619 #4

UNITED STATES DEPARTMENT OF COMMERCE
Office of the Under Secretary for
Oceans and Atmosphere
Washington, D.C. 20230

JAN 19 1999

To all Interested Government Agencies and Public Groups:

Under the National Environmental Policy Act, an environmental review has been performed on the following action.

TITLE: Environmental Assessment for a Regulatory Amendment to Reapportion Total Allowable Catch of Atka Mackerel and Reduce Fishery Effects on Steller Sea Lions; Change in Atka Mackerel Interim Specifications

LOCATION: Federal Waters of the Bering Sea and Aleutian Islands

SUMMARY: This final rule would implement regulations that divide the Atka mackerel total allowable catch (TAC) specified for the Aleutian Islands Subarea (AI) into two seasonal allowances; reduce the percentage of Atka mackerel TAC harvested from Steller sea lion critical habitat (CH) over a 4-year period in the Western and Central Districts of the AI; and extend the seasonal no-trawl zone around Seguam and Agligadak rookeries in the AI Eastern District into a year-round closure.

RESPONSIBLE OFFICIAL: Steven Pennoyer
Regional Administrator
Alaska Region
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The environmental review process led us to conclude that this action will not have a significant impact on the environment. Therefore, an environmental impact statement was not prepared. A copy of the *finding of no significant impact*, including the environmental assessment, is enclosed for your information. Also, please send one copy of your comment to me in Room 5805, PSP, U.S. Department of Commerce, Washington, D.C. 20230.

Sincerely,

Susan Fruchter

Director of the Office of Policy
and Strategic Planning

Enclosure

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FINAL

ENVIRONMENTAL ASSESSMENT REGULATORY IMPACT REVIEW AND FINAL REGULATORY FLEXIBILITY ANALYSIS FOR A REGULATORY AMENDMENT TO REAPPORTION TOTAL ALLOWABLE CATCH OF ATKA MACKEREL AND REDUCE FISHERY EFFECTS ON STELLER SEA LIONS

Prepared by

National Marine Fisheries Service
Alaska Regional Office and
Alaska Fisheries Science Center

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Executive Summary

This regulatory amendment would divide the Atka mackerel total allowable catch (TAC) specified for the Aleutian Islands Subarea into two seasonal allowances; and reduce the percentage of Atka mackerel TAC taken from Steller sea lion critical habitat over a 4-year period in the Western and Central Districts of the Aleutian Islands Subarea. The purpose of this action is to avoid significant fishery-induced localized depletions of Atka mackerel, a primary prey species for Steller sea lions in the Aleutian Islands; and avoid potential jeopardy to the continued existence of Steller sea lion populations and their critical habitat through excessive removal of prey. In 1990, the Steller sea lion (*Eumetopias jubatus*) was designated as a threatened species under the Endangered Species Act of 1973 (ESA). The designation followed severe declines throughout much of the Gulf of Alaska and Aleutian Islands region. In 1993, critical habitat for the species was defined to include (among other areas), the marine areas within 20 nm of major rookeries and haulouts of the species west of 144°W longitude. In 1997, two separate populations were recognized, and the western population (west of 144°W longitude) was reclassified as endangered. The estimated number of Steller sea lions in the western population has declined by more than 80% since the mid 1960s. The ultimate cause of the decline is unknown, but lack of available prey may be the most important proximate cause.

To avoid significant competition between Steller sea lions and the Atka mackerel fishery, the amendment is focused on two main issues: 1) fishery-induced localized depletion of prey for Steller sea lions, and 2) the degree to which a known important prey item can be removed from Steller sea lion critical habitat without adversely modifying that habitat. Management concern about the potential for localized depletion has been expressed in previous ESA section 7 consultations on the BSAI Fishery Management Plan (FMP). The concern was initially based on the hypothesis that the species' decline is due to lack of available prey, which could be exacerbated by fishery-induced localized depletions of prey. Recent statistical evaluations of catch per unit effort (CPUE) at various sites in the 1990s have indicated that the Atka mackerel fishery has led to localized depletions of Steller sea lion prey (Fritz, unpubl., Appendix 1), thereby increasing evidence for competition.

