the recent AI surveys than the recent GOA surveys: 0.27, 0.37, and 0.28 from the 199 1, 1994, and 1997 AI surveys, respectively, compared with 0.98, 0.61, 0.99, and 0.40 from the 1990, 1993, 1996, and 1999 GOA surveys. Second, while patchy in its distribution compared to other groundfish species, Atka mackerel have been much more consistently encountered in the Al than the GOA surveys, appearing in 4 1% , 33%, and 23% of the hauls in the 199 1, 1994, and 1997 AI surveys, compared to 5%, 28%, 12%, and 20% of the hauls in the Shumagin area in the 1990, 1993, 1996 and 1999 GOA surveys, respectively. For these reasons we utilize bottom trawl surveys to assess the relative abundance of Atka mackerel in the Aleutian Islands, but do not consider the highly variable estimates of biomass from the GOA surveys useful for tracking abundance trends.

<u>Survey Length Frequencies</u>

Both the 1994 and 1997 bottom trawl surveys revealed a strong east-west gradient in Atka mackerel size, with the smallest fish in the west and progressively larger fish to the east (Figure 12.8). This pattern is also apparent in the fishery data (Figures 12.3-12.5). In both years, the survey found smaller fish in the Western area than did the fishery, while the size distribution of their catches were more similar in the Central area (Figure 12.8). The 1997 survey found larger Atka mackerel than the fishery in the Eastern area. Differences in the timing and location of survey and fishery catches may account for the observed differences in Atka mackerel sizes encountered in the east. The fishery is currently excluded from Seguam Pass (10 and 20 nm trawl exclusion zones) and fishes almost exclusively southeast of the pass in winter. Recent surveys, conducted in summer, have been unsuccessful in capturing Atka mackerel southeast of the pass in the summer, but have found large fish inside the pass. The difference in timing and distribution of the fishery and survey, and the observed differences in fish size encountered may be related to inshore movements of the reproductive (i.e. larger-sized) fish in summer for spawning. In w-inter, the population moves offshore to deeper waters and appears to be more mixed by size and sex than in summer (Fritz and Lowe, 1998).

Survev Age Frequencies

The age compositions from the 1991, 1994, and 1997 Aleutian surveys are shown in Figure 12.9. In the 1991 survey, the catch was dominated by 3-year-old fish of the 1988 year class. The 1988 year class showed up strongly as 6-year-olds in the 1994 survey catches, and was still evident as 9-year-olds in the 1997 survey catch. The mean age in the 199 1 survey was 3.9 years, the youngest mean age of any survey. The mean ages of the 1994 and 1997 surveys were 5.4 and 4.8 years, respectively.

Atka mackerel are a summer-fall spawning fish that do not appear to lay down an otolith annulus in the first year (Anderl et al., 1996). For stock assessment purposes, one year is added to the number of otolith hyaline zones determined by the Alaska Fisheries Science Center Age and Growth Unit. All age data presented in this report have been corrected in this way.

Survev Abundance Indices

Two time series of survey data are used in the age-structured model: 1) relative indices of abundance with the associated standard errors, and correspondingagecompositionsfiomthe 1980, 1983, 1986, and 1991 Aleutian Islands surveys; and 2) absolute estimates of abundance with the associated standard errors, and corresponding age compositions from the 1986, 199 1, 1994, and 1997 surveys. These data sets were incorporated into the model to calibrate the estimated abundance to the appropriate level. The relative indices of abundance exclude biomass from the I-100 m depth strata of the Southwest region due to the lack of sampling in this strata in some years.

### 12.3.3 Weight at Age Data

Separate weight-at-age vectors were estimated for the fishery and survey data sets (Table 12.6). The survey vector was estimated with 1986,199 1, and 1994 survey data, and the fishery vector was estimated with 1990-1996 fishery data.

## 12.4 ANALYTIC APPROACH

### 12.4.1 Age-Structured Modeling Approach

The stock synthesis model described by Methot (1989, 1990) was used to assess the status of Aleutian Islands Atka mackerel for the first time in 199 1. This approach to catch-at-age analysis was designed to incorporate diverse auxiliary information, and follows the maximum likelihood approach described by Foumier and Archibald (1982). The model is structured to simultaneously analyze catch biomass, age composition and effort from multiple fisheries, and abundance and age composition from multiple surveys (Methot 1990).

A key difference in this type of approach and the least squares approach described by Deriso et al. (1985), is that the model is based on estimates of the total catch and on estimates of the proportion of catch at each age (Foumier and Archibald 1982). Other procedures typically compare the model's estimate of catch at age to the observed catch at age. In stock synthesis, fits to the catch biomass and the catch agecomposition are determined in separate steps (Methot 1990). Separating these steps facilitates incorporation of variability in the age determination process.

Deviations between the observations and the expected values are quantified with a specified error model and cast in terms of log-likelihood. The overall log-likelihood (L) is the weighted sum of the calculated log-likelihoods for each type of data or component. The emphasis factors (the component weights) should all be equal to 1 in a perfectly specified model. These emphasis factors are subjectively adjusted to distinguish those components which may be subject to greater error (i.e. those components in which less confidence is placed). Numerical estimation of tbe derivative of $L$ with respect to small changes in each pararneter is used in an iterative approach to maximization of $L$ (Methot 1990).

The basic equations describing the population dynamics are given below:

| | |
|---|---|
| $a$ | age |
| $Y$ | year |
| $j$ | fishery or survey |
| $M$ | instantaneous natural mortality rate |
| $m_a$ | proportion of mature females at age $a$ |
| $W_{aj}$ | body weight-at-age for fishery or survey $j$ |
| $s_{aj}$ | selectivity at age for fishery or survey $j$ |
| $f_y$ | annual fishing mortality factor |
| $F_{ya} = f_y s_a$ | fishing mortality at age |
| $Z_{ya}=M + \sum_j(F_{ya})$ | total fishing mortality rate |
| $N'_{y+1,a+1}=N_{ya}e^{-Z_{ya}}$ | population numbers at age at the beginning of year y |
| $c_{ya}=[N_{ya}(1-e^{-Z_{ya}})/Z_{ya}]F_{ya}$ | catch in numbers at age for year y |
| $C_{yj} = \sum_a(c_{yaj}W_{aj})$ | catch biomass in year y for fishery or survey $j$ |
| $B_y=N_{ya}\ W_{aj}$ | population biomass in year y |
| $S_y=0.5\sum_a(N_{ya}\ W_{aj}\ m,)$ | female spawner biomass in year y |

### 12.4.2 Model Assumptions

Some of the basic assumptions of the stock synthesis mode1 are: 1) Catch-at-age ($c_{ya}$) is modeled by the Baranov catch equation; 2) Catch biomass is measured with much greater precision than other types of data, thus in stock synthesis, the level of fishing mortality is calculated so that the estimated catch biomass matches the observed catch biomass; and 3) Fishing mortality is separable into a year-dependent factor and an age-dependent factor.

In addition to these basic assumptions, the following assumptions specific to Atka mackerel were used in tbis configuration of stock synthesis: 1) Natural mortality is equal to 0.3 and is constant for all ages and years; *2)* There are 2 time series of survey data. Survey data which exclude the I-100 m depth strata in the Southwest region represent an index of relative abundance, and the absolute estimates of abundance include all data from the 1986, 1991, 1994, and 1997 surveys. 3) Survey catchability associated with estimates of absolute biomass is fixed at 1 .O, and the catchability of the relative index of abundance is estimated within the model. 4) Survey selectivities are estimated from the survey age compositions; and 5) There is 1 fishery which is separated into 2 tune periods. Fishery selectivity-at-age vectors are estimated for two different tune periods, 1972-1983 and 1984-1998. Prior to 1984 the fishery basically consisted of fish *2-7* years old and was harvested by the foreign fishery. The oldest fish during this time period was 9 years old (Table 12.3). After 1983, fish greater than 7 years old appeared in the fishery (maximum of 15 years old from the 1994 fishery), and the fishery was prosecuted by domestic fishermen.

### 12.43 Model Components

The likelihood components and the corresponding emphasis factors used in this analysis are listed below:

| Likelihood component | Emphasis |
|---|---|
| Catch biomass | 1 |
| Catch age composition | 1 |
| Catch length composition | 1 |
| Survey biomass (indices) | 1 |
| Survey age comp. (indices) | 1 |
| Survey biomass (absolute) | 1 |
| Survey age comp. (absolute) | 1 |
| Stock recruitment-individual | 1 |
| Stock recruitment-mean | 1 |

In previous assessments, survey estimates of absolute biomass had a high emphasis ( 10) in order to tune the model to those levels of abundance. In the 1996 assessment, a sensitivity analysis of the absolute survey emphasis factor was conducted which led to the selection of an emphasis of I for absolute survey biomass (Lowe and Fritz 1995). The stock recruitment-individual component relates to the deviations between the individual recruitment estimates and the predicted values from the stock recruitment curve. The stock recruitment-mean component relates to the deviation between the stock recruitment curve parameters and the mean and variance of the individual recruitment estimates. The stock recruitment-mean component ensures that the expected value of the recruitment curve is consistent with the average of the individual recruitment estimates. In previous assessments with a single stock recruitment component, this component was de-emphasized (0.0 1) in order to allow for individual recruitment variability each year. Adding emphasis on the former stock recruitment component was overly restrictive on allowing for individual recruitment variability, e.g., with higher stock recruitment emphasis, recruitment variability approached zero. The stock recruitment mean component allows the underlying model to remain consistent with the average estimated recruitment without sacrificing recruitment variability. Thus, the emphases on the two stock recruitment components are set to 1.

### *12.4.4* Parameters

#### 12.4.4.1 Parameters Estimated Independently

Natural Mortality

Natural mortality $(M)$ is a very difficult parameter to estimate. The regression model of Hoenig (1983) which relates total mortality as a function of maximum age, was used to estimate $M$:

$$\ln(Z) = 1.46 - 1.01(\ln(Tmax)).$$

Where $Z$ is total instantaneous mortality (the sum of natural and fishing mortality, $Z=M+F$), and $Tmax$ is the maximum age. The instantaneous total mortality rate can be considered an upper bound for the natural mortality rate if the fishing mortality rate is minimal. The catch-at-age data showed a 14-year-old fish in the

1990 fishery, and a 15-year-old in the 1994 fishery. Assuming a maximum age of 14 years and Hoenig's regression equation, $Z$ was estimated to be 0.30 (Lowe 1992). Since fishing mortality was relatively low in 1990, natural mortality has been reasonably approximated by a value of 0.30 in this assessment.

An analysis was undertaken to explore alternative methods to estimate natural mortality for Atka mackerel (Lowe and Fritz, 1997). Several methods were employed based on correlations of $M$ with life history parameters including growth parameters (Alverson and Camey 1975, Pauly 1980, Chamov 1993), longevity (Hoenig 1983), and reproductive potential (Roff 1986, Rikhter and Efanov 1976).

Atka mackerel appear to be segregated by size along the Aleutian chain. Thus, natural mortality estimates based on growth parameters would be sensitive to any sampling biases that could result in under- or over-estimation of the von Bertalanffy growth parameters. Fishery data collections are more likely to be biased as the fishery can be more size selective and concentrates harvests in specific areas as opposed to the surveys. Natural mortality estimates derived from fishery data ranged from 0.05 to 1.13 with a mean of 0.53. Natural mortality estimates, excluding those based on fishery data, ranged from 0.12 to 0.74 with a mean value of 0.34. The current assumed value of 0.3 is consistent with these values. Also, a value of 0.3 is consistent with values of A4 derived by the methods of Hoenig (1983) and Rikhter and Efanov (1976) which do not rely on growth parameters (Lowe and Fritz, 1997). Differential mortality at age was explored in last year's assessment (Lowe and Fritz, 1998), and is summarfzed in Section 12-5 Model Evaluation.

Length and Weight at Age

Atka mackerel exhibit large annual and geographic variability in length at age. Because survey data provide the most uniform sampling of the Aleutian Islands region, data from these surveys were used to evaluate variability in growth (Kimura and Ronholt 1988). Length-at-age data from the 1980, 1983, and 1986 U.S.-Japan surveys, and the U.S.-U.S.S.R. surveys in 1982 and 1985 were analyzed by six areas. It appeared that length at age was smallest in the west and largest in the east.

Analysis of variance (ANOVA) was used to evaluate these differences statistically. The analyses indicated that length at age did not differ significantly by sex, so that factor was ignored in further analyses. Results showed that the area and age effects were both significant, but the year effect was not quite significant. The area effect appeared much stronger than the age effect and all interactions were significant.

Further analysis to determine whether the area differences could be expected to remain consistent over the years demonstrated that the differences in growth between areas is probably a real phenomenon rather than just a chance sampling of years.

Kimura and Ronholt (1988) estimated parameters of the von Bertalanffy length-age equation and a weight-length relationship using Aleutian Islands survey data from the 1980, 1983, and 1986 surveys. Sexes were combined in the analysis as sex was not determined to be an important differentiating variable for Atka mackerel growth. These parameters have also been calculated for (1) the combined 1986, 199 1, and 1994 survey data for the entire Aleutians region, and for the Eastern (54 1) and combined Central and Western (542 and 543) subareas, and (2) the combined 1990-96 fishery data for the same areas:

| Data source | $L_\infty$ (cm) | $K$ | $t_0$ |
|---|---|---|---|
| **Early surveys** | | | |
| Areas combined | 41.4 | 0.3 1 I | -1.23 |
| **86, 91& 94 surveys** | | | |
| Areas combined | 41.4 | 0.439 | -0.13 |
| 541 | 42.1 | 0.652 | 0.70 |
| 542 & 543 | 40.3 | 0.425 | -0.38 |
| **1990-96 fishery** | | | |
| Areas combined | 41.3 | 0.670 | 0.79 |
| 541 | 44.1 | 0.518 | 0.35 |
| 542 & 543 | 40.7 | 0.562 | 0.37 |

Length-age equation: Length (cm) = $L_\infty\{1\text{-}\exp[-K(\text{age}-t_0)]\}$

Both the combined survey and fishery data show a clear east to west size cline in length at age with the largest fish found in the eastern Aleutians (Figure 12. IO).

Theweight-length relationships determined from the early (1980, 1983 and 1986) and recent (1986, 1991, and 1994) surveys are similar:

weight (kg) = 4.98E-06 * length (cm) $^{3.2403}$ (early surveys; $N$=899)
weight (kg) = 9.08E-06 * length (cm) $^{3.0913}$ (recent surveys; $N$=1,052)

Weight-length data collected from the 1990 to 1996 domestic fisheries were also used to estimate a weight-length relationship:

weight (kg) = 3.72E-05 * length (cm) $^{2.6949}$ ($N$=4,041).

The observed differences in the weight-length relationships from the survey and recent fishery data, particularly in the exponent of length, probably reflect the differences in the timing of sample collection. The survey data were all collected in summer, the spawning period of Atka mackerel when gonad weight would contribute the most to total weight. The recent fishery data were collected primarily in winter, when gonad weight would be a smaller percentage of total weight than in summer.

## Maturity at Age

Female maturity at length and age were determined for Aleutian Islands Atka mackerel (McDermott and Lowe, 1997) The age at 50% maturity is 3.6 years. Length at 50% maturity differs by area as the length at age differs by Aleutian Islands subareas:

| | Length at 50% rnaturitv (cm) |
|---|---|
| Eastern Aleutians (541) | 33.9 |
| Central Aleutians (542) | 31.1 |
| Western Aleutians (543) | 31.2 |

The maturity schedules are given in Table 12.7.

12.4.4.2 Parameters Estimated Conditionallv

Deviations between the observations and the expected values are quantified with a specified error structure. Lognormal error is assumed for estimates of survey and fishery catch, and a multinomial error structure is assumed for analysis of the survey and fishery age compositions. These error structures are used to estimate the following parameters conditionally within the model.

Fishing Mortalitv

The time series of fishing mortalities ($F_{ya} = f_y s_a$) on fully selected age groups (s, = 1) are estimated within the model. The level of the annual fishing mortality factor ($f_y$) is adjusted within the model so that the estimated catch biomass matches the observed catch biomass.

Selectivitv

The patterns of selectivity-at-age of the 2 time series of survey data are modeled as the product of 2 logistic functions:

$$s_a = \frac{T_1}{\left(1 + e^{-P_1(a - P_2)}\right)\left(1 + e^{P_3(a - P_4)}\right)}$$

where $s_a$ is selectivity at age, $P_1$ relates to the slope of the first function, $P_2$ is the inflection age for the first function, $P_3$ relates to the slope of the second function, $P_4$ is the inflection age of the second function, and $T_1$ is a function of $P_1$, $P_2$, $P_3$, and $P_4$ which scales maximum selectivity to 1.

The fishery selectivity pattern (which is estimated for 2 time periods) is a 7-parameter dome-shaped relationship, which in addition to using the 4 parameters above, specifies a transition age at which the transition from the ascending to the descending side of the function occurs, a selectivity at the minimum age, and a selectivity at the maximum age. The following parameters are allowed to change between time periods: the transition age, the selectivity of the maximum age, the inflection age of the descending limb, and the slope of the descending limb.

Survev Catchabilitv

Catch-per-unit-effort for survey $j$ in year $y$ ($G_{yj}$), is expected to be proportional to the model's estimate of available biomass, $B_{yj}$, at the time of the survey:

$$G_{yj} = Q_j B_{yj}$$

where $Q_j$ is the catchability coefficient. For surveys that are expanded to a measurement of absolute biomass, the scaling factor (catchability coefficient) is assumed to be known. In the case where survey CPUE is interpreted as a relative index of population biomass, the scaling factor is calculated so that the mean log

deviation is zero:
where the summation is over years ($y$) and $n$ is the number of years. Cat&ability for the absolute abundance survey time series is assumed to be 1 .O, and catchability for the relative index survey time series is estimated within the model.

$$Q_j = \exp\left( \frac{\sum_y \ln\left(G_{yj} / \hat{G}_{yj}\right)}{n} \right)$$

## 12.5 MODEL EVALUATION

### 12.5.1 Past Assessment Model Evaluations

The sensitivity of the model output (total and component likelihoods, ending biomass, and recruitment and biomass trends) to changes in three key model elements was explored in the 1996 assessment (Lowe and Fritz 1995). The three elements were the selectivity at-age of both the fishery and absolute surveys, the natural mortality estimate, and the emphasis factor on the absolute survey biomass component.

Estimates of selectivity and natural mortality are confounded parameters. In the 1996 stock assessment, no maxima in relative likelihoods were observed when fishery (or survey) terminal (oldest age) selectivity varied from 0. I to 1, while at the same time fixing the survey (or fishery) terminal selectivity at 0.1 and allowing the model to estimate A4 (Lowe and Fritz 1995). In both cases, the ability of the model to fit the catch or survey age composition degraded and $M$ increased to > 0.4 with increasing terminal selectivities. Thompson (1994) showed that fixing A4 at it's expected value is generally a safer strategy than allowing $M$ to be estimated by assuming asymptotic selectivity. Based on these sensitivity analyses, it was determined that the model structure that best fit the data (highest total likelihoods) and provided the most reasonable biomass trend was one that had dome-shaped selectivities for both the surveys and fisheries (Lowe and Fritz, 1995).

There are rationale based on Atka mackerel life history characteristics and the operation of the fishery for survey and fishery dome-shaped selectivities for Atka mackerel. The surveys have been conducted solely in the summer, when some mature Atka mackerel move into shallow waters for spawning (Zolotov 1993; Fritz and Lowe 1998). Consequently, nest-guarding males and spawning females, the largest and oldest part of the population, would likely be less available to the survey trawl gear (due to difficulties in sampling the nearshore rocky, high current areas utilized by spawning Atka mackerel) than the smaller and younger portions of the population. Spawning and nest-guarding were observed (by divers and in *in situ* video) off Seguam Island in August 1999 (B. Lauth, AFSC, pers. comm.). This could lead to the estimation of dome-shaped survey selectivities. With regard to the fisheries, the early fisheries (1977-83) were also conducted solely in the summer; hence, much of the same rationale used to explain the dome-shaped survey selectivities applies to the early fisheries. The late fisheries (1984-present) have the highest selectivities on fish older than 8 years relative to the surveys and the early fishery. This could be attributed to increased fishing effort in winter, when the Atka mackerel population appears to be less segregated by sex and age than in summer. While this would tend to increase the selectivities on the older fish, there is still considerable summer fishing data from 1984 to the present averaged into the estimation of a single fishery selectivity curve from this period which could lead to dome-shaped selectivity.

At the time of development of the first stock synthesis model (Lowe, 199 l), only the 1986 and 199 1 biomass estimates were available and were weighted heavily (emphasis factor of 10) to insure that the model would closely approximate these levels; stock synthesis could not simultaneously fit both the 1986 and 199 1 survey biomass estimates (Lowe, 1991). A subsequent reanalysis of the absolute survey biomass emphasis factor (which included the 1994 survey biomass estimate) showed that increasing the emphasis factor from 1 to 10 had a negligible effect on the model fit and only a small effect on ending biomass, thus the emphasis on the absolute survey time series was set at 1 (Lowe and Fritz 1995).

12.5.2 Last Year's Evaluation of Current Model

An evaluation of alternative models was undertaken in last year's assessment (Section 12.5.2 in Lowe and Fritz, 1998). The 1998 baseline model configuration (described above in Section 12.4) denoted Model A, included fishery data from 1997 and 1998. Three alternative models were explored in last year's assessment which analyzed: changing the starting year (Model B), estimating survey cat&ability ofthe absolute abundance time series (Model C), and differential natural mortality at age (Model D). The models used in the evaluation did not include the 1997 survey age composition which was not available at the time. A summary of the evaluation follows.

Catch data for BSAI Atka mackerel start in 1972 but are negligible until 1975. The fishery catch-at-age tune series does not start until 1977 and includes very few fish older than age 7; 2-year old fish in 1972 would be 7 years old in 1977. Also, the first year of the time series of survey data is 1980. Thus the baseline model which started in 1972, had very little information with which to estimate the population abundance and age distribution of the early years of the time series. Model B was configured with a start year of 1977 which coincided with the beginning of the time series of catch-at-age data.

The cat&ability coefficient ($Q$) of the absolute survey time series is assumed to be 1 .O in the baseline model. Model C had a start year of 1977 and allowed the model to estimate $Q$, which resulted in a value of 0.60 (Lowe and Fritz, 1998). However, because selectivity and the catchability coefficient are confounded, these parameter estimates were considered unreliable. To further explore survey catchability, Model C was profiled over fixed values of $Q$ ranging from 0.5 to 1.2 (Figure 12.12 in Lowe and Fritz, 1998). All likelihood components were quite flat over the range of $Q$ values, but ending biomass was significantly different over the range of $Q$ values.

Model D had a start year of 1977 and included an exploration of differential mortality at age. The catch-at-age data indicates either a decreased availability of the older fish or increasing natural mortality. Various versions of Model D were explored in which natural mortality was assumed to be constant at a value of 0.30 for at least ages 1-6, and linearly increasing up to a value of 0.40 beginning at ages 7, 8, 9, and 10. Additionally, a run was made with linearly increasing natural mortality from 0.30 to 0.40 starting at age 1. The final version of Model D was configured with constant natural mortality of 0.30 for ages 1-6, and linearly increasing natural mortality up to 0.40 beginning at age 7.

The estimation of survey cat&ability and natural mortality [Models C and D, respectively) had a sign&cant impact on ending biomass (Lowe and Fritz, 1998). The estunation of cat&ability in synthesis is problematic in that 1) it is highly confounded with selectivity, and 2) the estimation of cat&ability assumes equivalent standard errors for the survey time series, an assumption which is not met. The estimation of natural mortality in synthesis is also problematic due to the confounding of selectivity and natural mortality. These issues and the added uncertainty they present are currently being explored with alternative models.

Model B was selected as the final model configuration based on the assumptions that constant natural mortality equal to 0.3 and absolute survey cat&ability of 1 .O are reasonable given the current difficulties in estimating $M$ and $Q$ simultaneously with selectivity (Lowe and Fritz, 1998). Model B was updated in the current assessment with 1998 fishery catch biomass, and the 1999 TAC as a proxy for 1999 fishery catch biomass.

## 12.6 MODEL RESULTS

### 12.6.1 Selectivity

The estimated selectivity at age schedules for the fishery and surveys are given in Table 12.8. The fishery basically consists of fish 3-12 years old, although a 1 j-year-old fish was found in the 1994 fishery. Estimated selectivity for the fishery and particularly for the survey data, are dome-shaped with steep ascending and descending limbs (Figure 12.11). Survey catches were mostly comprised of fish 3-8 years old (Figure 12.9). A 14-year old fish was found in the 1994 survey, accounting for the low selectivity out to age 15 for the absolute surveys (Figure 12.1 lc). The estimated selectivities of 3-year-old fish from the 2 types of survey data are quite different (Figure 12.11 b,c). Data from the 1- 100 m depth interval apparently included a large number of 3-year-olds, as the selectivities at this age showed the most notable difference. The estimated survey cat&ability for the relative index survey was 0.7 1.

### 12.6.2 Abundance Trend

The estimated time series of biomass for ages 3+ are shown in Figure 12.12 and given in Table 12.9. The corresponding time series of total numbers at age are given in Table 12.10. The biomass trend increases during the late 70s and early 80s and again in the early 90s (Figure 12.12). The stock has been on a fairly steep declining trend since 199 1.

### 12.6.3 Recruitment Trend

The estimated time series of age 2 recruits are shown in Figures 12.13 and 12.14 and given in Table 12.11. The strong 1977 year class is most notable followed by the 1988 year class. The model estimates above average recruitment from the 1984-86, 1988, and 1992 year classes (Figure 12.13). This is corroborated by the catch-at-age data which showed large numbers of 4-year-old fish recruiting to the 1988, 1989, 1990, 1992, and 1996 fisheries. The average estimated recruitment from the entire time series ( 1977- 1997) is 6 14 million fish and the median is 425 million fish (Figure 12.13). The entire time series of recruitments includes the 1975-1995 year classes. The Alaska Fisheries Science Center has recognized that an environmental "regime shift" affecting the long-term productive capacity of the groundfish stocks in the BSAI occurred during the period 1976-1977. Thus, an average recruitment value based on year classes spawned after 1976 (1977-1995 year classes) for the years 1979-1997, is 622 million fish.

Projections of biomass are based on estimated recruitments from 1979-1997 using a stochastic projection model described below.

### 12.6.4 Trend in Exnloitation

The estimated time series of of fishing mortalities on fully selected age groups and the catch-to-biomass (age 3+) ratios are given in Table 12.12.

### 12.6.5 Model Fit

Figure 12. 15 compares the observed (a) relative and (b) absolute abundance values from the surveys with the model estimates of survey abundance values (observed versus expected). Stock synthesis applies the estimated survey selectivities to the population estimates to provide the expected values of survey abundance. The population estimates are also depicted for comparison to absolute estimates of biomass from the surveys (Figure 12.15b). The 1986, 1991, 1994, and 1997 observed trawl survey biomass estimates represented 60, 47, 54, and 46% respectively, of the population estimates.

The model fit the 1986 and 199 1 survey estimates poorly compared to the more recent 1994 and 1997 surveys (Figure 12.15b). The catch-at-age data do not show another strong year class following the 1977 year class that would allow the model to achieve a better fit to the 1986 survey estimate. From 1986 to 1991, the population is estimated to have increased at a greater rate than shown by the surveys (Figure 12.14b). This lack of fit is confounded by the large coefficient of variation associated with the 1986 biomass estimate. The large decrease in biomass from the 1994 to 1997 surveys appears to be consistent with the recent recruitment pattern.

The fits to the fishery and survey age compositions are depicted in Figure 12.16, and show relatively good fits each year.

## 12.7 HARVEST ALTERNATIVES AND PROJECTIONS

### 12.7.1 Reference Fishing Mortalitv Rates and Yields

The overfishing and maximum allowable ABC fishing mortality rates ($F_{OFL}$ and *max* $F_{ABC}$, respectively) are given in terms of percentages of unfished female spawning biomass per recruit ($F_{SPR\%}$), on fully selected age groups. The associated long-term average female spawner biomass that would be expected under average estimated recruitment from 1979- 1997 (622 million recruits) and $F = F_{40\%}$, denoted $B_{40\%}$, is estimated to be 154,300 mt. The projected 2000 female spawning biomass ($SB_{00}$) is 162,500 mt. Given reliable estimates of current spawning biomass ($SB_{00}$), $B_{40\%}$, $F_{40\%}$, $F_{35\%}$, and that $SB_{00}$ is greater than $B_{40\%}$, Atka mackerel fall into Tier 3a of the ABC/OFL definitions (Amendment 56 to the BSAI FMP). According to the definitions and results from the current assessment, $F_{OFL} = F_{35\%} = 0.42$, and *max* $F_{ABC} = F_{40\%} = 0.35$. Projected 2000 yields associated with $F_{OFL}$ and max $F_{ABC}$ are 119,300 and 102,700 mt, respectively.

| Harvest Strategy | $F_{SPR\%}$ | Fishing Mortality Rate | 2ooo Projected Yield (mt) |
|---|---|---|---|
| $F_{OFL}$ | $F_{35\%}$ | 0.42 | 119,300 |
| - $F_{ABC}$ | $F_{40\%}$ | 0.35 | 102,700 |

Alternative harvest strategies used in the past for Atka mackerel are given below with the projected 2000 yields:

| Harvest Strategy | $F_{SPR\%}$ | Fishing Mortality Rate | 2000 Projected Yield (mt) |
|---|---|---|---|
| $F=M$ | $F_{49\%}$ | 0.30 | 89,900 |
| 1999 $F_{ABC}$ | $F_{52\%}$ | 0.23 | 70,800 |

## 12.7.2 ABC Considerations

Several observations and uncertainties were noted in the ABC recommendation section in the 1997 and 1998 stock assessments (Lowe and Fritz 1997, 1998). Two of these are still of concern for this assessment and are repeated below:

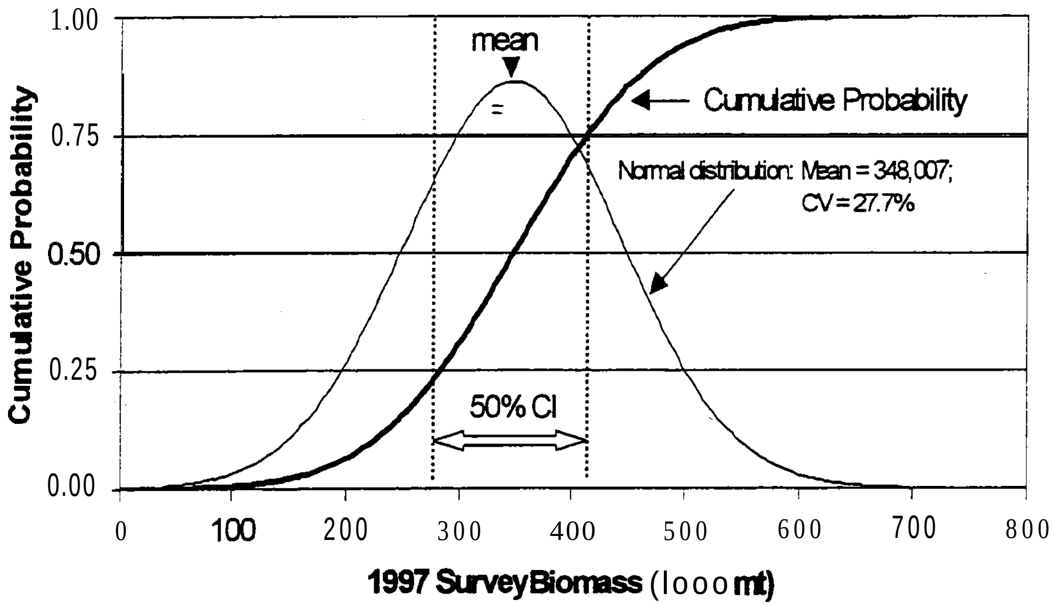
1) Stock size as estimated by the age-structured model has declined by approximately 60% since 199 1;
2) The 1997 Aleutian trawl survey biomass estimate was about 50% lower than the 199 1 and 1994 survey estimates;

In their report to Congress ("Ecosystem-based Fishery Management"), the Ecosystem Principles Advisory Panel (Panel) suggested sets of principles, goals and policies that should "embody key elements for ecosystem-based management of fisheries". Two similar policies suggested by the Panel were that managers should apply the precautionary approach and purchase "insurance" against unforeseen, adverse ecosystem impacts. The precautionary approach can be used to incorporate uncertainties in stock assessments in the determination of ABC. In cases where stock synthesis model applications are used to project stock size (e.g., BSAI Atka mackerel), some of the uncertainties in the stock assessment process can be characterized in the model, but there is no simple, direct method to obtain confidence limits for key parameters of interest, or probability distributions for current year biomass or yield calculations using various harvest scenarios.

In the past, yield determinations for Atka mackerel using various reference points ($F_{52\%}$, $F_{40\%}$, $F_{OFL\%}$) have been computed with no confidence bounds surrounding them. These are the point estimates based on current year biomass, age composition, and biological characteristics of the species. A large component of the variance (uncertainty) for Atka mackerel is survey biomass estimates, a crucial value in the stock assessment in that it scales the population abundance trend. The 1986,199 1, 1994, and 1997 survey estimates for Atka mackerel are treated as absolute abundance estimates in the model. The point estimates of Atka mackerel biomass and the respective coefficients of variation ($CV$) are listed in the table below (taken from Tables 12.4 and 12.5). Using these values, the approximate lower 50% confidence limits (CL.) on each mean biomass estimate can be calculated. An example of how the confidence limits are computed using the 1997 survey data is shown in the figure below. At the mean value, 50% of the probability is to the right (greater than the mean) and 50% is to the left (less than the mean). That is, there is only a 50% probability that the true mean is at *least as* big as the calculated mean. Contrasted with the lower 50% confidence limit of the mean, 75% of the cumulative probability on survey biomass is to the right (greater than) this value. That is, there is a 75% probability that the true mean is at least this large. This is some measure of the "insurance" we purchase by incorporating this information into the determination of ABC.

For the four absolute estimates of survey abundance used in the assessment, the ratio of the lower 50% confidence limit divided by the mean is calculated along with the average for the four surveys. This average ratio provides a measure of some of the uncertainty associated with our estimate of stock size from the model, and ultimately our estimate of yield at $F_{ABC}$.

| Survev Year | Mean Biomass (mt) | CV | Lower 50% CL (mt) | Lower 50% CL / Mean |
|---|---|---|---|---|
| 1986 | 544,754 | 0.630 | 310,510 | 0.57 |
| 1991 | 688,150 | 0.266 | 564,283 | 0.82 |
| 1994 | 623,826 | 0.366 | 467,870 | 0.75 |
| 1997 | 348,007 | 0.277 | 281,886 | 0.81 |
| Average | | | | 0.74 |




12.7.3 Projections

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 1999 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2000 using constant natural mortality of 0.3, the schedules of selectivity estimated in the assessment, and the 1999 TAC as a proxy for total (year-end) catch for 1999. 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 for 1979-1997 in the assessment. Spawning biomass is computed in each year based on the time of peak spawning (August) 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 2000, are as follow ("*max* $F_{ABC}$" refers to the maximum permissible value of $F_{ABC}$ under Amendment 56):

*Scenatio 1: In* all future years, $F$ is set equal to max $F_{ABC}$.

*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 2000 recommended in the assessment to the *max* $F_{ABC}$ for *2000.*

*Scenatio 3:* In all future years, $F$ is set equal to 50% of max $F_{ABC}$.

*Scenatio 4:* In all future years, $F$ is set equal to the 1994-1998 average $\bar{F}$.

Scenatio 5: In all future years, $F$ is set equal to zero.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a 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 ½ of its MSY level in 2000 and above its MSY level in 2010 under this scenario, then the stock is not overfished.)

*Scenario 7: In 2000* and 200 1, $F$ 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 2012 under this scenario, then the stock is not approaching an overfished condition.)

These projections differ from previous assessments since stochastic recruitment was used, compared to constant recruitment at fixed levels. Last year's assessment projected 1999 biomass and yield assuming recruitment equal to the median of the estimated recruitments from 1977- 1996 (425 million recruits, Lowe and Fritz 1998). The average recruitment from 1979- 1997 used in the current stochastic projections is 622 million fish.

The projected biomass of ages 3+ at the beginning of 2000 is 565,150 mt. The projected yields, female spawning biomass, and associated fishing mortality rates for the seven harvest strategies are shown in Table 12.13. Under a harvest strategy of $F_{40\%}$ (Scenario 1), female spawning biomass is projected to drop below $B_{40\%}$ in 200 1 and 2002. Female spawning biomass is also projected to drop below $B_{40\%}$ when fishing at $F_{OFL}$ (Scenarios 6 & 7, Table 12.13). The other harvest strategies all maintain female spawning biomass above $B_{40\%}$ in the projections. It should be noted that in the projections, the fishing mortality rates are prescribed on the basis of the harvest scenario and the spawning biomass in each year. Thus, fishing mortality rates may not be constant within the projection if spawning biomass drops below $B_{40\%}$ in any run. Figure. *12.17* illustrates 5-year projections for $F = F_{40\%}$ *(Scenario* 1), $F = F_{ABC}$ *(Scenario* 2), and $F = F_{OFL} = F_{35\%}$ (Scenario 6). The associated long-term average female spawner biomass that would be expected under average estimated recruitment from 1979- 1997 (622 million recruits) and $F = F_{35\%}$, denoted $B_{35\%}$, is estimated to be 135,000 mt.

This value ($B_{35\%}$), which is used in the status determination criteria (Section 12.7.4), is provided as a reference level along with $B$,, (Figure 12.17).

For comparison, projections were also made under an alternative assumption of recruitment for the seven harvest scenarios. Table 12.14 gives projections of yield, female spawning biomass. and the associated fishing mortality rates using only the estimated recruitments from the last 10 years of the recruitment time series (1988-1997, average recruitment equal to 579 million fish). Using recruitment from the last 10 years of the time series provides more pessimistic projections as they do not include the strong 1977 and 1984-1986 year classes.

12.7.4 ABC Recommendation. Overfishing Level. and Status Determination

As a form of "insurance" and as a suggested direct application of the precautionary approach advocated by the Panel, we explored an alternative harvest strategy determined by multiplying max $F_{ABC} = F_{40\%} = 0.35$ by 0.74, resulting in an $F$ = 0.26. The factor 0.74 was determined as outlined above in section 12.7.2 and used for the Scenario 2 harvest projection. Short-term stochastic projections under an $F$ = 0.26, result in female spawning biomass remaining above $B_{40\%}$ within 12 years, compared to harvesting at $F_{40\%}$ in which projected female spawning biomass drops below $B_{40\%}$ in 200 1 and 2002 (Figure 12.17). Based on a comparison of the $F_{40\%}$ strategy versus an $F$ = 0.26 in the projections, we recommend that **$F_{ABC}$ = 0.26. The associated 2000 yieid with a fishing mortality rate of 0.26 is 78,500 mt, which is our 2000 ABC recommendation for** BSAI **Atka mackerel. A** yield of 78,500 mt represents a 7% increase relative to the 1999 ABC due to a change in harvest strategy and the use of stochastic rather than constant recruitment in the projections.

The ***$F_{35\%}$* overfishing level** is 119,300 **mt.** The estimated $B_{35\%}$ female spawner biomass is 135,000 mt. Female spawning biomass for 2000 is projected to be above $B_{35\%}$ (Table 12.13, Scenario 6), thus, the BSAI Atka mackerel stock is determined to be above its minimum stock size threshold (MSST) and is *not overfished.* Female spawning biomass for 20 12 is projected to be above $B_{35\%}$ (Table 12.13, Scenario 7) , thus the BSAI Atka mackerel stock is *not* expected to fall below its MSST *in two years* and is *not approaching an overfished condition.*

12.7.5 Apportionment of Catch

Amendment 28 of the Bering Sea/Aleutian Islands Fishery Management Plan divided the Aleutian subarea into 3 districts at 177" E and 177" W longitude, providing the mechanism to apportion the Aleutian Atka mackerel TACs. The Council used the average of the 1994 and 1997 survey biomass distributions of Atka mackerel to apportion the 1999 ABC. The distributions from the 1994 and 1997 surveys are shown below. The average distribution from the 1994 and 1997 surveys resulted in the following subarea apportionments of the 1999 ABC of 73,300 mt and the 2000 recommended ABC of 78,500 mt:

| Subarea | 1994 Survey | 1997 Survey | 1994 & 1997 Average | 1999 ABC Split (mt) | 2000 ABC Split (mt) |
|---|---|---|---|---|---|
| Eastern (541) | 34.1% | 12.3% | 23.2% | 17,000 | 18,200 |
| Central (542) | 14.0% | 55.8% | 34.9% | 25,600 | 27,400 |
| Western (543) | 51.9% | 31.9% | 41.9% | 30,700 | '32,900 |

A Regulatory Amendment for the Bering Sea/Aleutian Islands Atka mackerel fishery mandated percent allocations of Atka mackerel catch to A and B seasons for all subareas, and inside and outside of Steller sea lion critical habitat in areas 542 and 543 for 2000 (see section 12.2.6 for percentages). The allocations applied to the subarea apportionments of the 2000 recommended ABC (18,200 mt - 54 1, 27,400 mt - 542, and 32,900 mt - 543) are shown below:

**Temporal-Spatial Allocation of Recommended 2000 ABC**

| Subarea | 541 & EBS | | 542 | | | | 543 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season | A | B | A | | B | | A | | B | |
| Critical Habitat | | | Inside | Outside | Inside | Outside | Inside | Outside | Inside | Outside |
| 2000 ABC (mt) | 9,100 | 9,100 | 9,180 | 4,520 | 9,180 | 4,520 | 9,380 | 7,070 | 9,380 | 7,070 |

## 12.8 SUMMARY

$M = 0.30$

1999: $F_{MC} = 0.23$ yield= 73,300 mt

2000

Maximum permissible ABC $F_{40\%} = 0.35$ yield = 102,700 mt
Recommended ABC : $F_{ABC\%} = 0.26$ yield = 78,500 mt
Overfishing $F_{OFL}$ : $F_{35\%} = 0.42$ yield = 119,300 mt

$B_{40\%}$ female spawning biomass = 154,300 mt
$B_{35\%}$ female spawning biomass = 135,000 mt

Projected 2000 3+ biomass = 565,150 mt
Projected 2000 female spawning biomass = 162,500 mt

Note: The $F$ values are the full-selection fishing mortality rates.

## 12.9 ACKNOWLEDGMENTS

We thank the AFSC survey personnel for the collection of data and providing the biomass estimates. In particular we acknowledge Michael Martin and Robin Harrison. We also thank the staff of the AFSC Age and Growth Unit for the ageing of otoliths used to determine the age compositions in the assessment. James Ianelli and Anne Hollowed provided helpful reviews of this document.