The second objective is based on the statutory requirement of the ESA that Federal actions within the critical habitat of a listed species not jeopardize the continued existence of Steller sea lion populations or adversely modify their critical habitat. The single most important feature of critical habitat for the Steller sea lion is its prey base. Since 1977, the portion of catch (prey) taken annually within Steller sea lion critical habitat has varied from 15% to 98%, with an average of 71%. A marked increase in the annual catch in the 1990s, and the high percent of the catch generally taken within Steller sea lion critical habitat has resulted in a marked increase in the amount (tons) of fish taken from areas considered essential to the recovery and conservation of the Steller sea lion, again increasing concerns that the fishery competes with Steller sea lions. The point at which fishery removals of prey from that habitat becomes adverse modification is not clear. In spite of such uncertainty, however, the ESA requires that a judgement be made on the basis of the best available scientific and commercial data.

The purposes of this regulatory amendment, then, are 1) to avoid significant fishery-induced localized depletions of Atka mackerel and 2) to avoid significant adverse modification of Steller sea lion critical habitat through excessive removal of prey.

Six alternatives are presented for discussion, including the status quo (no change in management) and voluntary redistribution of fishing effort by fishery participants. The remaining four alternatives are all based on time and/or area management of the fishery. None of these alternatives involves a reduction in TAC or a change to the manner in which the overall TAC is set. The key distinguishing features of these alternatives are 1) whether they involve a seasonal split, 2) whether they involve an apportionment of the TAC inside and outside of critical habitat; 3) the extent to which they use past commercial and scientific data to establish

TACs for subareas and seasons, and 4) the number of TAC releases associated with each alternative. Selection of the appropriate alternative must be based on an evaluation of whether or not each possible alternative meets the primary criteria of avoiding significant localized depletions and avoiding adverse modification of Steller sea lion critical habitat. Only alternatives three and four meet both criteria.
In June 1998, the North Pacific Fisheries Management Council (NPFMC) reviewed this environmental assessment and selected Alternative 3, Option 2, as the preferred alternative. Alternative 3, Option 2 requires the following:

- Splitting of the BSAI Atka mackerel fishery into A (1 January to 15 April) and B (1 September to 1 November) seasons,

- Reduction of the percent of the Atka mackerel Total Allowable Catch (TAC) taken from Steller sea lion critical habitat over a 4-year period in the western and central Aleutian Islands management districts as follows:

Minimum percent of annual Atka mackerel TAC taken outside of Steller sea lion critical habitat		
	Aleutian Islands District	
Year	Western (543)	Central (542)
Current	15	5
1999	35	20
2000	43	33
2001	52	46
2002	60	60

- Extension of the 20-nm trawl exclusion zone around Seguam and Agligadak rookeries in management district 541 to include both the A and B seasons,

- Installation of equipment for vessel monitoring (consistent with standards established in the final rule) for all vessels participating in the Atka mackerel fishery,

- Exemption of Community Development Quota (CDQ) fishing vessels from the A/B season split, but such vessels would still be required to adhere to percentage limits for fishing inside of Steller sea lion critical habitat,

- Exemption of the Atka mackerel jig fishery from these actions, and

- Annual review of the impact and effectiveness of these measures by the National Marine Fisheries Service (NMFS) and the Council. The Council also recommended that NMFS conduct research with other parties and industry to develop a research plan to determine effects of these management measures by area.

1.0 INTRODUCTION

The groundfish fisheries in the Exclusive Economic Zone (EEZ; 3 to 200 miles offshore) off Alaska are managed under the Fishery Management Plan for the Groundfish Fisheries of the Gulf of Alaska and the Fishery Management Plan for the Groundfish Fisheries of the Bering Sea and Aleutian Islands Area. Both fishery management plans (FMP) were developed by the North Pacific Fishery Management Council (Council) under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). The Gulf of Alaska (GOA) FMP was approved by the Secretary of Commerce and became effective in 1978 and the Bering Sea and Aleutian Islands Area (BSAI) FMP became effective in 1982.

Actions taken to amend FMPs or implement other regulations governing the groundfish fisheries must meet the requirements of Federal laws and regulations. In addition to the Magnuson-Stevens Act, the most important of these are the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), Executive Order (E.O.) 12866, and the Regulatory Flexibility Act (RFA).