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Table 12.1. Atka mackerel catches (including discards) by region and corresponding Total Allowable Catches (TAC) set by the North Pacific Fishery Management Council from 1978 to the present. Catches are in mt.

| Year | Eastern Bering Sea | | | | Aleutian Islands Region | | | | EBS-AI | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Foreign | Domestic JVP | Domestic DAP | Total | Foreign | Domestic JVP | Domestic DAP | Total | Total | TAC |
| 1977 | 0 | 0 | 0 | a | 21,763 | 0 | 0 | 21,763 | 21,763 | b |
| 1978 | 831 | 0 | 0 | 831 | 23,418 | 0 | 0 | 23,418 | 24,249 | 24,800 |
| 1979 | 1,985 | 0 | 0 | 1,985 | 21,279 | 0 | 0 | 21,279 | 23,264 | 24,800 |
| 1980 | 4,690 | 265 | 0 | 4,955 | 15,533 | 0 | 0 | 15,533 | 20,488 | 24,800 |
| 1981 | 3,027 | 0 | 0 | 3,027 | 15,028 | 1,633 | 0 | 16,661 | 19,688 | 24,800 |
| 1982 | 282 | 46 | 0 | 328 | 7,117 | 12,429 | 0 | 19,546 | 19,874 | 24,800 |
| 1983 | 140 | 1 | 0 | 141 | 1,074 | 10,511 | 0 | 11,585 | 11,726 | 24,800 |
| 1984 | 41 | 16 | 0 | 57 | 71 | 35,927 | 0 | 35,998 | 36,055 | 23,130 |
| 1985 | 1 | 3 | 0 | 4 | 0 | 37,856 | 0 | 37,856 | 37,860 | 37,700 |
| 1986 | 6 | 6 | 0 | 12 | 0 | 31,978 | 0 | 31,978 | 31,990 | 30,800 |
| 1987 | 0 | 12 | 0 | 12 | 0 | 30,049 | 0 | 30,049 | 30,061 | 30,800 |
| 1988 | 0 | 43 | 385 | 428 | 0 | 19,577 | 2,080 | 21,656 | 22,084 | 21,000 |
| 1989 | 0 | 56 | 3,070 | 3,126 | 0 | 0 | 14,868 | 14,868 | 17,994 | 20,285 |
| 1990 | 0 | 0 | 480 | 480 | 0 | 0 | 21,725 | 21,725 | 22,205 | 21,000 |
| 1991 | 0 | 0 | 2,596 | 2,596 | 0 | 0 | 24,144 | 24,144 | 26,740 | 24,000 |
| 1992 | 0 | 0 | 2,610 | 2,610 | 0 | 0 | 47,425 | 47,425 | 50,035 | 43,000 |
| 1993 | 0 | 0 | 213 | 213 | 0 | 0 | 65,524 | 65,524 | 65,737 | 64,000 |
| 1994 | 0 | 0 | 189 | 189 | 0 | 0 | 69,401 | 69,401 | 69,590 | 68,000 |
| 1995 | 0 | 0 | a | a | 0 | 0 | 81,554 | 81,554 | 81,554 | 80,000 |
| 1996 | 0 | 0 | a | a | 0 | 0 | 103,943 | 103,943 | 103,943 | 106,157 |
| 1997 | 0 | 0 | a | a | 0 | 0 | 65,845 | 65,845 | 65,845 | 66,700 |
| 1998 | 0 | 0 | a | a | 0 | 0 | 57,177 | 57,177 | 57,177 | 64,300 |
| 1999c | 0 | 0 | a | a | 0 | 0 | 50.240 | 50.240 | 50.240 | 66.400 |

Catch table footnotes:

a) Eastern Bering Sea catches included with Aleutian Islands.

b) Atka mackerel was not a reported species group until 1978

c) 1999 data as of 10/21/99 from NMFS Alaska Regional Office Home Page.

Table 12.2 Research catches (mt) of Atka mackerel from NMFS trawl surveys in the Aleutian Islands.

| Year | Aleutian Islands |
|---|---|
| 1977 | |
| 1978 | |
| 1979 | |
| 1980 | 47.9 |
| 1981 | 3.9 |
| 1982 | 0.9 |
| 1983 | 151.4 |
| 1984 | |
| 1985 | |
| 1986 | 130.2 |
| 1987 | |
| 1988 | |
| 1989 | |
| 1990 | |
| 1991 | 77.1 |
| 1992 | |
| 1993 | |
| 1994 | 146.5 |
| 1995 | |
| 1996 | |
| 1997 | 85.2 |
| 1998 | |
| 1999 | |

Table 12.3 Estimated catch-in-numbers at age (in millions) of Atka mackerel from the Aleutian Islands.

| Age | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 6.827 | 2.702 | 0.011 | --- | --- | --- | --- | 0.094 | 0.627 | 0.369 | 0.563 | 0.400 | 0.185 | --- | --- | 0.215 | 0.700 | 0.025 | 0.238 | 0.029 | 1.050 | --- |
| 3 | 31.522 | 60.155 | 4.477 | 12.681 | 5.393 | 0.188 | 1.900 | 0.977 | 15.971 | 11.454 | 10.441 | 9.966 | 3.298 | 4.047 | 1.957 | 2.765 | 2.335 | 9.572 | 19.042 | 3.449 | 4.736 | 11.340 |
| 4 | 20.056 | 15.573 | 26.778 | 5.920 | 17.106 | 2.629 | 1.433 | 7.295 | 8.787 | 6.457 | 7.602 | 22.487 | 7.635 | 12.055 | 5.576 | 28.091 | 11.860 | 6.949 | 41.265 | 65.693 | 9.890 | 18.946 |
| 5 | 15.113 | 9.221 | 13.000 | 7.220 | 0.002 | 25.828 | 2.535 | 7.070 | 9.428 | 4.423 | 4.582 | 6.148 | 8.672 | 6.790 | 10.112 | 7.692 | 35.869 | 23.997 | 9.776 | 22.307 | 34.603 | 17.302 |
| 6 | 1.223 | 3.750 | 2.197 | 1.665 | 1.612 | 3.861 | 10.596 | 10.793 | 6.010 | 5.335 | 1.891 | 1.797 | 3.043 | 2.490 | 5.901 | 13.838 | 8.183 | 39.771 | 14.849 | 12.765 | 13.837 | 31.933 |
| 7 | 0.393 | 0.592 | 1.109 | 0.591 | 8.104 | 0.676 | 1.587 | 21.775 | 5.453 | 4.531 | 2.373 | 1.535 | 1.305 | 0.893 | 3.064 | 7.504 | 13.674 | 4.573 | 27.633 | 20.870 | 4.016 | 11.651 |
| 8 | 0.197 | 0.343 | --- | 0.240 | --- | --- | --- | 2.212 | 11.685 | 5.841 | 2.192 | 0.627 | 0.467 | 0.189 | 1.285 | 6.103 | 6.856 | 9.416 | 3.565 | 31.928 | 4.312 | 4.153 |
| 9 | --- | 0.106 | --- | 0.131 | --- | --- | --- | 0.957 | 1.263 | 9.912 | 1.708 | 0.959 | 0.412 | 0.134 | 0.269 | 1.803 | 5.504 | 6.588 | 4.007 | 3.023 | 9.393 | 3.834 |
| 10 | --- | --- | --- | --- | --- | --- | --- | --- | 0.269 | 1.036 | 6.777 | 0.202 | 0.213 | 0.054 | 0.406 | 0.684 | I.593 | 4.257 | 5.361 | 3.603 | 1.835 | 5.579 |
| 11 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.846 | 0.530 | 0.437 | 0.164 | 0.016 | 0.397 | 0.226 | 0.585 | 0.612 | 2.044 | 2.635 | 2.745 | 0.473 |
| 12 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.220 | 0.040 | 0.533 | 0.038 | 0.087 | 0.177 | 0.183 | 0.267 | --- | 0.506 | 1.261 | 0.851 |
| 13 | --- | --- | --- | --- | --- | — | --- | --- | --- | --- | --- | --- | 0.032 | 0.164 | --- | 0.074 | 0.128 | 0.000 | --- | 0.047 | 0.841 | 0.761 |
| 14 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.038 | 0.032 | -- | 0.036 | 0.040 | 0.000 | --- | --- | 0.156 | --- |
| 15 | --- | --- | --- | --- | --- | --- | — | — | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0,033 | --- | — | --- | --- |

Table 12.4 Atka mackerel estimated biomass in metric tons from the bottom trawl survey, by subregion, depth interval, and survey year, with the corresponding coefficients of variation.

| Area | Depth (m) | Biomass (mt) 1980 | 1983 | 1986 | Coefficient of variation 1980 | 1983 | 1986 |
|---|---|---|---|---|---|---|---|
| Aleutian | 1-100 | 48,306 | 140,552 | 450,869 | 1.00 | 0.26 | 0.76 |
| | 101-200 | 144,431 | 162,399 | 93,501 | 0.46 | 0.25 | 0.30 |
| | 201-300 | 4,296 | 3,656 | 331 | 0.59 | 0.42 | 0.57 |
| | 301-500 | 483 | 172 | 16 | 0.77 | 1.00 | 0.87 |
| | 501-900 | 13 | 1 | 37 | 0.75 | 1.00 | 1.00 |
| | Total | 197,529 | 306,780 | 544,754 | 0.42 | 0.22 | 0.63 |
| Southwest Aleutian | 1-100 | 95 | 15,321 | 418,271 | 0.00 | 0.61 | 0.82 |
| | 101-200 | 75,857 | 120,991 | 51,312 | 0.58 | 0.41 | 0.39 |
| | 201-300 | 619 | 2,304 | 122 | 0.61 | 0.57 | 0.83 |
| | 301-500 | 105 | 172 | 14 | 0.77 | 1.00 | 0.98 |
| | 501-900 | 9 | 1 | 0 | 0.96 | 1.00 | 0.00 |
| | Total | 76,685 | 138,789 | 469,719 | 0.57 | 0.36 | 0.73 |
| Southeast Aleutian | 1-100 | 0 | 65,814 | 33 | 0.00 | 0.00 | 0.42 |
| | 101-200 | 21,153 | 854 | 89 | 0.87 | 0.92 | 0.90 |
| | 201-300 | 115 | 202 | 3 | 0.14 | 0.86 | 0.88 |
| | 301-500 | 16 | 0 | 0 | 0.00 | 0.00 | 0.00 |
| | 501-900 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 |
| | Total | 21,284 | 66,870 | 125 | 0.86 | 0.01 | 0.64 |
| Northwest Aleutian | 1-100 | 0 | 41,235 | 32,564 | 0.00 | 0.72 | 0.65 |
| | 101-200 | 382 | 5,571 | 211 | 0.71 | 0.69 | 0.54 |
| | 201-300 | 2,524 | 34 | 0 | 0.96 | 0.69 | 0.00 |
| | 301-500 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 |
| | 501-900 | 4 | 0 | 0 | 1.12 | 0.00 | 0.00 |
| | Total | 2,910 | 46,840 | 32,775 | 0.84 | 0.64 | 0.65 |
| Northeast Aleutian | 1-100 | 48,211 | 18,182 | 1 | 1.00 | 1.00 | 1.00 |
| | 101-200 | 47,039 | 34,983 | 44,889 | 0.98 | 0.71 | 0.46 |
| | 201-300 | 1,038 | 1,116 | 206 | 0.65 | 0.69 | 0.78 |
| | 301-500 | 362 | 0 | 2 | 1.00 | 0.00 | 0.71 |
| | 501-900 | 0 | 0 | 37 | 0.00 | 0.00 | 1.00 |
| | Total | 96,650 | 54,281 | 42,135 | 0.69 | 0.57 | 0.46 |

Table 12.5 Atka mackerel biomass (mt), and the percentage distribution and coefficients of variation by management area from the bottom trawl surveys in the Aleutian Islands in 1991, 1994, and 1997. Biomass is also reported by survey depth interval.

| Area | Depth (m) | Biomass (mt) | | | Percent Distribution | | | Coefficient of Variation | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1991 | 1994 | 1997 | 1991 | 1994 | 1997 | 1991 | 1994 | 199’ |
| Aleutian Islands | 1-100 | 349,146 | 114,558 | 144,592 | | | | | | |
| | 101-200 | 338,563 | 507,107 | 203,235 | | | | | | |
| | 201-300 | 441 | 2,140 | 161 | | | | | | |
| | 301-500 | - | 21 | 20 | | | | | | |
| | Total | 688,150 | 623,826 | 348,007 | 100% | 100% | 100% | 0.266 | 0.366 | 0.27’ |
| Western 543 | 1-100 | 100,045 | 68,699 | 63,448 | | | | | | |
| | 101-200 | 205,879 | 253,020 | 47,525 | | | | | | |
| | 201-300 | 163 | 2,107 | 76 | | | | | | |
| | 301-500 | - | 6 | | | | | | | |
| | Total | 306,087 | 323.832 | 111,050 | 44.5% | 51.9% | 31.9% | 0.445 | 0.627 | 0.54. |
| Central 542 | 1-100 | 181,439 | 45,299 | 57,977 | | | | | | |
| | 101-200 | 126,074 | 42,090 | 136,230 | | | | | | |
| | 201-300 | 101 | 16 | 76 | | | | | | |
| | 301-500 | | 3 | 5 | | | | | | |
| | Total | 307,614 | 87,408 | 194,289 | 44.7% | 14.0% | 55.8% | 0.355 | 0.445 | 0.35 |
| Eastern 541 | 1-100 | 67,662 | 560 | 23,166 | | | | | | |
| | 101-200 | 6,610 | 211,997 | 19,479 | | | | | | |
| | 201-300 | 177 | 17 | 9 | | | | | | |
| | 301-500 | - | 12 | 14 | | | | | | |
| | Total | 74,449 | 212,586 | 42,669 | 10.8% | 34.1% | 12.3% | 0.753 | 0.445 | 0.65 |
| Bering Sea | 1-100 | 59 | 93,170 | 128,000 | | | | | | |
| | 101-200 | 4 | 80 | 32 | | | | | | |
| | 201-300 | 25 | 4 | | | | | | | |
| | 301-500 | - | 7 | | | | | | | |
| | Total | 88 | 93,261 | 128,032 | | | | 0.261 | 0.991 | 0.98 |

Table 12.6 Mean weight-at-age values (kg) for Atka mackerel from the Aleutian trawl surveys and the commercial fishery. The survey weight-at-age vector was derived from the 1986, 1991, and 1994 weight-at-age data; the fishery weight-at-age data was derived from fishery weight-at-age data from 1990 to 1996.

| Age | Survey | Fishery |
|---|---|---|
| 2 | 0.184 | 0.128 |
| 3 | 0.398 | 0.421 |
| 4 | 0.549 | 0.660 |
| 5 | 0.656 | 0.756 |
| 6 | 0.732 | 0.794 |
| 7 | 0.785 | 0.810 |
| 8 | 0.823 | 0.816 |
| 9 | 0.850 | 0.818 |
| 10 | 0.869 | 0.819 |
| 11 | 0.882 | 0.820 |
| 12 | 0.892 | 0.820 |
| 13 | 0.899 | 0.820 |
| 14 | 0.903 | 0.820 |
| 15 | 0.907 | 0.820 |

Table 12.7 Schedules of age and length specific maturity of Atka mackerel from McDermott and Lowe (1997) by Aleutian Islands subareas. Eastern - 541, Central - 542, and Western - 543.

| | Proportion mature | | |
|---|---|---|---|
| Length (cm) | 541 | 542 | 543 |
| 25 | 0.00 | 0.00 | 0.00 |
| 26 | 0.00 | 0.00 | 0.00 |
| 27 | 0.00 | 0.01 | 0.01 |
| 28 | 0.00 | 0.02 | 0.02 |
| 29 | 0.01 | 0.04 | 0.04 |
| 30 | 0.01 | 0.07 | 0.07 |
| 31 | 0.03 | 0.14 | 0.13 |
| 32 | 0.06 | 0.25 | 0.24 |
| 33 | 0.11 | 0.40 | 0.39 |
| 34 | 0.20 | 0.58 | 0.56 |
| 35 | 0.34 | 0.73 | 0.72 |
| 36 | 0.51 | 0.85 | 0.84 |
| 37 | 0.68 | 0.92 | 0.92 |
| 38 | 0.81 | 0.96 | 0.96 |
| 39 | 0.90 | 0.98 | 0.98 |
| 40 | 0.95 | 0.99 | 0.99 |
| 41 | 0.97 | 0.99 | 0.99 |
| 42 | 0.99 | 1.00 | 1.00 |
| 43 | 0.99 | 1.00 | 1.00 |
| 44 | 1.00 | 1.00 | 1.00 |
| 45 | 1.00 | 1.00 | 1.00 |
| 46 | 1.00 | 1.00 | 1.00 |
| 47 | 1.00 | 1.00 | 1.00 |
| 48 | 1.00 | 1.00 | 1.00 |
| 49 | 1.00 | 1.00 | 1.00 |
| 50 | 1.00 | 1.00 | 1.00 |

| Age | Proportion mature |
|---|---|
| 1 | 0.00 |
| 2 | 0.04 |
| 3 | 0.22 |
| 4 | 0.69 |
| 5 | 0.94 |
| 6 | 0.99 |
| 7 | 1.00 |
| 8 | 1.00 |
| 9 | 1.00 |
| 10 | 1.00 |

Table 12.8 Atka mackerel age specific selectivities (percent) for fishery and survey data as estimated by stock synt

| | Age | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Fishery (1977-83) | 2 | 31 | 87 | 100 | 99 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Fishery (1984-98) | 2 | 19 | 79 | 97 | 100 | 95 | 83 | 71 | 59 | 47 | 35 | 23 |
| Survey (indices) | 1 | 16 | 73 | 97 | 100 | 99 | 65 | 3 | 0 | 0 | 0 | 0 |
| Survey (absolute) | 6 | 100 | 100 | 94 | 85 | 71 | 54 | 37 | 24 | 16 | 12 | 10 |

Table 12.9 Estimated time series of Atka mackerel female spawning biomass (1000s mt) and age 3+ biomass ( 1000s mt) as estimated by stock synthesis in the current assessment. Estimated age 3+ biomass from last year's assessments is given for comparison.

| | Current Assessment | | Last Year's Assessment |
|---|---|---|---|
| Year | Female Spawning Biomass | Age 3+ Biomass | Age 3+ Biomass |
| 1977 | 70.6 | 238.4 | 240.9 |
| 1978 | 87.2 | 423.1 | 423.9 |
| 1979 | 131.8 | 442.2 | 442.6 |
| 1980 | 193.6 | 962.4 | 960.6 |
| 1981 | 300.1 | 992.7 | 990.2 |
| 1982 | 334.1 | 927.1 | 924.4 |
| 1983 | 311.2 | 851.3 | 848.7 |
| 1984 | 274.1 | 755.3 | 752.8 |
| 1985 | 236.2 | 688.8 | 686.4 |
| 1986 | 219.6 | 695.3 | 693.0 |
| 1987 | 238.8 | 888.5 | 886.8 |
| 1988 | 295.0 | 1013.2 | 1011.9 |
| 1989 | 351.5 | 1188.3 | 1187.8 |
| 1990 | 393.2 | 1156.7 | 1156.7 |
| 1991 | 412.2 | 1381.4 | 1383.4 |
| 1992 | 436.7 | 1302.2 | 1304.7 |
| 1993 | 407.1 | 1117.9 | 1120.7 |
| 1994 | 345.7 | 1006.0 | 1009.3 |
| 1995 | 305.5 | 1016.0 | 1021.6 |
| 1996 | 278.6 | 846.2 | 852.1 |
| 1997 | 234.5 | 679.0 | 684.7 |
| 1998 | 196.9 | 613.9 | 628.3 |
| 1999 | 156.9 | 588.1 | |

Table 12.10 Atka mackerel numbers at age as estimated by stock synthesis (millions). Zero values denote less than 1,000 fish.

| | Age | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 77 | 816.9 | 178.9 | 54.2 | 35.0 | 0.0 | 7.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 119.7 |
| 78 | 245.4 | 602.1 | 122.3 | 32.2 | 20.1 | 0.0 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 83.8 |
| 79 | 2019.9 | 181.3 | 426.6 | 80.1 | 20.7 | 13.0 | 0.0 | 3.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 60.1 |
| 80 | 346.0 | 1494.1 | 131.1 | 295.8 | 55.0 | 14.2 | 9.4 | 0.0 | 2.7 | 0.0 | 0.0 | 0.0 | 0.0 | 43.8 |
| 81 | 266.3 | 256.1 | 1091.8 | 93.5 | 209.9 | 39.1 | 10.4 | 6.9 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 32.1 |
| 82 | 313.3 | 197.2 | 188.2 | 791.3 | 67.6 | 151.6 | 28.8 | 7.7 | 5.1 | 0.0 | 1.4 | 0.0 | 0.0 | 23.7 |
| 83 | 213.8 | 23 1.9 | 144.8 | 136.0 | 569.9 | 48.7 | 111.6 | 21.2 | 5.7 | 3.8 | 0.0 | 1.1 | 0.0 | 17.4 |
| 84 | 359.2 | 158.3 | 170.8 | 105.5 | 98.9 | 414.1 | 35.9 | 82.3 | 15.6 | 4.2 | 2.8 | 0.0 | 0.8 | 12.9 |
| 85 | 546.9 | 265.8 | 115.8 | 120.2 | 73.3 | 68.6 | 288.5 | 25.2 | 58.2 | 11.1 | 3.0 | 2.0 | 0.0 | 10.1 |
| 86 | 1113.0 | 404.5 | 193.6 | 80.1 | 81.9 | 49.9 | 46.9 | 199.0 | 17.6 | 41.0 | 7.9 | 2.2 | 1.5 | 7.5 |
| 87 | 856.5 | 823.2 | 294.9 | 134.5 | 54.9 | 56.0 | 34.2 | 32.5 | 13912 | 12.4 | 29.2 | 5.7 | 1.6 | 6.6 |
| 88 | 1084.8 | 633.7 | 601.9 | 207.2 | 93.4 | 38.1 | 38.9 | 24.0 | 22.9 | 99.1 | 8.9 | 21.2 | 4.2 | 6.0 |
| 89 | 446.2 | 803.1 | 466. I | 433.4 | 148.3 | 66.8 | 27.2 | 28.0 | 17.3 | 16.6 | 72.2 | 6.5 | 15.5 | 7.5 |
| 90 | 1436.2 | 330.4 | 592.1 | 338.8 | 3 13.6 | 107.2 | 48.4 | 19.8 | 20.4 | 12.7 | 12.2 | 53.0 | 4.8 | 17.1 |
| 91 | 411.8 | 1063.4 | 243.5 | 429.6 | 244.7 | 226.4 | 77.5 | 35.1 | 14.4 | 14.9 | 9.3 | 8.9 | 39.0 | 16.2 |
| 92 | 233.5 | 304.9 | 782.9 | 175.9 | 308.7 | 175.6 | 162.8 | 55.9 | 25.4 | 10.5 | 10.9 | 6.8 | 6.6 | 40.8 |
| 93 | 510.4 | 172.8 | 223.5 | 555.9 | 123.7 | 216.8 | 123.7 | 115.3 | 39.9 | 18.2 | 7.6 | 7.9 | 5.0 | 35.1 |
| 94 | 841.1 | 377.5 | 126.0 | 155.4 | 381.1 | 84.7 | 148.9 | 85.8 | 80.7 | 28.2 | 13.0 | 5.4 | 5.7 | 29.6 |
| 95 | 186.5 | 621.7 | 273.8 | 85.8 | 103.8 | 253.8 | 56.7 | 101.0 | 58.9 | 56.1 | 19.8 | 9.3 | 3.9 | 26.1 |
| 96 | 245.2 | 137.8 | 447.7 | 180.9 | 55.2 | 66.6 | 164.0 | 37.2 | 67.5 | 40.0 | 38.8 | 14.0 | 6.6 | 22.2 |
| 97 | 392.4 | 180.9 | 98.3 | 284.5 | 111.1 | 33.7 | 41.1 | 103.5 | 24.0 | 44.6 | 27.1 | 26.9 | 9.9 | 21.3 |
| .98 | 425.0 | 289.8 | 130.0 | 64.3 | 181.2 | 70.5 | 21.6 | 26.7 | 68.6 | 16.2 | 30.7 | 19.0 | 19.2 | 22.9 |
| 99 | 425.0 | 313.8 | 207.9 | 84.6 | 40.7 | 114.1 | 44.7 | 14.0 | 17.6 | 46.1 | 11.1 | 21.4 | 13.5 | 30.9 |

Table 12.1 I Estimated age 2 recruits (millions of Atka mackerel) from the current assessment and last year's assessment.

| Year | Current Assessment | Last Year's Assessment |
|---|---|---|
| 1977 | 816.9 | 813.9 |
| 1978 | 245.4 | 245.8 |
| 1979 | 2019.9 | 2013.0 |
| 1980 | 346.0 | 344.3 |
| 1981 | 266.0 | 265.0 |
| 1982 | 313.3 | 312.1 |
| 1983 | 213.8 | 213.0 |
| 1984 | 359.2 | 358.3 |
| 1985 | 546.9 | 545.7 |
| 1986 | 1113.0 | 1113.6 |
| 1987 | 856.5 | 856.6 |
| 1988 | 1084.8 | 1086.6 |
| 1989 | 446.2 | 446.9 |
| 1990 | 1436.2 | 1442.5 |
| 1991 | 411.8 | 413.1 |
| 1992 | 233.5 | 235.3 |
| 1993 | 510.4 | 513.6 |
| 1994 | 841.1 | 850.2 |
| 1995 | 186.5 | 189.2 |
| 1996 | 245.2 | 247.2 |
| 1997 | 392.4 | |

Table 12.12 Time series of historical fishing mortality rates for Atka mackerel, and catch/biomass (age 3+) rates estimated by stock synthesis.

| Year | F[a] | Catch/Biomass Rate[b] |
|---|---|---|
| 1977 | 0.25 | 0.09 |
| 1978 | 0.14 | 0.06 |
| 1979 | 0.08 | 0.05 |
| 1980 | 0.04 | 0.02 |
| 1981 | 0.03 | 0.02 |
| 1982 | 0.03 | 0.02 |
| 1983 | 0.02 | 0.01 |
| 1984 | 0.06 | 0.05 |
| 1985 | 0.09 | 0.05 |
| 1986 | 0.08 | 0.05 |
| 1987 | 0.07 | 0.03 |
| 1988 | 0.04 | 0.02 |
| 1989 | = 0.02 | 0.02 |
| 1990 | 0.03 | 0.02 |
| 1991 | 0.03 | 0.02 |
| 1992 | 0.05 | 0.04 |
| 1993 | 0.08 | 0.06 |
| 1994 | 0.11 | 0.07 |
| 1995 | 0.14 | 0.08 |
| 1996 | 0.19 | 0.12 |
| 1997 | 0.16 | 0.10 |
| 1998 | 0.16 | 0.09 |
| 1999' | 0.21 | 0.11 |

a/ Fishing mortality rate on fully-recruited fish.

b/ Catch/biomass rate is the catch to beginning year biomass (ages 3+) ratio.

c/ The 1999 fishing mortality and catch/biomass rates are likely over-estimates, as the 1999 TAC was used as a proxy for 1999 catch and the full 1999 TAC may not be utilized.

Table 12.13 Projections of Bering Sea/Aleutian Islands Atka mackerel female spawning biomass (1000 mt), yield (1000 mt), and full-selection fishing mortality rate for seven future harvest scenarios. The average recruitment from the stochastic projections is 622 million recruits which gives $B_{40\%}$ and $B_{35\%}$ levels (female spawning biomass) of 154,300 and 135,000 mt, respectively.

Scenario 1

Maximum Permissible $F_{ABC}$ (max $F_{ABC}$)

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.396 | 0.21 |
| 2000 | 156.864 | 102.682 | 0.35 |
| 2001 | 146.521 | 92.832 | 0.33 |
| 2002 | 160.626 | 102.172 | 0.32 |
| 2003 | 156.529 | 111.705 | 0.32 |
| 2004 | 160.004 | 117.569 | 0.32 |
| 2005 | 161.821 | 121.048 | 0.32 |
| 2006 | 162.515 | 123.023 | 0.32 |
| 2007 | 162.197 | 123.239 | 0.32 |
| 2008 | 162.105 | 123.796 | 0.32 |
| 2009 | 162.223 | 124.578 | 0.32 |
| 2010 | 161.485 | 123.437 | 0.32 |
| 2011 | 161.698 | 123.955 | 0.32 |
| 2012 | 161.799 | 124.214 | 0.32 |

Scenario 2

F = 0.74 of max $F_{ABC}$

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.396 | 0.21 |
| 2000 | 182.536 | 78.550 | 0.26 |
| 2001 | 158.278 | 76.868 | 0.25 |
| 2002 | 166.307 | 85.923 | 0.25 |
| 2003 | 175.729 | 94.726 | 0.25 |
| 2004 | 182.088 | 100.834 | 0.25 |
| 2005 | 186.074 | 104.326 | 0.25 |
| 2006 | 188.338 | 106.563 | 0.25 |
| 2007 | 189.068 | 107.213 | 0.25 |
| 2008 | 189.647 | 107.825 | 0.25 |
| 2009 | 190.242 | 108.699 | 0.25 |
| 2010 | 189.769 | 107.961 | 0.25 |
| 2011 | 190.099 | 108.340 | 0.25 |
| 2012 | 190.385 | 108.388 | 0.25 |

Scenario 3

50% of max $F_{ABC}$

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.396 | 0.21 |
| 2000 | 168.000 | 54.754 | 0.18 |
| 2001 | 170.736 | 57.408 | 0.17 |
| 2002 | 184.091 | 65.566 | 0.17 |
| 2003 | 198.397 | 73.097 | 0.17 |
| 2004 | 208.957 | 78.430 | 0.17 |
| 2005 | 216.320 | 81.965 | 0.17 |
| 2006 | 221.219 | 84.123 | 0.17 |
| 2007 | 223.911 | 85.024 | 0.17 |
| 2008 | 225.875 | 85.733 | 0.17 |
| 2009 | 227.530 | 86.489 | 0.17 |
| 2010 | 227.799 | 86.117 | 0.17 |
| 2011 | 228.801 | 86.403 | 0.17 |
| 2012 | 229.274 | 86.499 | 0.17 |

Scenario 4

F = to the 1994-1998 average F

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.394 | 0.21 |
| 2000 | 169.753 | 47.007 | 0.15 |
| 2001 | 174.926 | 50.493 | 0.15 |
| 2002 | 190.172 | 58.576 | 0.15 |
| 2003 | 206.205 | 65.516 | 0.15 |
| 2004 | 218.330 | 70.400 | 0.15 |
| 2005 | 227.047 | 73.608 | 0.15 |
| 2006 | 233.085 | 75.580 | 0.15 |
| 2007 | 236.693 | 76.434 | 0.15 |
| 2008 | 239.370 | 77.055 | 0.15 |
| 2009 | 241.604 | 77.706 | 0.15 |
| 2010 | 242.314 | 77.434 | 0.15 |
| 2011 | 243.414 | 77.733 | 0.15 |
| 2012 | 244.319 | 77.827 | 0.15 |

Scenario 5

F=O

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.394 | 0.21 |
| 2000 | 180.136 | 0 | 0 |
| 2001 | 202249 | 0 | 0 |
| 2002 | 233.893 | 0 | 0 |
| 2003 | 266.360 | 0 | 0 |
| 2004 | 293.831 | 0 | 0 |
| 2005 | 316.042 | 0 | 0 |
| 2006 | 333.462 | 0 | 0 |
| zoo7 | 346.300 | 0 | 0 |
| 2008 | 366.194 | 0 | 0 |
| 2009 | 364.124 | 0 | 0 |
| 2010 | 369.204 | 0 | 0 |
| 2011 | 373.501 | 0 | 0 |
| 2012 | 378.901 | 0 | 0 |

Table 12.13 cont. Projections of Bering Sea/Aleutian Islands Atka mackerel female spawning biomass (1000 mt), yield (1000 mt), and full-selection fishing mortality rate for seven future harvest scenarios. The average recruitment from the stochastic projections is 622 million recruits which gives ***B,,*** and $B_{35\%}$ levels (female spawning biomass) of 154,300 and 135,000 mt, respectively.

**Scenario 6**

**$F = F_{OFL}$**

**Determination if Atka mackerel are overfished**

| Year | Female Spawning biomass | Yield | $F$ |
|---|---|---|---|
| 1999 | 175.650 | 66.396 | 0.21 |
| 2000 | 152.888 | 119.280 | 0.42 |
| 2001 | 139.115 | 100.979 | 0.38 |
| 2002 | 141.347 | 111.164 | 0.37 |
| 2003 | 145.427 | 121.129 | 0.37 |
| 2004 | 147.445 | 126.783 | 0.37 |
| 2005 | 148.275 | 129.764 | 0.37 |
| 2006 | 148.304 | 131.646 | 0.37 |
| 2007 | 147.630 | 131.334 | 0.37 |
| 2008 | 147.400 | 131.773 | 0.37 |
| 2009 | 147.417 | 132.639 | 0.37 |
| 2010 | 146.637 | 131.318 | 0.37 |
| 2011 | 146.799 | 132.144 | 0.37 |
| 2012 | 146.789 | 132.411 | 0.37 |

**Scenario 7**

**$F$ = to max $F_{ABC}$ in 2000 and 2001, and $F_{OFL}$ in all subsequent years**

**Determination if Atka mackerel are approaching an overfished condition**

| Year | Female Spawning biomass | Yield | $F$ |
|---|---|---|---|
| 1999 | 175.650 | 66.484 | 0.21 |
| 2000 | 156.864 | 102.682 | 0.35 |
| 2001 | 146.521 | 92.832 | 0.33 |
| 2002 | 147.075 | 118.617 | 0.38 |
| 2003 | 148.322 | 124.274 | 0.38 |
| 2004 | 146.860 | 127.990 | 0.37 |
| 2005 | 149.995 | 130.208 | 0.37 |
| 2006 | 148.702 | 131.791 | 0.37 |
| 2007 | 147.873 | 131.377 | 0.37 |
| 2008 | 147.559 | 131.784 | 0.37 |
| 2009 | 147.527 | 132.637 | 0.37 |
| 2010 | 146.715 | 131.313 | 0.37 |
| 2011 | 146.856 | 132.133 | 0.37 |
| 2012 | 146.831 | 132.408 | 0.37 |

Table 12.14 Projections of Bering Sea/Aleutian Islands Atka mackerel female spawning biomass (1000 mt), yield (1000 mt), and full-selection fishing mortality rate for seven future harvest scenarios under an alternative assumption of recruitment using estimated recruitment from 1988- 1997 (average recruitment equal to 579 million fish).

**Scenario 1**
**Maximum Permissible $F_{ABC}$ (max $F_{ABC}$)**

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.396 | 0.21 |
| 2000 | 156.734 | 102.646 | 0.35 |
| 2001 | 144.336 | 95.683 | 0.34 |
| 2002 | 144.710 | 99.418 | 0.33 |
| 2003 | 147.946 | 105.816 | 0.33 |
| 2004 | 149.974 | 110.141 | 0.33 |
| 2005 | 151.104 | 113.027 | 0.33 |
| 2006 | 151.441 | 114.726 | 0.33 |
| 2007 | 150.817 | 114.657 | 0.33 |
| 2008 | 150.493 | 115.023 | 0.33 |
| 2009 | 150.488 | 115.645 | 0.33 |
| 2010 | 149.843 | 114.740 | 0.32 |
| 2011 | 150.063 | 115.347 | 0.32 |
| 2012 | 150.116 | 115.539 | 0.32 |

**Scenario 2**
*F = 0.74 of max $F_{ABC}$*

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.649 | 66.396 | 0.21 |
| 2000 | 164.202 | 70.762 | 0.23 |
| 2001 | 160.550 | 71.868 | 0.23 |
| 2002 | 166.436 | 77.946 | 0.23 |
| 2003 | 173.974 | 84.081 | 0.23 |
| 2004 | 179.368 | 88.523 | 0.23 |
| 2005 | 183.021 | 91.528 | 0.23 |
| 2006 | 185.235 | 93.378 | 0.23 |
| 2007 | 185.895 | 93.818 | 0.23 |
| 2008 | 186.383 | 94.294 | 0.23 |
| 2009 | 186.949 | 95.009 | 0.23 |
| 2010 | 166.635 | 94.513 | 0.23 |
| 2011 | 187.038 | 94.885 | 0.23 |
| 2012 | 187.329 | 94.950 | 0.23 |

**Scenario 3**
**50% of max $F_{ABC}$**

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.394 | 0.21 |
| 2000 | 167.870 | 54.736 | 0.18 |
| 2001 | 169.263 | 57.480 | 0.18 |
| 2002 | 178.952 | 64.039 | 0.17 |
| 2003 | 189.648 | 69.763 | 0.17 |
| 2004 | 197.648 | 73.937 | 0.17 |
| 2005 | 203.375 | 76.810 | 0.17 |
| 2006 | 207.215 | 78.593 | 0.17 |
| 2007 | 209.083 | 79.208 | 0.17 |
| 2008 | 210.422 | 79.725 | 0.17 |
| 2009 | 211.647 | 80.336 | 0.17 |
| 2010 | 211.810 | 80.017 | 0.17 |
| 2011 | 212.530 | 80.334 | 0.17 |
| 2012 | 213.079 | 80.423 | 0.17 |

**Scenario 4**
**F = to the 1994-1998 average F**

| Year | Female Spawning biomass | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.395 | 0.21 |
| 2000 | 169.623 | 48.992 | 0.15 |
| 2001 | 173.565 | 50.121 | 0.15 |
| 2002 | 185.300 | 56.667 | 0.15 |
| 2003 | 197.708 | 62.269 | 0.15 |
| 2004 | 207.129 | 66.217 | 0.15 |
| 2005 | 214.028 | 68.876 | 0.15 |
| 2006 | 218.827 | 70.543 | 0.15 |
| 2007 | 221.450 | 71.155 | 0.15 |
| 2008 | 223.361 | 71.611 | 0.15 |
| 2009 | 225.048 | 72.135 | 0.15 |
| 2010 | 225.561 | 71.902 | 0.15 |
| 2011 | 226.519 | 72.213 | 0.15 |
| 2012 | 227.260 | 72.292 | 0.15 |

**Scenario 5**
*F=O*

| Year | Female Spawning biomss | Yield | F |
|---|---|---|---|
| 1999 | 175.650 | 66.395 | 0.21 |
| 2wo | 160.005 | 0 , | 0 |
| 2001 | 200.863 | 0 | 0 |
| 2002 | 228.611 | 0 | 0 |
| 2003 | 256.457 | 0 | 0 |
| 2004 | 279.934 | 0 | 0 |
| 2005 | 299.001 | 0 | 0 |
| 2006 | 313.988 | 0 | 0 |
| 2007 | 324.820 | 0 | 0 |
| 2008 | 333.087 | 0 | 0 |
| 2009 | 339.754 | 0 | 0 |
| 2010 | 344.075 | 0 | 0 |
| 2011 | 347.831 | 0 | 0 |
| 2012 | 350.768 | 0 | 0 |

Table 12.14 cont. Projections of Bering Sea/Aleutian Islands Atka mackerel female spawning biomass (1000 mt), yield ( 1000 mt), and full-selection fishing mortality rate for seven future harvest scenarios, under an alternative assumption of recruitment using estimated recruitment from 1988- 1997 (average recruitment equal to 579 million fish).

**Scenario 6**

$F = F_{OFL}$

**Determination if Atka mackerel are overfished**

| Year | Female Spawning biomss | Yield | $F$ |
|---|---|---|---|
| 1999 | 175.650 | 66.396 | 0.21 |
| 2000 | 152.502 | 120.272 | 0.42 |
| 2001 | 136.474 | 104.193 | 0.40 |
| 2002 | 135.152 | 107.676 | 0.38 |
| 2003 | 136.963 | 114.267 | 0.38 |
| 2004 | 137.888 | 118.457 | 0.38 |
| 2005 | 138.278 | 120.975 | 0.37 |
| 2006 | 138.099 | 122.659 | 0.37 |
| 2007 | 137.207 | 122.111 | 0.37 |
| 2008 | 136.806 | 122.355 | 0.37 |
| 2009 | 136.751 | 123.041 | 0.37 |
| 2010 | 136.092 | 122.012 | 0.37 |
| 2011 | 136.270 | 122.928 | 0.37 |
| 2012 | 136.232 | 123.088 | 0.37 |

**Scenario 7**

**$F$ = to max $F_{ABC}$ in 2000 and 2001, and $F_{OFL}$ in all subsequent years**

**Determination if Atka mackerel are approaching an overfished condition**

| Year | Female Spawning biomss | Yield | $F$ |
|---|---|---|---|
| 1999 | 176.060 | 66.483 | 0.21 |
| 2000 | 160.541 | 105.248 | 0.35 |
| 2001 | 154.397 | 105.440 | 0.34 |
| 2002 | 149.665 | 126.253 | 0.40 |
| 2003 | 144.790 | 123.519 | 0.39 |
| 2004 | 142.088 | 123.032 | 0.33 |
| 2005 | 140.322 | 123.392 | 0.38 |
| 2006 | 138.599 | 122.342 | 0.38 |
| 2007 | 137.739 | 122.400 | 0.37 |
| 2008 | 137.399 | 123.042 | 0.37 |
| 2009 | 136.551 | 121.999 | 0.37 |
| 2010 | 136.600 | 122.910 | 0.37 |
| 2011 | 136.471 | 123.076 | 0.37 |
| 2012 | 138.280 | 123.326 | 0.37 |

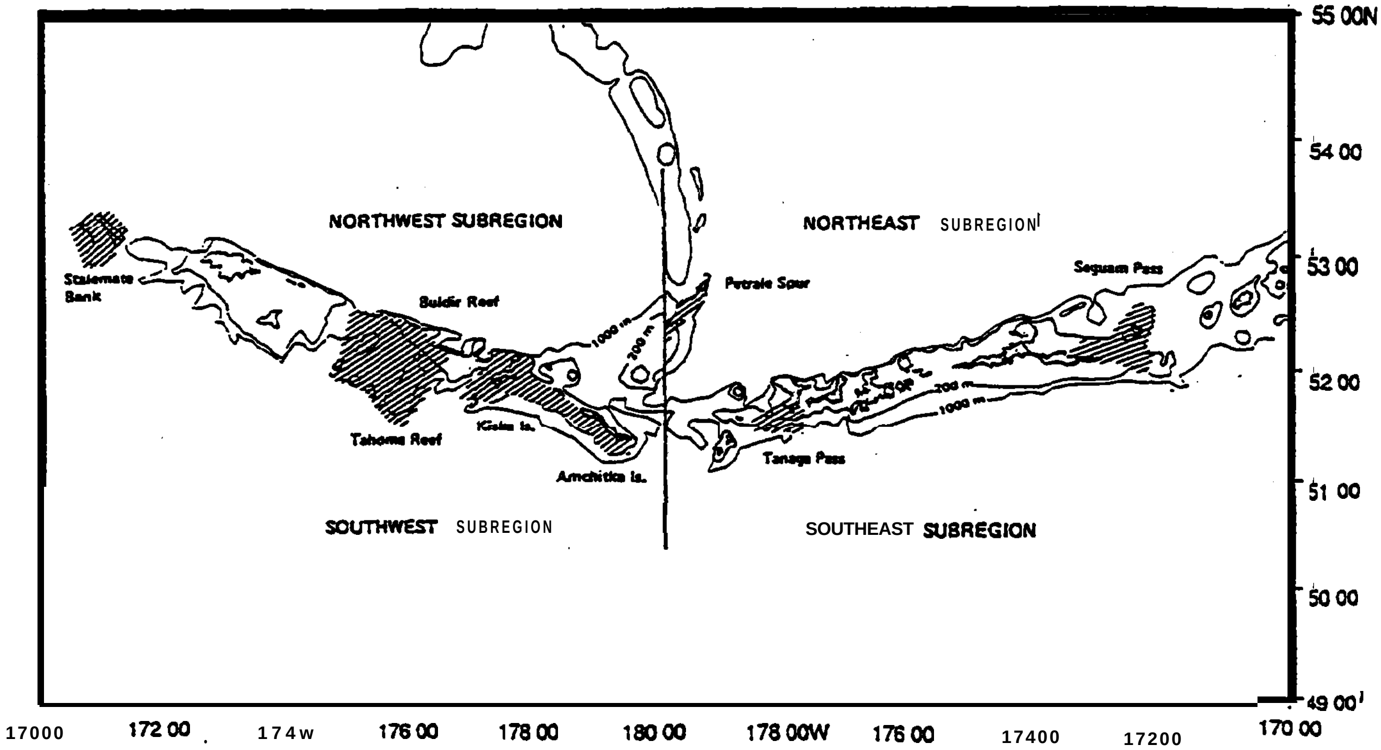



Figure 12.1 Map of the Aleutian Islands region showing major concentrations of Atka mackerel found in resource assessment surveys.