NEPA, E.O. 12866 and the RFA require a description of the purpose and need for the proposed action as well as a description of alternative actions which may address the problem. This information is included in section 1 of this document. Section 2 contains goals, objectives, and analyses of the alternatives, and section 3 includes information on the biological and environmental impacts of the alternatives as required by NEPA. Impacts on endangered species and marine mammals are also addressed in this section. Section 4 contains a Regulatory Impact Review (RIR) which addresses the requirements of both E.O. 12866 and the RFA that economic impacts of the alternatives be considered. Section 5 contains the Initial Regulatory Flexibility Analysis (IRFA) required by the RFA which specifically addresses the impacts of the proposed action on small businesses.

This Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis (EA/RIR/IRFA) addresses reapportionment of the BSAI Total Allowable Catch (TAC) to avoid significant fishery impacts on the endangered western population of Steller sea lions.

1.1 **Problem Statement** (as prepared by the Council)

There are concerns relating to the potential effects on Steller sea lions arising from removals of Atka mackerel from waters within Steller sea lion critical habitat. The Council and the National Marine Fisheries Service (NMFS) may need additional management measures to address these concerns. Therefore, the Council seeks to institute management measures, if warranted, to address concerns regarding potential depletion of Atka mackerel in Steller sea lion critical habitat in BSAI management areas 541, 542, and 543.

1.2 Purpose of and Need for the Action

The fundamental concern leading to this amendment proposal is whether, and to what extent, the Atka mackerel fishery competes for prey with the endangered and declining western population of Steller sea lions. Two specific questions must be addressed:

1) Does the fishery result in significant localized depletion of Atka mackerel that could reduce foraging success of Steller sea lions, and

2) How much of a known important prey can be removed from Steller sea lion critical habitat before the removal constitutes adverse modification of that critical habitat?

The NMFS is the lead agency responsible for the recovery and conservation of the Steller sea lion. As such, it has periodically consulted (with itself) on the BSAI groundfish FMP, and on the potential effects of the various groundfish fisheries that could affect the Steller sea lion. Under the ESA, the Steller sea lion was listed as threatened in 1990, and in three subsequent biological opinions (the products of ESA section 7 consultations), NMFS has expressed concern that fisheries may reduce sea lion foraging success by causing changes in prey composition, age/size composition of available prey species, or localized depletions of prey. A recent evaluation of catch per unit effort (CPUE) of the Atka mackerel fishery indicates that such localized depletions are occurring. Thus, the first of two main objectives of this amendment is to modify the management of the fishery to avoid such depletions.

To address the second question above, this amendment seeks to reduce the proportion of the annual Atka mackerel catch taken from within Steller sea lion critical habitat. In spite of limited scientific and commercial data, the ESA requires that management make a judgement to address this question. For areas within the current geographic range of a listed species, the ESA defines critical habitat to be the specific areas ". . . on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection . . . . " For the Steller sea lion, the significance of certain marine areas may have importance for predator avoidance (i.e., may include waters not accessible to predators), or pup development (i.e., protected areas where pups may learn to swim and forage). However, the single most important feature of marine areas critical to the Steller sea lion is their prey base. Areas designated as critical habitat for this species must include sufficient food to meet the energetic demands of a stable and healthy sea lion population. Thus, the availability of prey in critical habitat is a matter of considerable concern, particularly since lack of available prey may have contributed to the decline of the western population or may be impeding its recovery.

1.3 Cause versus Amelioration

The proposed regulatory amendment to the BSAI groundfish FMP is not based on the assumption that the Atka mackerel fishery caused the decline of the western population of Steller sea lions. The proximate cause is thought to be related to lack of available prey, but the ultimate cause is not known. The past relationship between Steller sea lion status (foraging success and population dynamics) and the Atka mackerel fishery is also not known.

Nevertheless, NMFS is responsible for ensuring that the fishery is not an impediment to sea lion recovery and conservation in the future. Given the apparent importance of Atka mackerel in the diet of sea lions, particularly in the central and western Aleutian Islands, careful management of the fishery is essential to ameliorate any potential impact of the fishery.