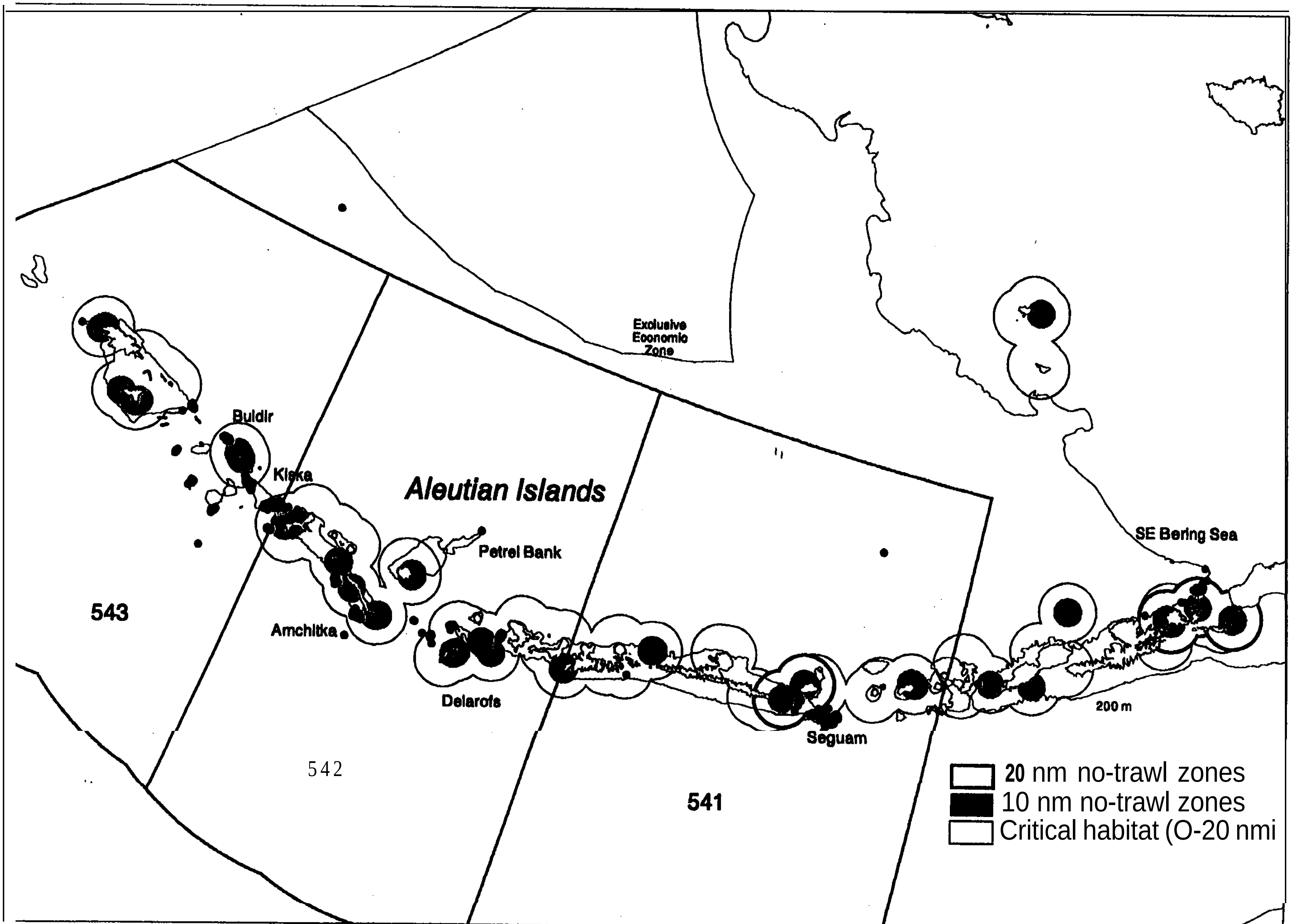



Figure 12.2.a. Observed trawl locations of the **1998** Atka mackerel fishery in the Aleutian Islands and SE Bering Sea.

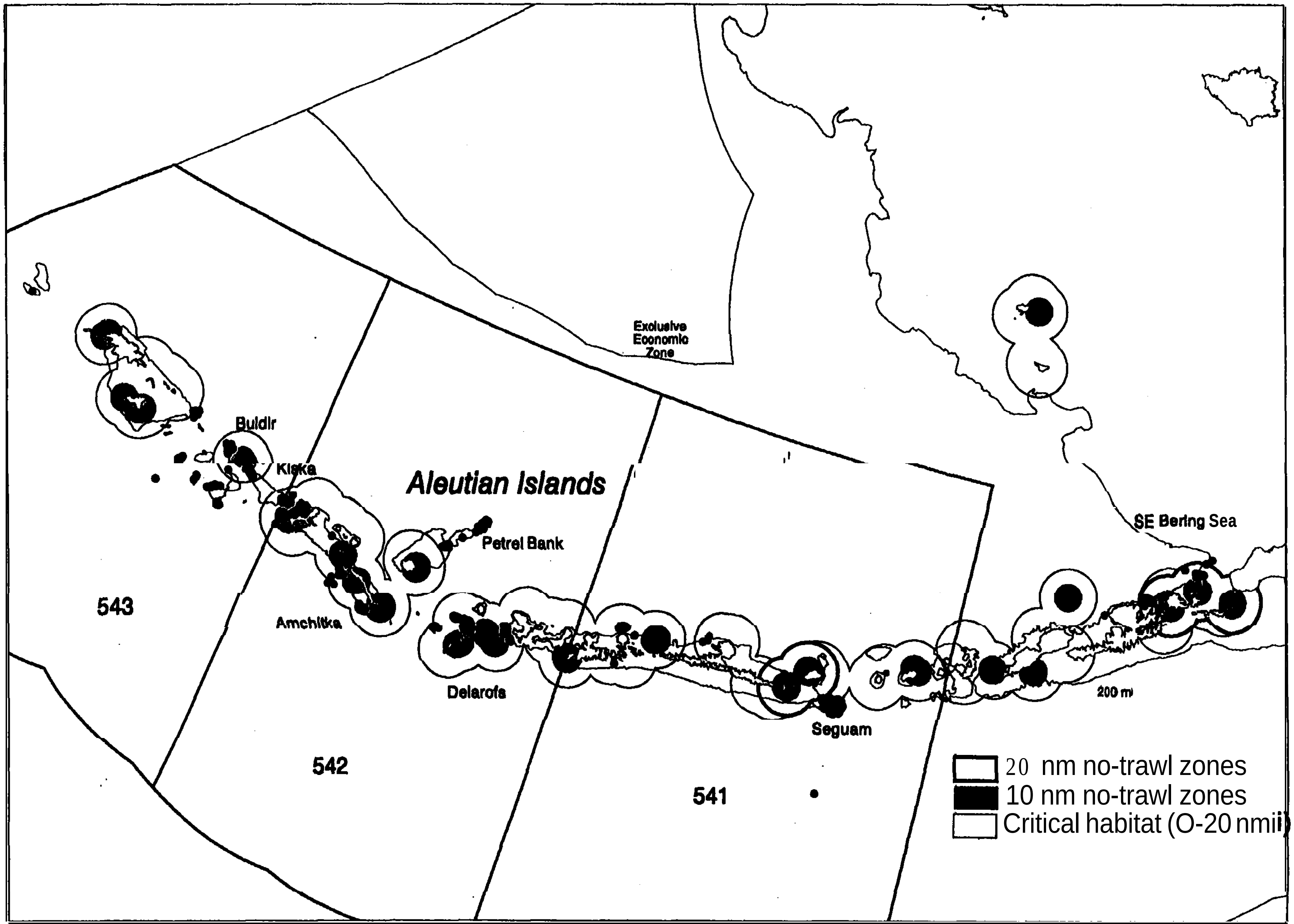



Figure 12.2.b. Observed trawl locations of the **1999** Atka mackerel fishery in the Aleutian Islands and SE Bering Sea (preliminary data).

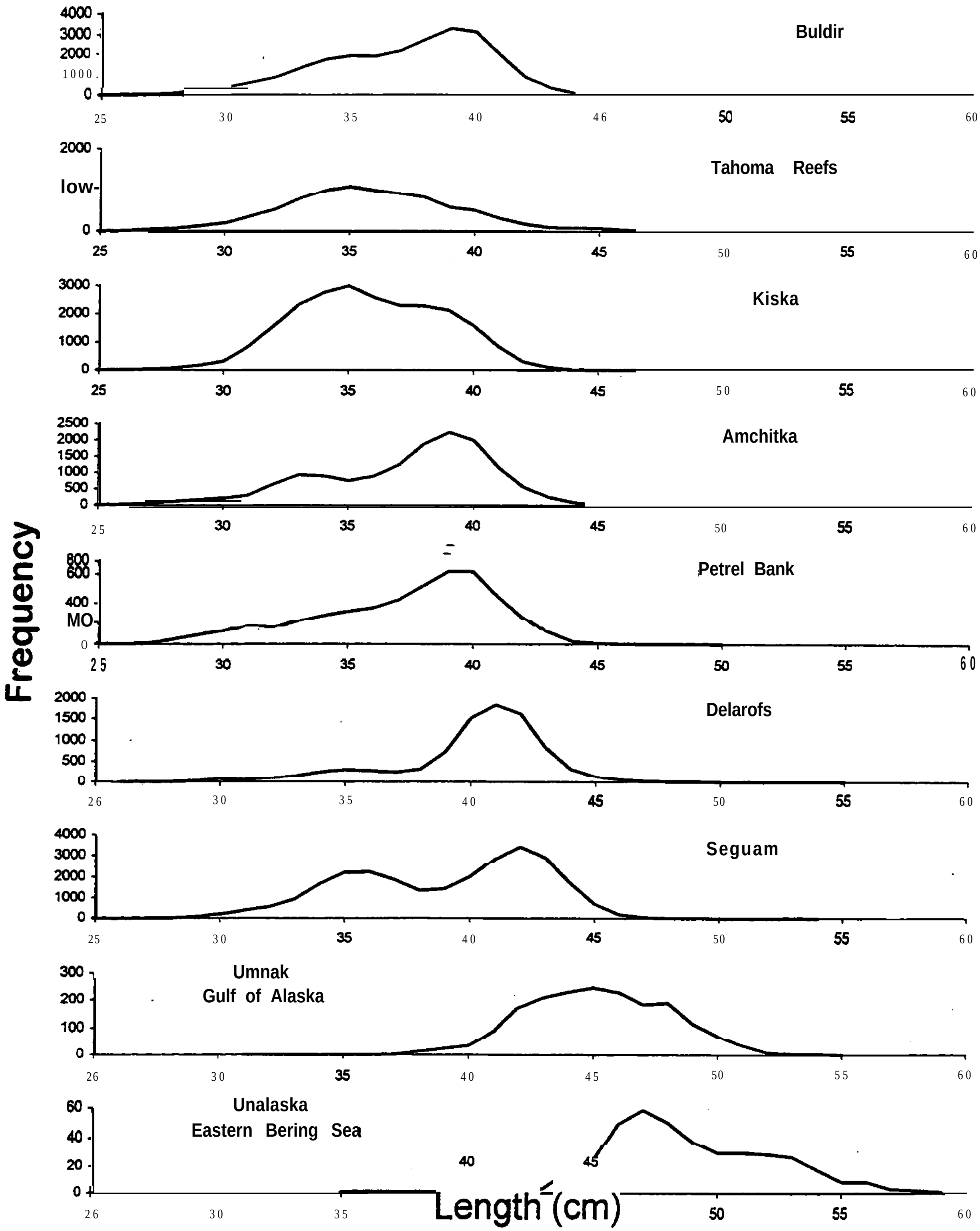



Figure 12.3. Atka mackerel length-frequency distributions caught by the fishery at various locations in 1996 from west (top) to east in the Aleutian Islands (top 7 panels), Gulf of Alaska (Umnak Island), and eastern Bering Sea management areas (Unalaska Island).

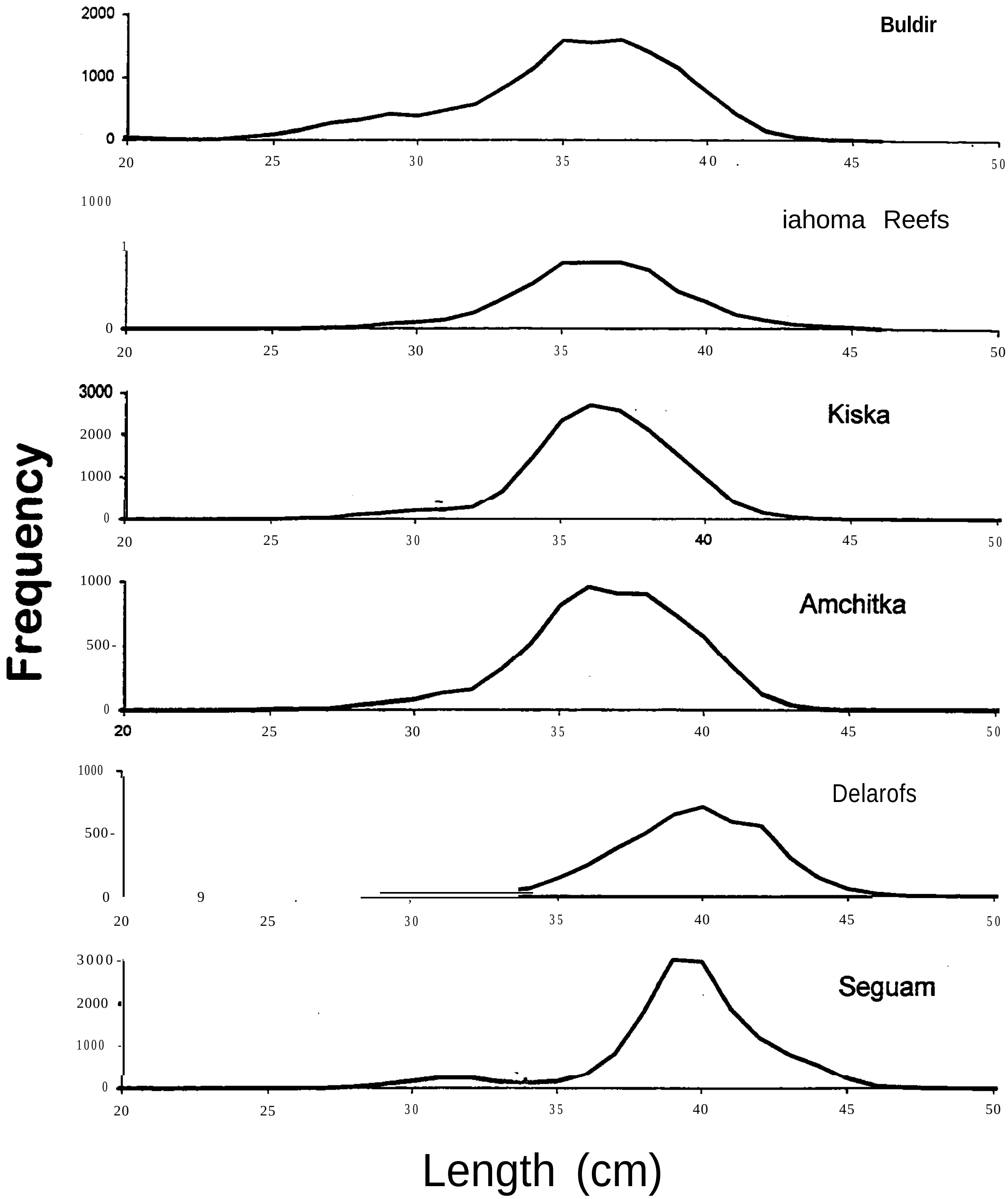



**Figure 12.4. Atka mackerel length-frequency distributions caught by the fishery at various locations in 1997 from west (top) to east in the Aleutian Islands. See Figure 12.2 for locations.**

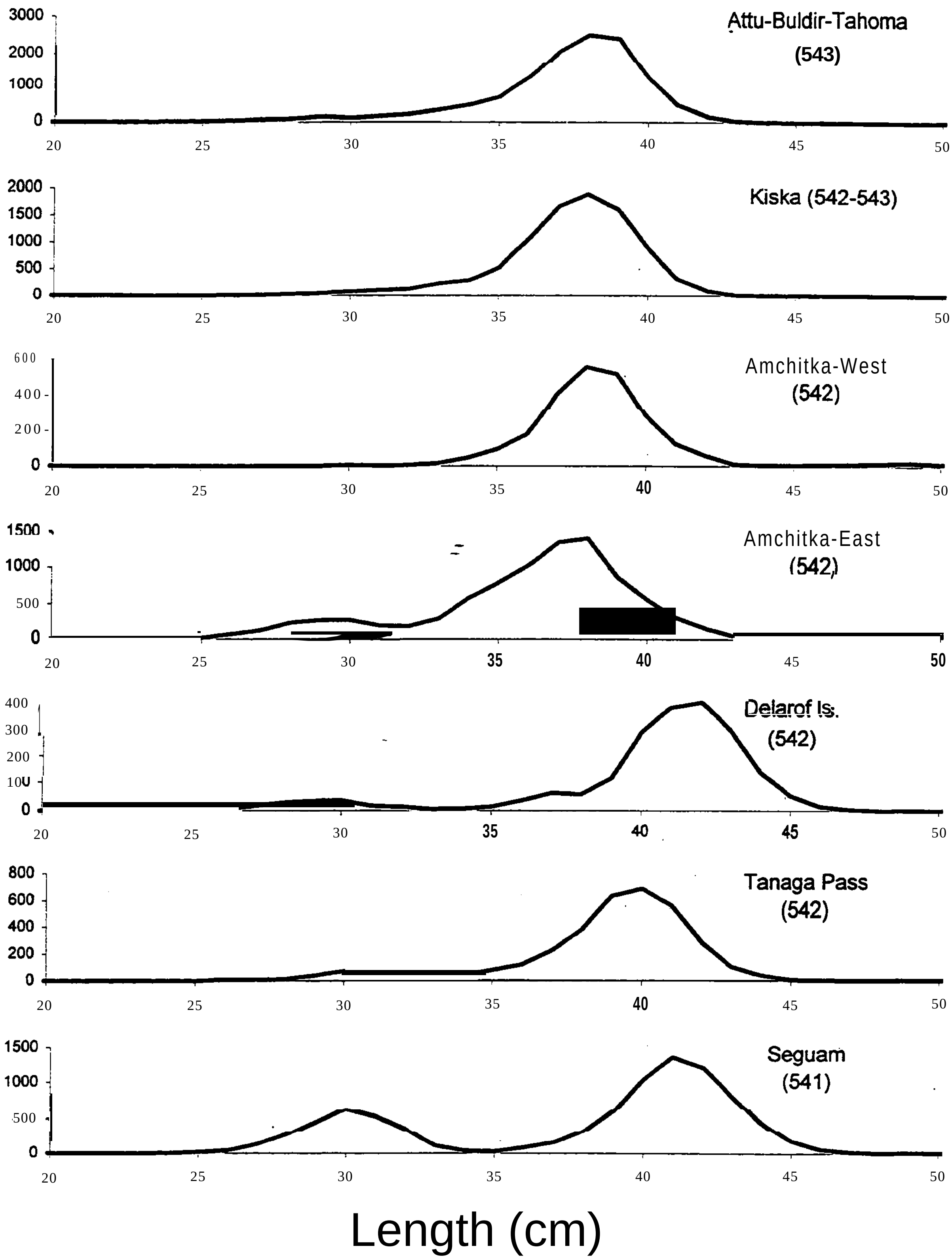



Figure 12.5. Atka mackerel length-frequency **distributions** caught by the fishery at various locations in 1998 from west (top) to east in the Aleutian Islands. See Figure **12.2 for locations. The management area(s) in which each location is within is listed (541-543).**

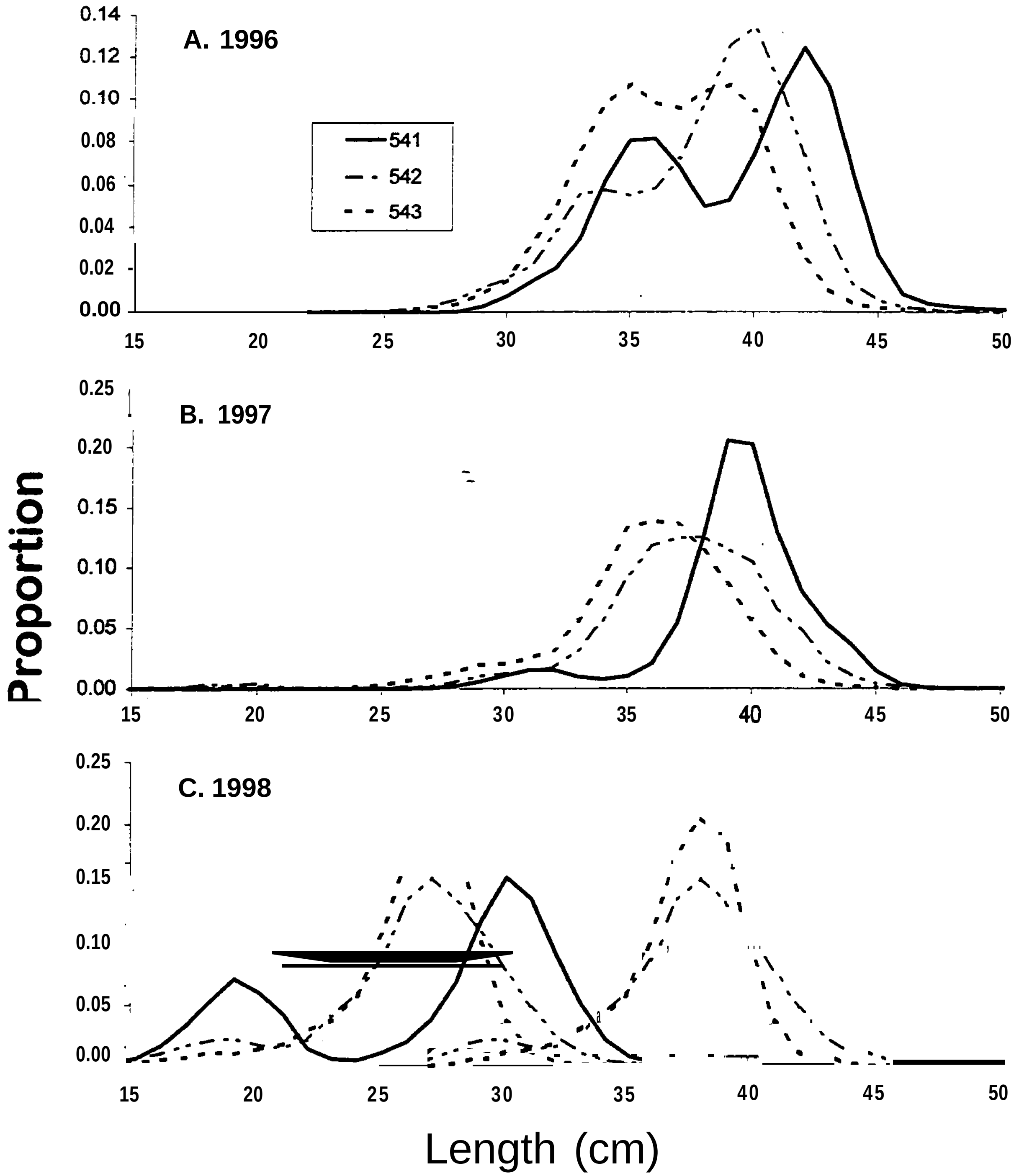



**Figure 12.6. Fishery Atka mackerel length-frequency distributions by management area in** the Aleutian Islands in 1996 (A), 1997 (B), and 1998 (C).

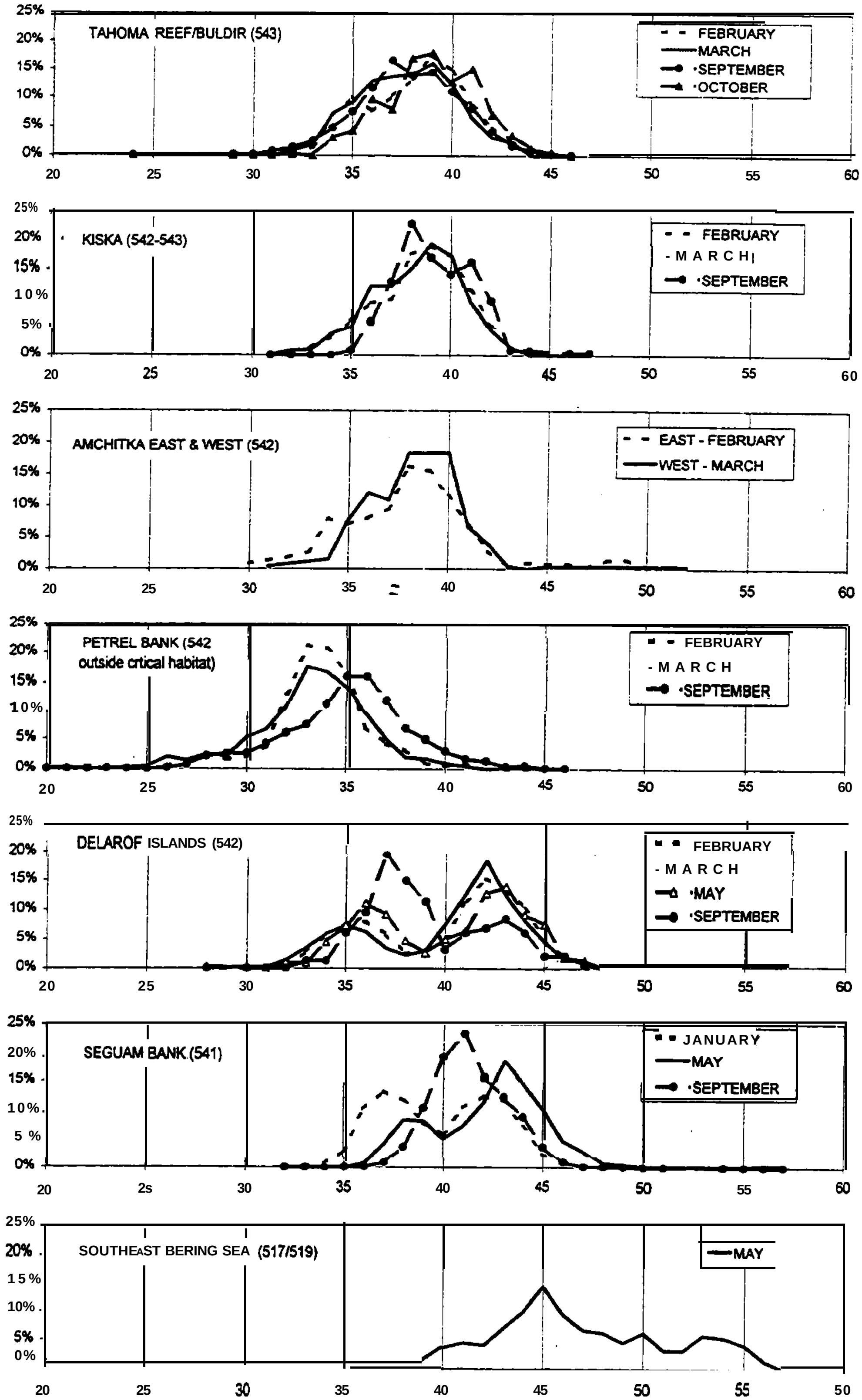



Figure 12.7. 1999 Atka mackerel **fishery** monthly length-frequency (preliminary data) by area fished (sea Figures 12.2a.b). Numbers refer to management areas.

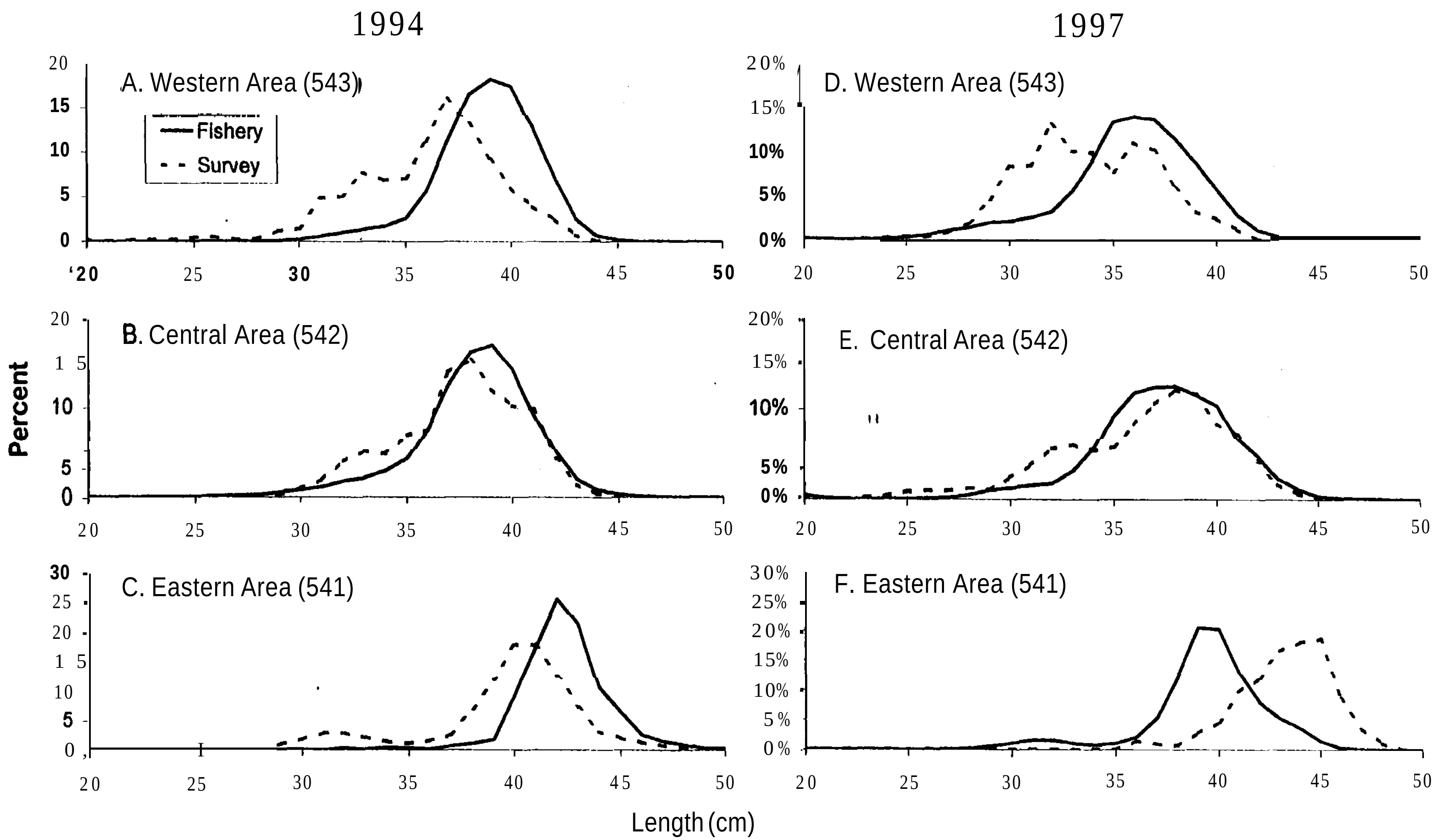



Figure 12.8. Comparison of 1994 and 1997 fishery and survey length-frequencies for Atka mackerel by area in the Aleutian Islands. Fishery length-frequencies are plotted as percent at each length. Survey data are plotted as percentages of estimated population at each length.

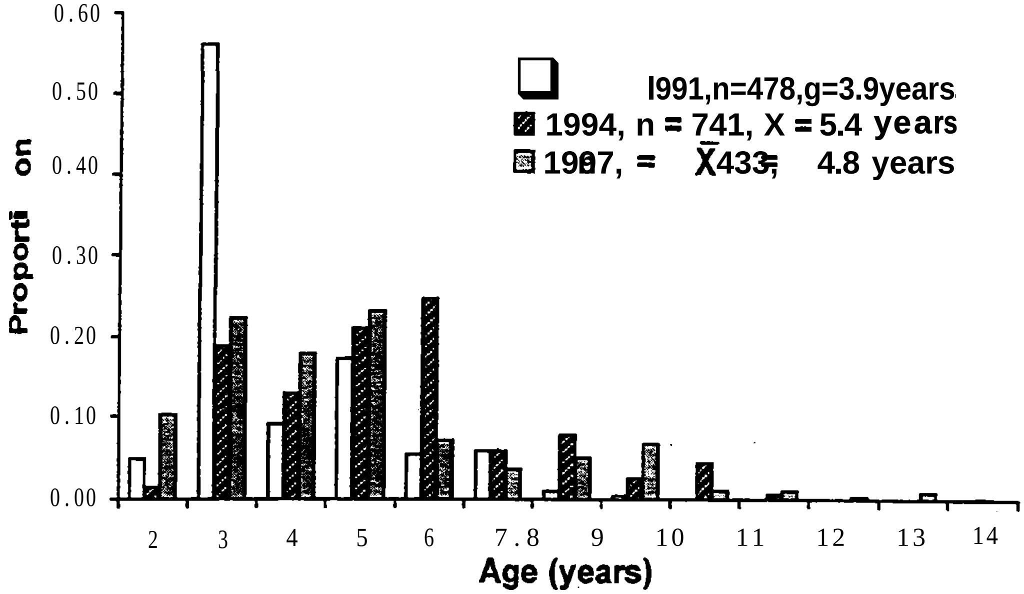



Figure 12.9 Age distributions from the Aleutian Islands region from the 1991, 1994 and 1997 surveys.

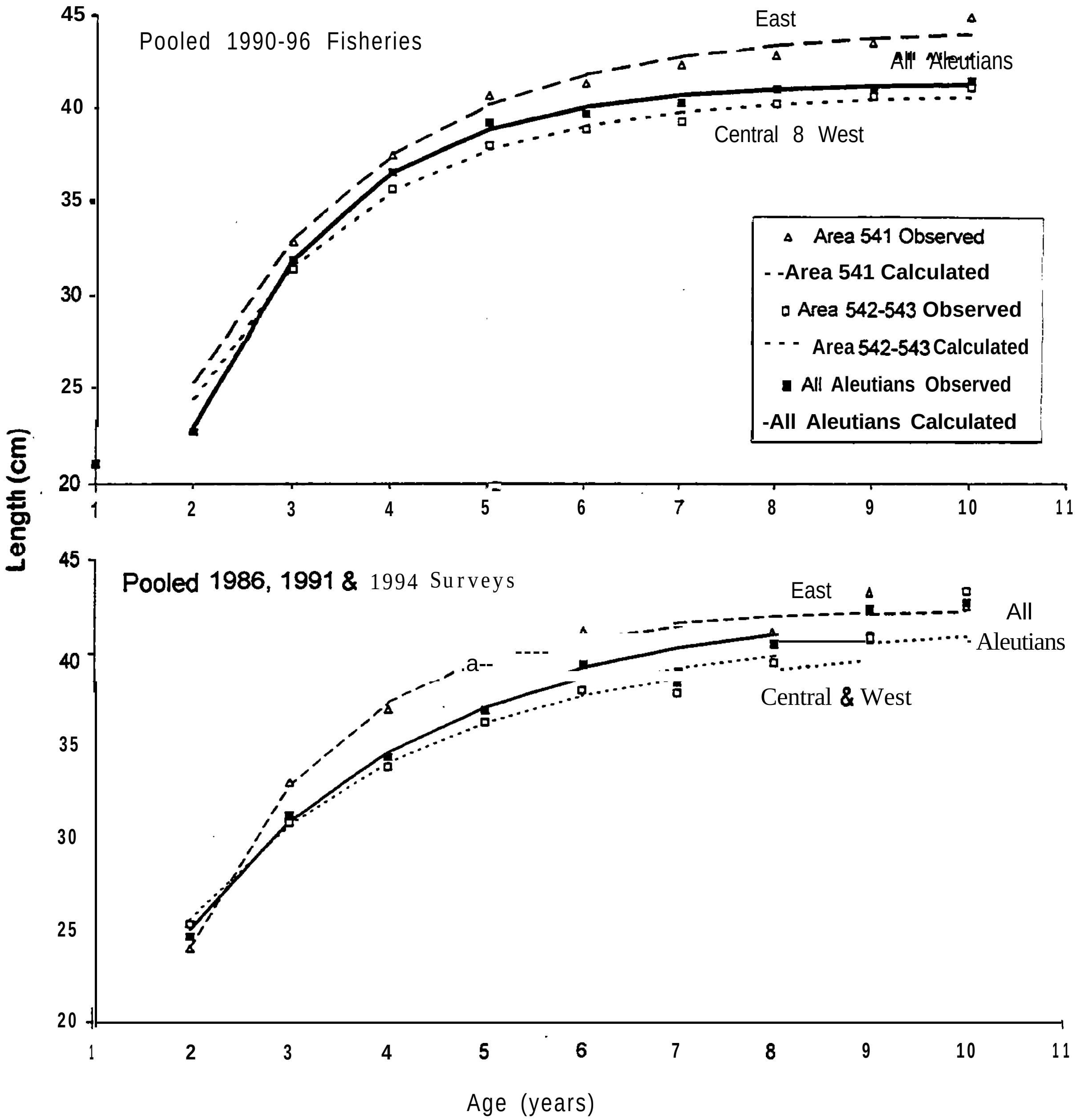



Figure 12.10. Length-at-age of Atka mackerel in the Aleutian Islands by area (East=54 1; Central & West=542 and 543) from the combined 1990-96 fisheries (top) and the combined 1986, 199 1, and 1994 bottom trawl surveys (bottom).

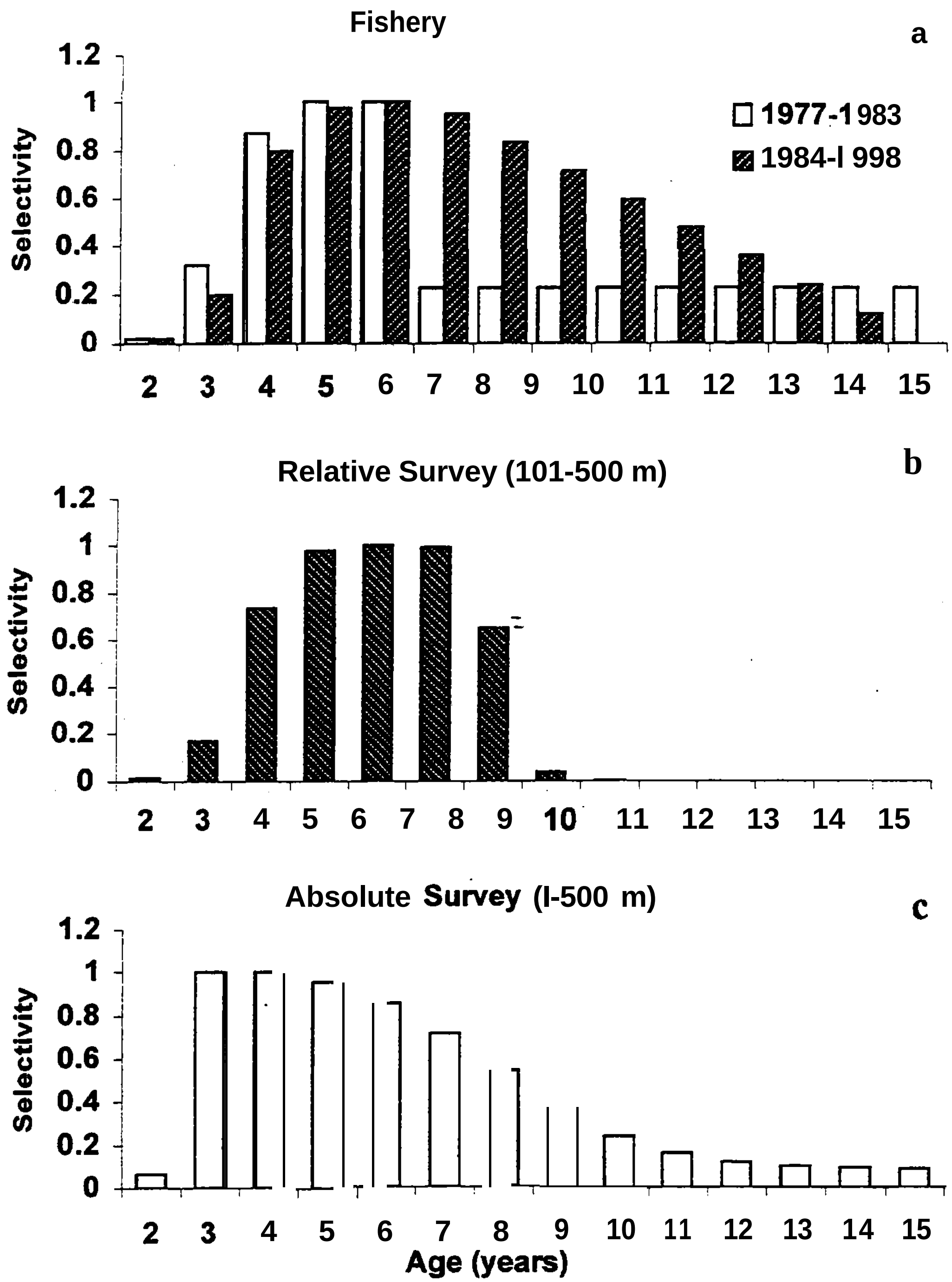



Figure 12.11 Selectivity of (a) the fishery; (b) survey data from 1980, 1983, 1986 and 1991 which excludes the l-100 m depth strata in the Southwest Aleutian region; and (c) survey data from the 1986, 1991, 1994 and 1997 surveys for all depth strata.