1.4 Alternatives Considered

1.4.1 Alternative 1: No Action: no change in management of the fishery.

1.4.2 Alternative 2: Seasonal A:B split (50%:50%) in TAC.

1.4.3 Alternative 3:(Preferred) Seasonal A:B split (50%:50%) in TAC, plus additional split of TAC to subareas inside and outside of Steller sea lion critical habitat. Additional options for alternative 3 include:

1.4.3.1 Critical habitat split of 40% inside: 60% outside (target split), in areas 542 and 543 during both seasons. Area 541 would not be split for critical habitat because of the 20-nm no-trawl zone during the A season.

1.4.3.2 (Preferred) Critical habitat split of 40% inside: 60% outside in areas 542 and 543 during both seasons, achieved in incremental changes as detailed in the following table. The current 20-nm no-trawl zones around Agligadak and Seguam rookeries would remain in effect for both A and B seasons. CDQ vessels would be exempt from the A:B season split, but would abide by the percent limits listed in the table. The Atka mackerel jig fishery in area 541/Bering Sea would be exempt from seasonal and critical habitat splits. The effectiveness and impact of the amendment would be reviewed annually.

Minimum percent of annual Atka mackerel TAC taken outside of Steller sea lion critical habitat

	Aleutian Islands District	
Year	Western (543)	Central (542)
Current	15	5
1999	35	20
2000	43	33
2001	52	46
2002	60	60

1.4.3.3 Critical habitat split of 0% inside: 100% outside.

1.4.4 Alternative 4: Seasonal split in all three regulatory areas, or in critical habitat in management areas 542, 543, or both, plus setting of maximum TAC in any season/area based on estimates of initial biomass and application of a target harvest rate.

1.4.5 Alternative 5: Seasonal split and geographic rotation. Establish TAC for each regulatory area, begin with a time-limited season (e.g., 5 days) for 1/3 of TAC in regulatory area 541, then close area 541 and move to area 542 for a second time-limited season on 1/3 of TAC for that area, and then shift to area 543. When all three areas were fished, then return to area 541 and start the cycle again.

1.4.6 Alternative 6: Voluntary fleet distribution of effort throughout regulatory areas throughout year.

1.5 Background

1.5.1 Atka Mackerel

1.5.1.1 Distribution and Life History

Atka mackerel are distributed from Kamchatka peninsula through the Aleutian Islands and Gulf of Alaska (GOA) to southeast Alaska. The center of abundance appears to be in the Aleutian Islands from Seguam Pass to Buldir Island. Results from the 1991 and 1994 stock assessment surveys indicate areas of concentration at Seguam Pass, Tanaga pass, Petrel Spur, Amchitka and Kiska Islands, Tahoma and Buldir Reefs, and Stalemate Bank; all areas consistent with the historical distribution of the fishery (Fig. 1).

The spatial dynamics of Atka mackerel are poorly understood. Morphological and meristic studies (Levada 1979, Lee 1985) suggested the possibility of separate stocks in the BSAI and the GOA, but genetic studies (Lowe et al. *In press*) indicate the stocks in these regions are well mixed. The larger size of Atka mackerel in the GOA, the greater sensitivity to fishing in that region, and the time-lagged correspondence of recruitment in the two regions all support the hypothesis that the GOA stock may be dependent on recruitment from the BSAI stock (Lowe and Fritz 1997).

Atka mackerel are pelagic during much of the year but migrate from the lower edge of the shelf to shallow coastal waters to spawn. During the spawning period (July to October; McDermott and Lowe 1997), they aggregate near the bottom in dense schools. Females lay their eggs in crevices or among stones, and males guard the eggs until they hatch in 40-45 days (Musienko 1970). The larvae are planktonic and little is known of their life history until they reach the age of two to three years and begin to appear in the fishery. They appear to grow rapidly until reaching maturity at about 4 years (50%) to 6 years (100%). Natural mortality rate is about 0.3, and maximum age observed has been about 15 years, with most of the population ≤10 years. Maximum size is ca. 50-55 cm.