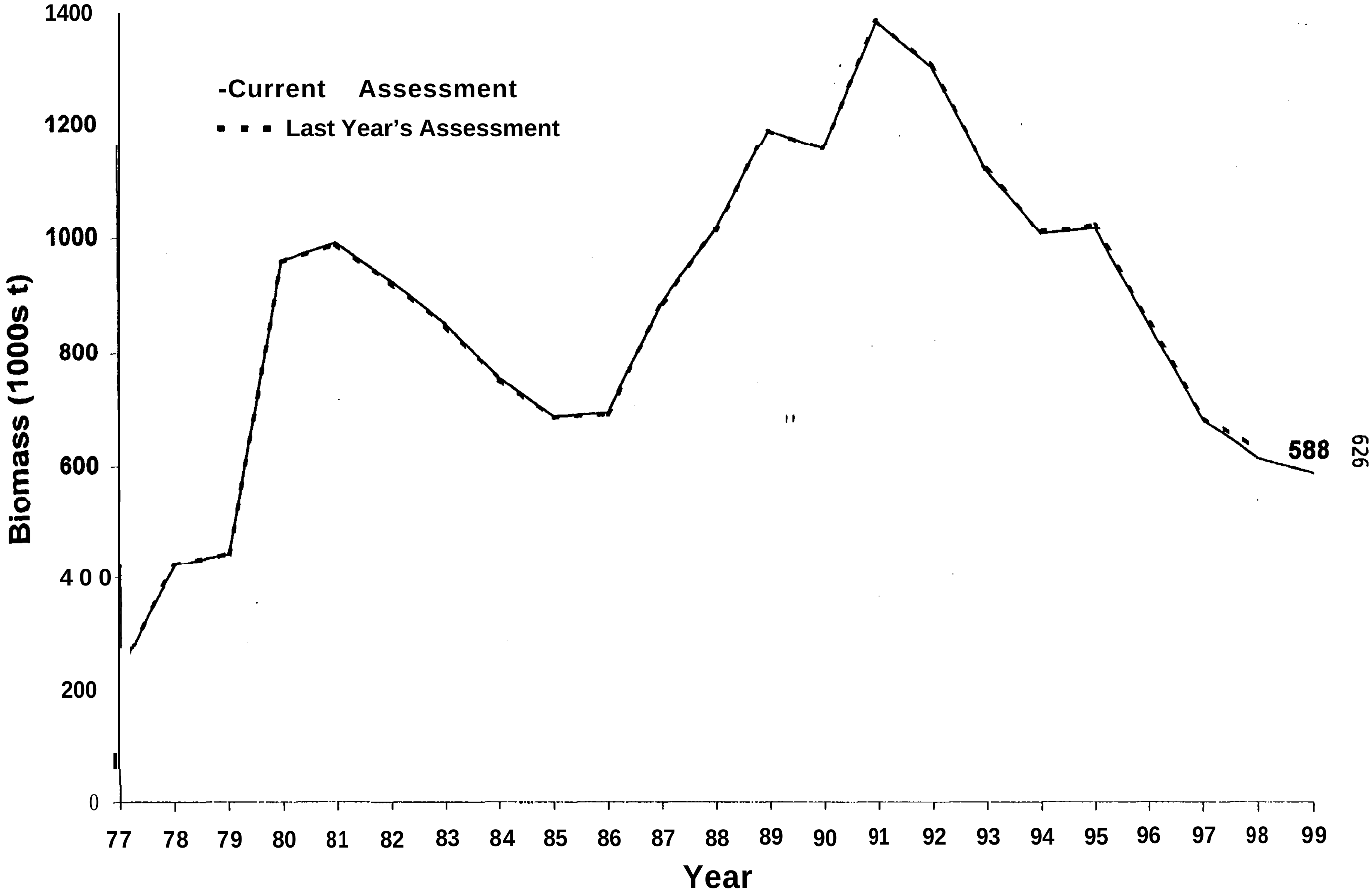



Figure 12.12. Atka mackerel biomass estimates (ages 3 +) from 1977-99 for the Aleutian Islands estimated by stock synthesis in the current assessment and last year's assessment.

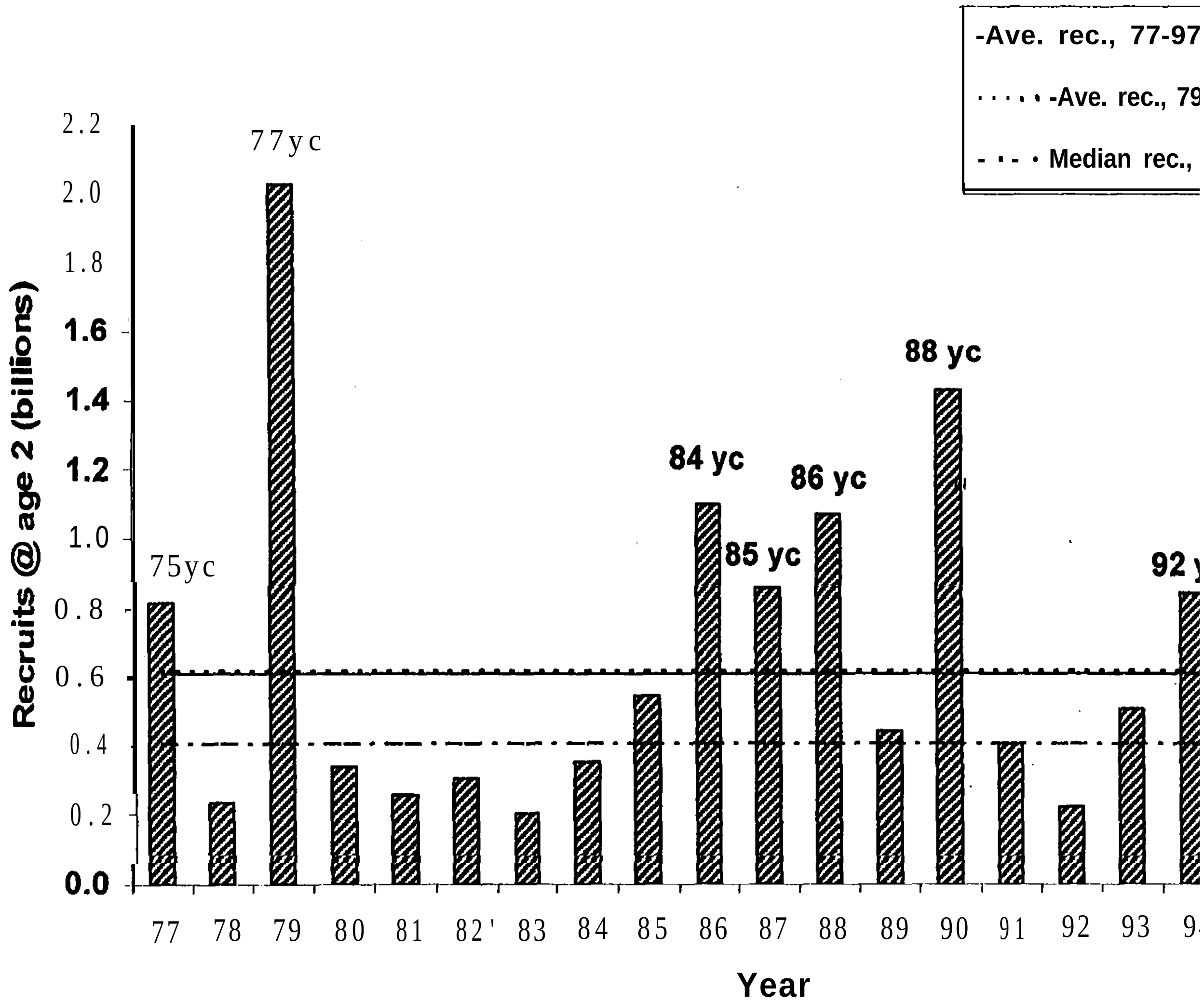



Figure 12.13 Numbers of age 2 Atka mackerel recruits by year (1977-97) as estimated by stock synthesis

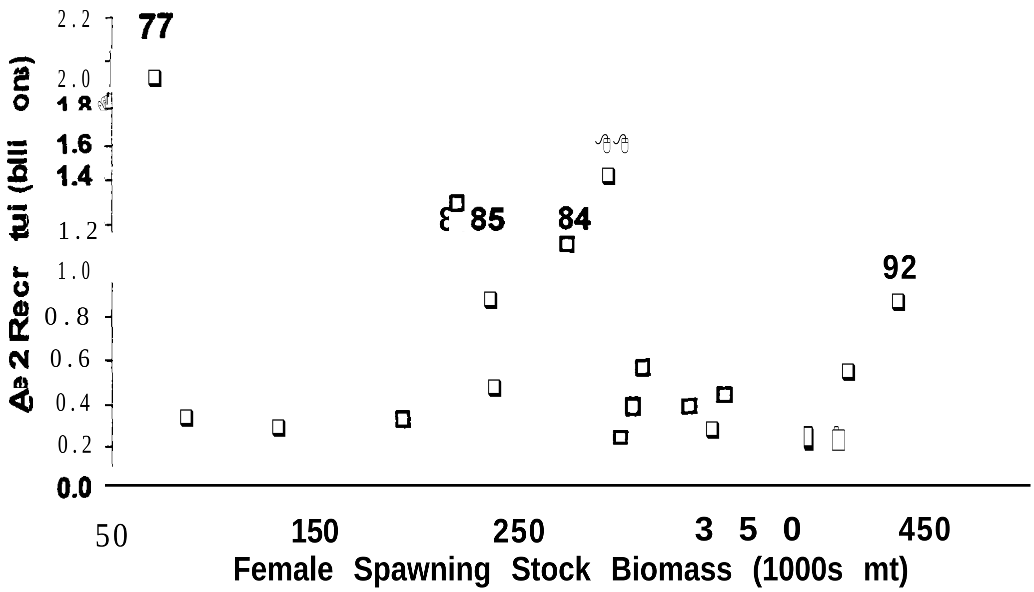



Figure 12.14 Estimated age 2 recruits plotted against the estimated spawning stock biomass as determined by stock synthesis. Strong year 'classes are noted.

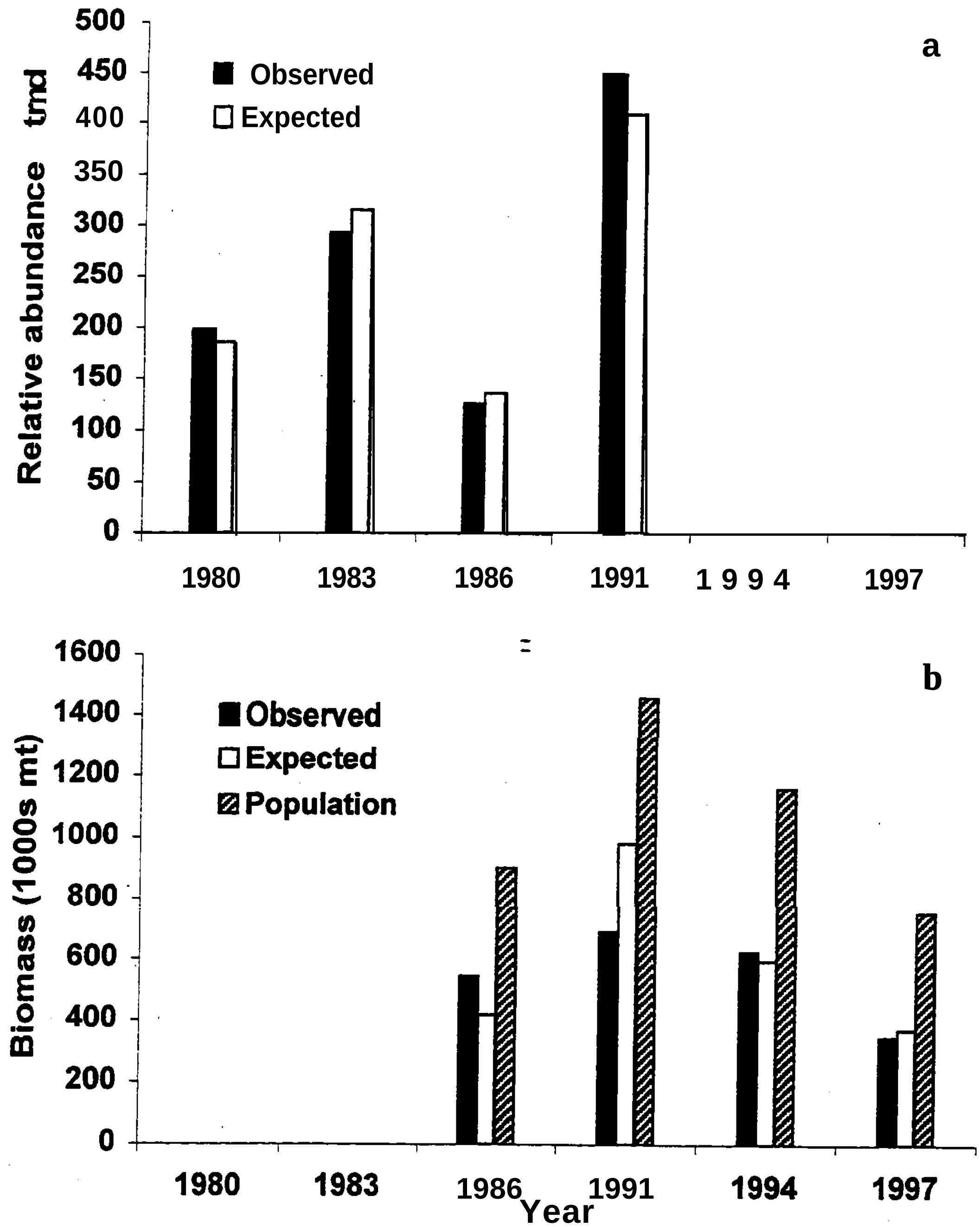



Figure 12.15 Comparison of observed and expected (stock synthesis results) estimates of (a) relative survey abundance and (b) absolute survey abundance of Atka mackerel and estimated population (age 2+) biomass.

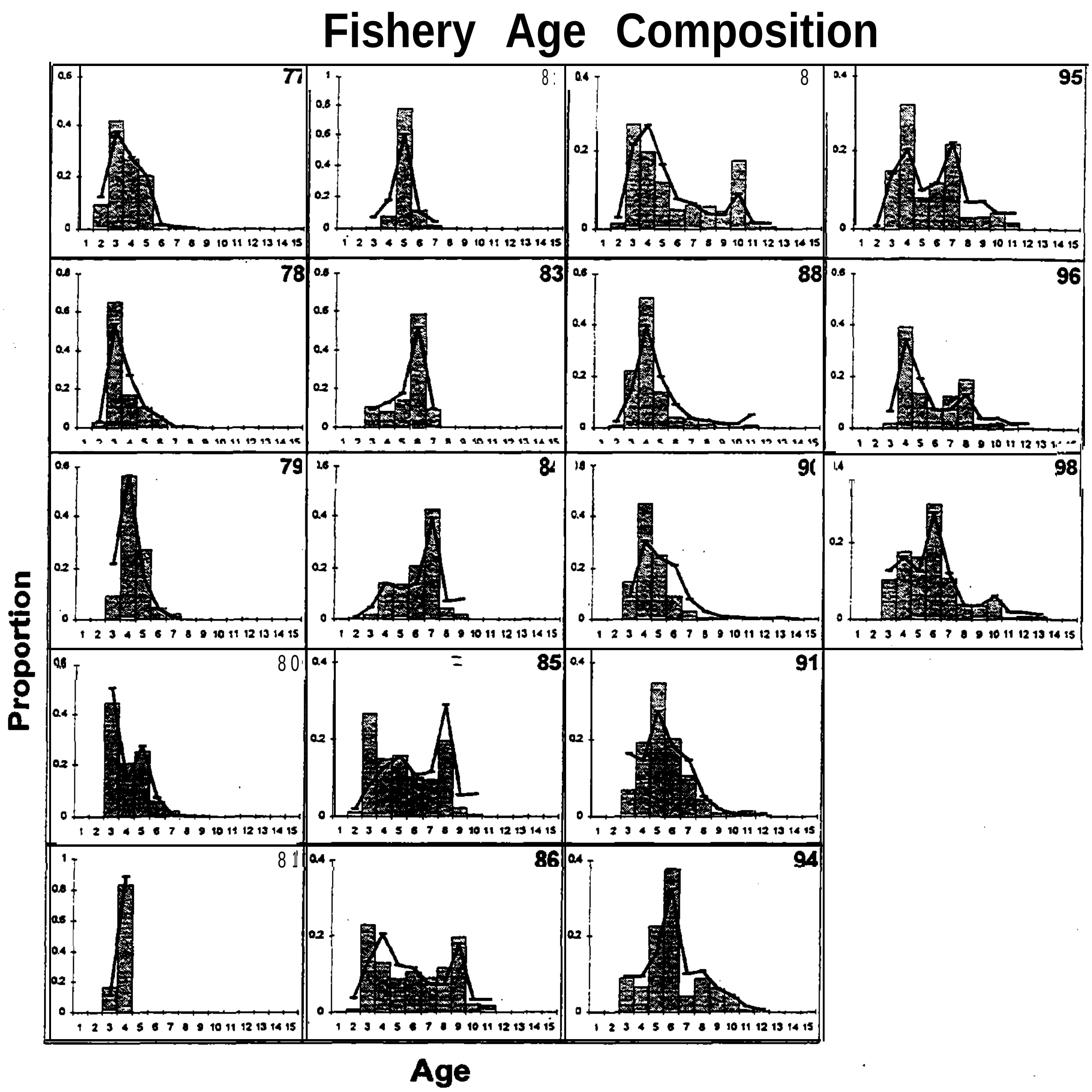
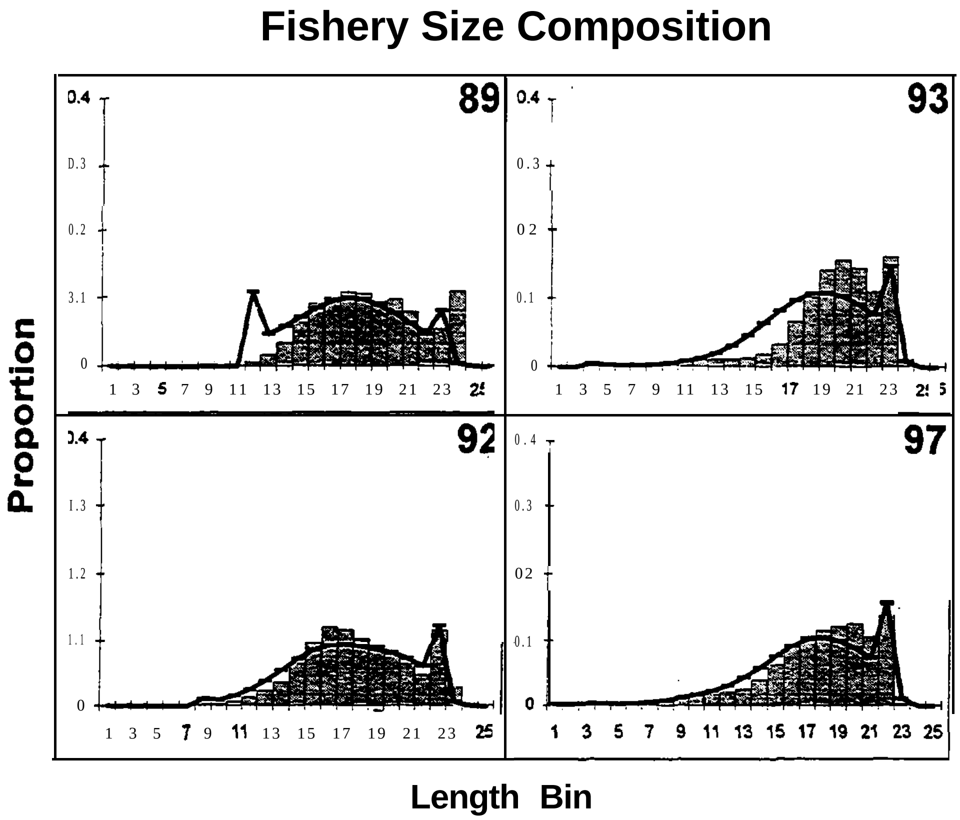



Figure 12.16a Model fits to the fishery catch at age data (proportions). Lines represent predictions, vertical columns represent the data




| Bin | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Length (cm)** | **20** | 21 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |

| Bin | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Length (cm)** | 35 | 36 | 37 | 38 | 39 | 40 | **41-45** | 46-50 | 51-55 | 56-64 |

Figure 12.16b Model fits to the fishery size composition data (proportions). Lines represent predictions, vertical columns represent data.

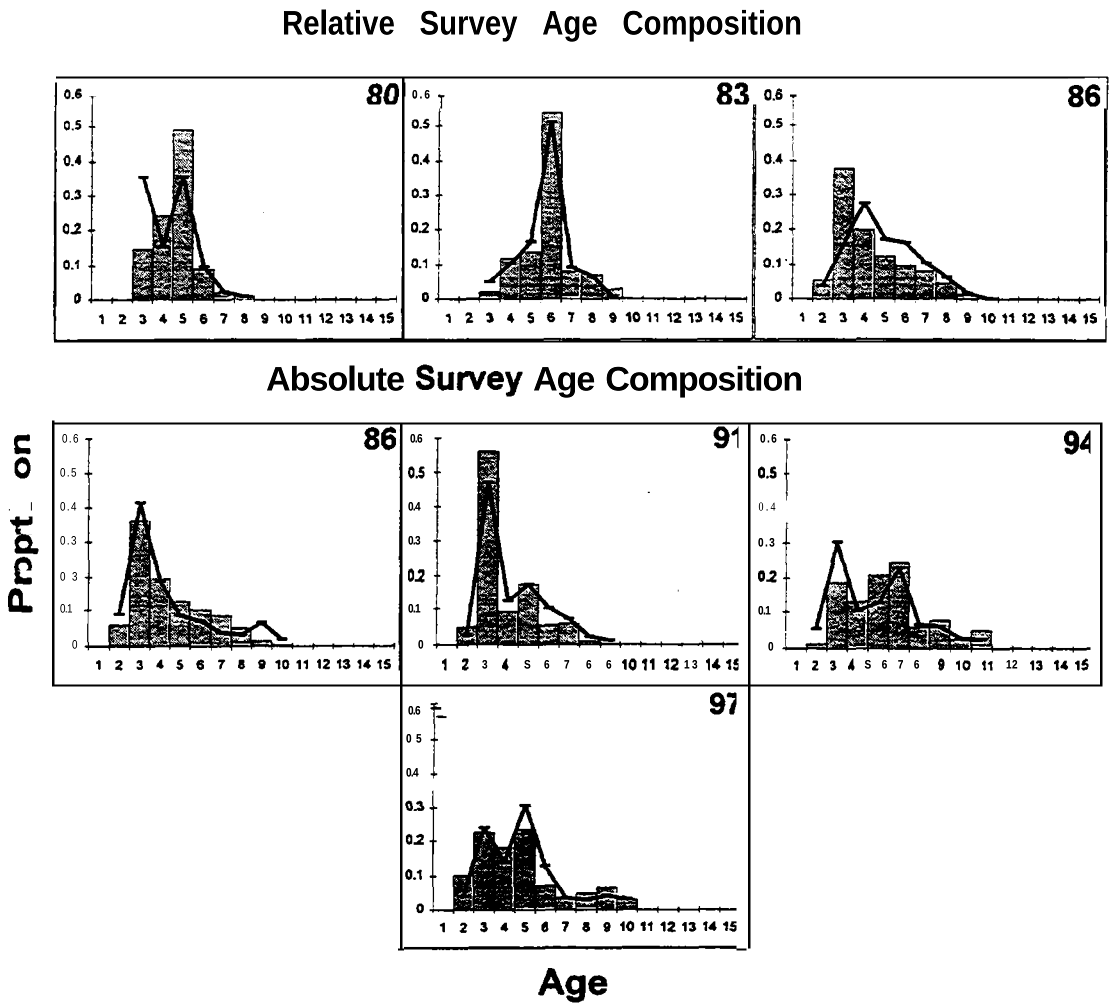



Figure 12.16c Model fits to the relative and absolute survey age composition data (proportions). Lines represent predictions, vertical columns represent the data.

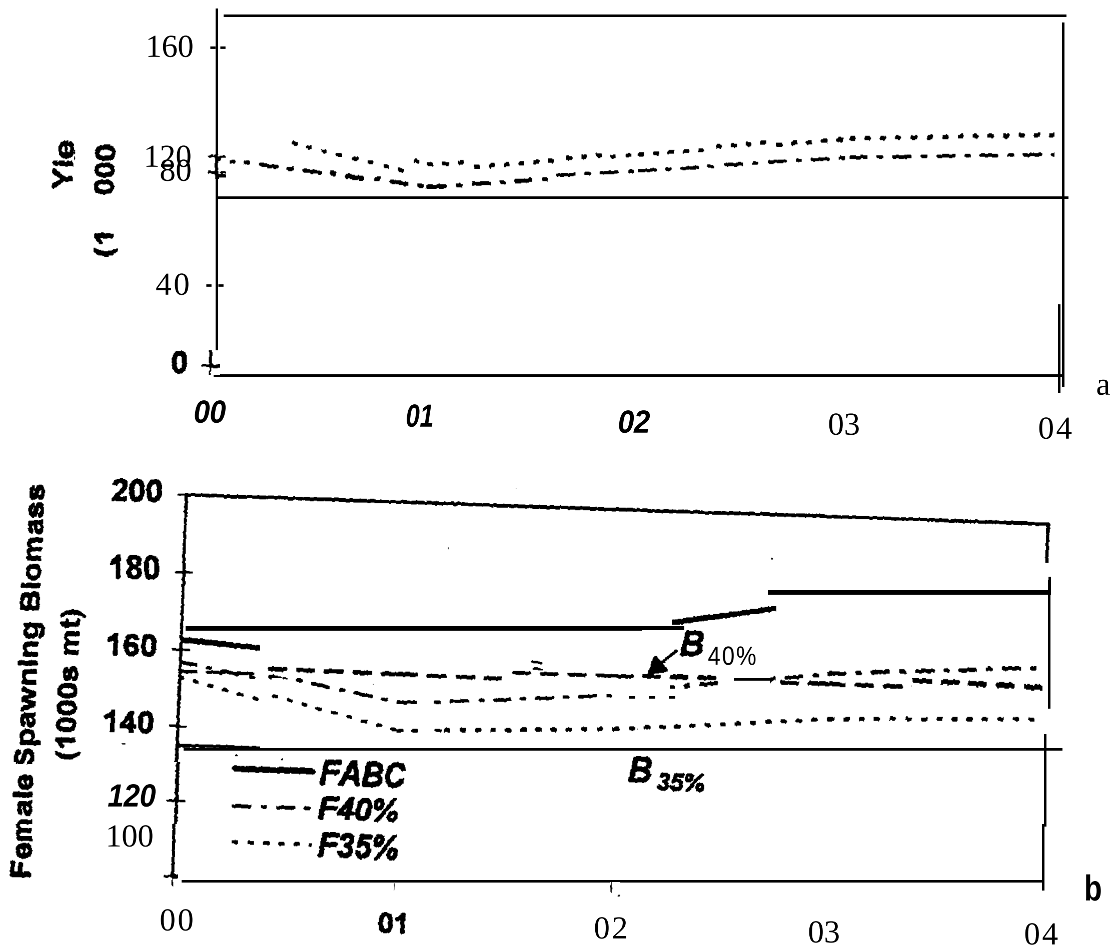



Figure 12.17 Projections of (a) yield and (b) female spawning biomass over various fishing mortality rates ($F_{ABC}$, $F_{40\%}$, and $F_{35\%}$), and stochastic recruitment from a distribution of estimated recruitments from 1 979-1997.

# Appendix 1. Atka mackerel pilot survey description, August 1999, Seguam Pass

## AREA AND PEFUOD OF OPERATION

*The vessel* F/T ***Seafreeze Alaska,*** owned and operated by U.S. Seafoods LP, was chartered for 16 days to conduct a pilot study to determine the variance structure of CPUE data and tag mortality for Atka mackerel in the vicinity Seguam Pass, in the Aleutian Islands. The charter will began on 4 August in Dutch Harbor and ended in the same port on 18 August.

## RATIONALE AND OBJECTIVES

Data collected in this pilot study will be used to design a larger scale experiment for detecting effects of fishing fish abundance and distribution within and outside of trawl exclusion zones. Trawl exclusion zones were established around sea lion rookeries as a precautionary measure to protect critical sea lion habitat, including local populations of such prey as the Atka mackerel. Localized fishing may affect Atka mackerel abundance and distribution near sea lion rookeries. The larger project is intended to assess such effects. To this end, AFSC scientists are considering two types of fishery independent methods to measure changes in abundance and distribution of Atka mackerel:

1. Bottom trawl surveys before and after a fishery. Potential impact of the fishery will be judged by change in catch per unit effort (CPUE) where the effort is the area swept by the trawl.
2. Mark and recapture (tagging) experiments to estimate abundance and movement between areas open and closed to the Atka mackerel fishery.

Results from the pilot study will help determine design parameters and feasibility for these two methods.

Trawl CPUEs may provide an adequate index of change in abundance. The pilot study tested survey strategies that are appropriate for estimating change in CPUE. The data collected will be used to estimate within-station and between-station variances and assess the sample size required for the larger experiment to detect effects of the local fishery on Atka mackerel abundance near sea lion rookeries.

Initial research on the feasibility of tagging Atka mackerel and on tag mortality of tagged fish will also be conducted as part of this study. This initial tagging work will allow us to estimate tagging mortality, daily tagging production, and methodologies for tagging aboard a commercial vessel. Results from this work will help determine the feasibility and design of future mark-recapture research for estimation of abundance and movement of Atka mackerel between areas opened and closed to the commercial fishery.

## OVERVIEW OF OPERATIONS

### *The study area and survey design*

The study area was defined based on locations of catches from the foreign and domestic commercial fisheries. (When foreign vessels were permitted to harvest Atka mackerel in U. S . waters there were also no areas closed to fishing to protect sea lions. Data from this period of history show preferred and unpreferred fishing grounds in the region.) It is the region of approximately 70 m to 250 m depth that lies between Amlia island and Seguam Island and extends in a bank to the southeast (see Figure 1). Trawl stations were selected according to stratified random sampling methods. Strata were defined as preferred fishing grounds within the trawl closure zone, preferred fishing grounds outside the trawl closure zone, and unpreferrecl fishing grounds. Forty stations were distributed among the three strata by random selection: After forty tows were successfully completed the station pattern was repeated, providing a set of paired observations. The initial station pattern was used to assess the variance of random CPUE observations and to investigate components of variance that could be explained by environmental variables. The paired CPUE observations will be used to assess the variance of paired differences. CPUE data was also collected at single stations over a 24 hour period, repeating tows at the same station These data will be used to detect any possible diurnal patterns that might contribute to variability in Atka mackerel CPUE.

***Towing procedures***

Towing procedures were as consistent as possible from tow to tow. Details were worked out between the vessel's master and the field party chief, and reflected the realities of fishing in areas of high current. One and a half days of charter tune were used to get towing procedures standardized. The duration of a tow was 1.5 minutes from the time the net reached a stable fishing configuration (as indicated by Scanmar sensors) until haul-back was initiated, though the duration was shorter on some tows if sensors indicated the net was full. Towing speed was kept as close as possible to 3 knots, though some variation was inevitable because of currents.

***Catch sampling***

When the catch was brought aboard the vessel at the end of each haul, total weight of the catch was accurately determined using a vessel-provided conveyer-belt flow scale. Back up measures of catch size were taken for every tow, using cod-end volume methods or a load cell. The catch was then sampled by the scientific party to determine species composition. If the catch was relatively small (up to about 1000 kg), it was sampled in its entirety. Larger catches were subsampled to save time. Sampling involved sorting the catch by species into baskets, weighing the baskets, and counting the fish in a subsample of the baskets. Information on length frequency distribution of Atka mackerel (by sex) was collected from a subsample of the catch using hand-held electronic data loggers. Biological samples, such as otoliths, gonads, and stomachs were collected from 5-10 Atka mackerel per tow. After the scientific sampling was completed, the catch was turned over to the vessel's factory crew for commercial processing or return to the sea.

***Gear***

The Government supplied trawl nets, trawl rigging, and doors. The net was the Bering Sea Combination trawl sized for a main engine of 800 to 900 horsepower. The footrope had tire gear at the bosom and disks on the wings in a rockhopper configuration. Doors were steel "V" type and measured 1.8 m X 2.74 m (6 X 9 ft) and weighed approximately 800 kg (1,800 lb) each. Other than the doors, this gear had never before been used in NMFS research and the NMFS scientists.

On most tows, a Government-provided SCANMAR net mensuration system was used to measure the width and height of the net opening. This equipment includes sensors which attach to the net and a microcomputer system to read mensuration data from the sensors. This gear was not deployed on very rough or steep substrates to ensure that it wasn't lost. A Government-provided Micro-bathythermograph (Micro-BT) was also mounted on the net to record the precise time when the net reached and left the bottom. These data were integrated with a GPS unit (provided by the Government) so that starting and ending positions of the tow could be determined. The Micro-BT also served as a record of the temperature of the water column for each tow.

## ITINERARY

| | |
|---|---|
| 4 August | Charter begins; load and set up fishing gear and sampling equipment in Dutch Harbor, AK; begin transit to Seguam Pass |
| 5 August | Finish transit to Seguam Pass; begin fishing operations to determine proper towing and sampling procedures, begin tag mortality study. |
| 6 - 17 August | Finish determining towing and sampling protocols; begin collecting CPUE data, tagging and releasing Atka mackerel as opportunity allows. |
| 18 August | Transit from Seguam Pass to Dutch Harbor, AK |
| 19 August | Off-load fishing gear and sampling equipment in Dutch Harbor, AK; charter ends. |

## SCIENTIFIC STAFF AND AFFILIATIONS

| | |
|---|---|
| Munro, Peter; Field Party Chief | @C/RACE |
| Hoff, Jerry, Watch Leader | AFSC/RACE |
| Benjamin, Dennis | AFSC/RACE |
| Fritz, Lowell | AFSC/REFM |
| McDermott, Susanne | UW |
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| Shaw, Gary | AFSC/OFIS |
| Wion, Destry | AFSC/RACE |
| York, Anne | AFSC/NMML |

## PRELIMINARY RESULTS

A total of 40 randomly selected stations spread amongst the three strata were sampled twice. This constituted the 40 paired stations for CPUE variance determination. In addition, 4 stations (2 within the buffer zone and 2 outside of it) were sampled every 3-4 hours over a 24-36 hour period to determine die1 variations in Atka mackerel abundance at defined locations related to tides, light, current, etc. A total of 140 hauls were taken during the 12 days of trawl operations from 6- 17 August.

Approximately 2,500 tagged Atka mackerel were released during the cruise. Most of these (approx. 1,600) were tagged and released opportunistically during trawl operations from 6-16 August. About 10% of the tagged fish were double tagged to estimate tag shedding rates. During the last 12 hours on station, however, all time was devoted to tagging; 9 11 mackerel were tagged and released on August 17 in the area currently open to the fishery. In addition, 393 mackerel were tagged and released from 6- 16 August in the area currently open to the fishery. To date, we are aware of 48 tagged fish that were recovered during the B-season fishery on Seguam Bank; 45 of these were fish that were released on August 17, while 3 were fish that were released during the CPUE portion of the study (6-16 August). To date, the tag returns are from 6 of the 8 vessels that fished there during the B-season; observers from the remaining 2 vessels have not been debriefed as yet and any tag recoveries have not been reported. To date, we have recovered 7 fish that were originally double-tagged, and 3 of these had lost a tag. This suggests that tag shedding rates were relatively high during this 3-4 week experiment.

The tagging mortality experiment was begun on 6 August and was terminated on 17 August. Twenty fish were placed in each of 4 tanks; 10 of these fish were tagged (2 double tagged) and 10 were untagged. By the end of the 12-day experiment, only 3 fish had died, one untagged fish and two tagged fish, resulting in a 97.5% survival rate for untagged fish and 95% survival rate for tagged fish. Observations of internal injuries and scale/skin loss suggest that the three fish died not from the tagging procedure, but the effects of initial trawl capture. On August 17, all untagged fish in the experiment were tagged and released, aiong with all tagged fish.

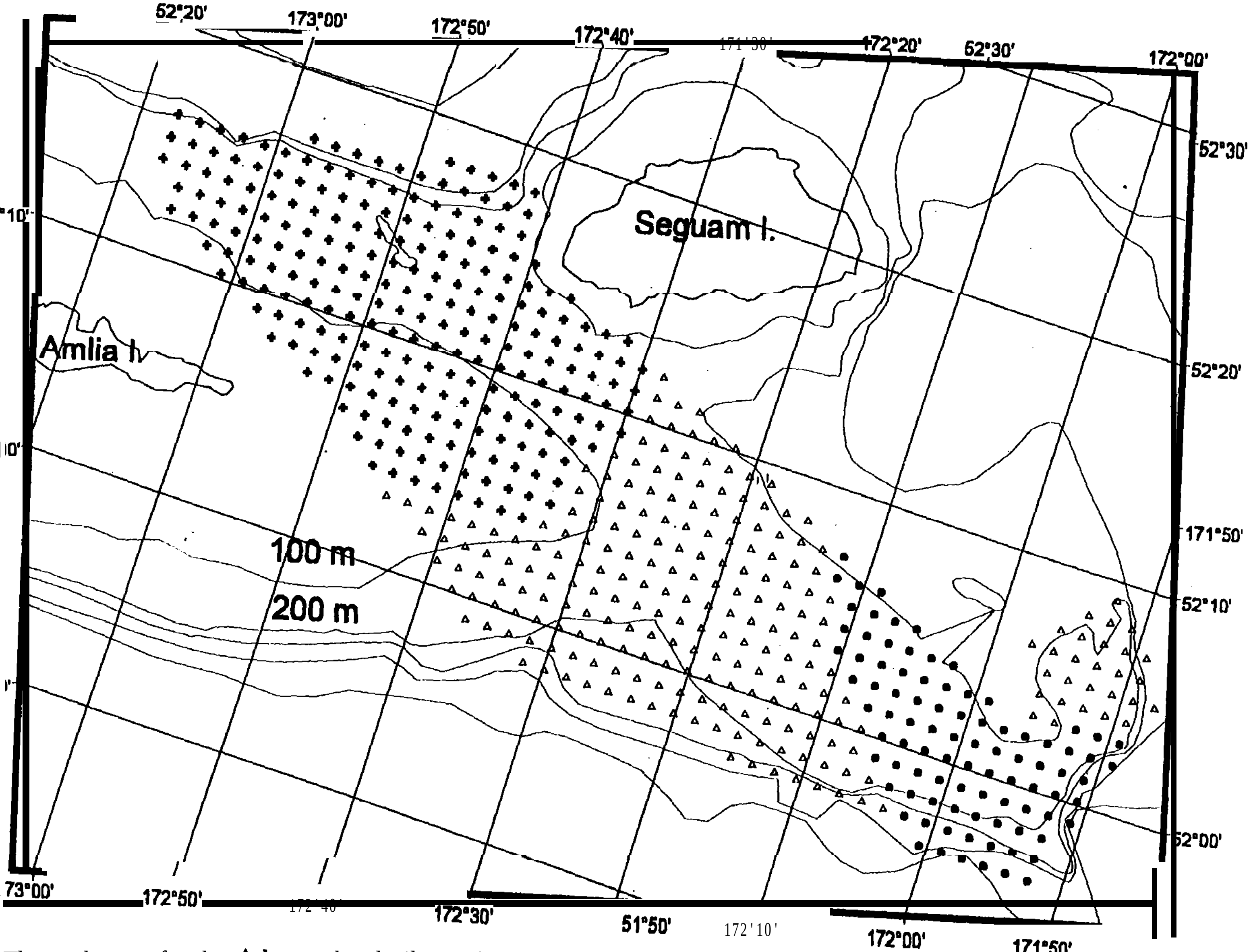


Figure 1. The study area for the Atka mackerel pilot project. Stations are at the center of approximately square regions of 1 sq nm area. Tows will be conducted at a random selection of these stations. Pluses indicate the sampling stratum that corresponds to preferred fishing grounds within the trawl closure zone. Solid dots indicate the sampling stratum that corresponds to Preferred fishing grounds outside of the trawl closure zone. Open triangles indicate the stratum that corresponds to grounds that appear not to be preferred,

Section 13

# SUMMARY OF CHANGES IN THE BERING SEA-ALEUTIAN ISLANDS **SQUID AND OTHER SPECIES ASSESSMENT**

by
**Lowell W. Fritz**

Relative to the November 1998 **SAFE** report, the following changes have been made in the current draft of the squid and other species chapter:

1) Catch and survey biomass data are updated.

2) The recommended ABC for squid in the year 2000 is calculated as 0.75 times the average catch from 1978-95, or **1,970 mt; the** recommended overfishing level for squid in the year 2000 is calculated as the average catch from 1978-95, or 2,624 mt.

3) The recommended ABC for the other species complex in the year 2000 is calculated as the average catch from 1977-98, or 26,800 **mt. The** recommended overfishing level for the other species complex in the year 2000 is **122,100 mt,** which was calculated by multiplying an estimate of the natural mortality rate (M=0.2) by a biomass estimate for the complex (average of the last 3 eastern Bering Sea bottom trawl surveys plus the **most** recent Aleutian **Islands** bottom trawl survey = 6 10,400 mt).