Estimated biomass for BSAI Atka mackerel rose to a peak in 1981 at 1,027,000 t, dropped to 750,000 t in 1986, then reached a second peak at just under 1,300,000 t in 1991, and thereafter dropped steadily to about 605,000 in 1998 (Fig. 2). Recruitment at age 2 (Fig. 3) has been variable with strong year classes from 1975, 1977, 1984-86, and 1988 (all ≥0.777 billion fish). The 1992 year class (0.676 billion fish) is the largest for the 1990s.

1.5.1.2 The Atka Mackerel Fishery

In the 1970s, the BSAI fishery for Atka mackerel was prosecuted by Russia, Japan, and the Republic of Korea (Lowe and Fritz 1997). U.S.-foreign joint ventures began in 1980 and dominated the fishery until 1988. Since 1990, the fishery has been entirely domestic. From 1992 to 1996, the numbers of vessels participating in the fishery annually were 34, 23, 15, 17, and 17, for an annual total of 106, 122, 126, 144, and 191 vessel-weeks (Kinoshita et al. 1997). Twelve vessels participated in the fishery in 1997.

From 1978 to 1983, total annual catch varied from just under 12,000 mt to just over 24,000 mt (Fig. 4). From 1984 to 1987, total annual catch was higher, ranging from 30,000 mt to 38,000 mt. Catch was reduced again until 1992, but then increased incrementally until it reached 104,000 mt in 1996. In 1997, catch was about 66,000 mt, and the 1998 TAC was set at ca. 64,000 mt. Estimated harvest rates (catch/estimated biomass; Fig. 4) were 6% or less until 1993, but increased thereafter to a peak of 15% in 1996.

Prior to the early 1990s, the fishery occurred primarily in the spring and summer months. Since the early 1990s, the fishery has started earlier (January) and has been condensed into a shorter season, so that most or all of the TAC has been taken by late March or April. In 1995 and 1996, the fishery was also open briefly in July and/or August to allow complete removal of the TAC.

The fishery occurs in relatively predictable or constant areas throughout the central and western Aleutian Islands. Figure 5 shows the geographic distribution of the fishery in 1993-97 in the Aleutian Islands. Lowe and Fritz (1997) provide the following description.

> ". . . (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 1990s, 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 ½ ° 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). Other areas fished since the mid 1980s include north of the eastern Aleutian Islands (in areas 518 and 519 in the eastern Bering Sea), Tanaga Pass, north of the Delarof Islands, Petrel Bank, south of Amchitka Island, east and west of Kiska Island, and on the seamounts and reefs near Buldir Island . . . ."

Since 1979, the fishery has occurred largely within areas designated in 1993 as Steller sea lion critical habitat (Fig. 6, lower panel). The amount of Atka mackerel taken from critical habitat remained relatively low through the early 1990s, but then increased about three-fold in 1995 and 1996 due to a steady increase in the TAC during the 1990s. The second objective of this amendment involves a judgement about whether or not removal of this proportion and amount of Atka mackerel from critical habitat constitutes adverse modification.

1.5.1.3 Survey Estimation of Atka Mackerel Biomass

Cooperative groundfish trawl surveys were conducted by the U.S. and Japan in 1980, 1983, and 1986. Domestic surveys were conducted in 1991, 1994, and 1997. These surveys provide the only direct estimates of Atka mackerel population biomass in the Aleutian Islands region. Biomass estimates increased from 197,529 mt in 1980 to 306,780 mt in 1983, and 544,754 mt in 1986. The 1986 biomass estimate is associated with a large coefficient of variation (0.63) and may not be comparable to earlier years because of different areas and depths covered in the surveys. The 1991 biomass estimate for the Aleutian Islands was 688,150 mt, similar in magnitude to the 1994 estimate of 623,826 mt. The 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. The coefficient of variation (*CV*) of the 1997 mean Aleutian biomass is 28%, consistent with the *CV*s from the 1991 and 1994 surveys. Survey biomass estimates along with the associated standard errors are discussed in the stock assessment (Lowe and Fritz, 1997) and utilized directly in the age-structured model.

Survey biomass estimates are based on subarea strata which are designed to accommodate the current fishery management areas in the Aleutian Islands (Fig. 7). Survey biomass estimates are typically provided by Aleutian Islands areas (541, 542, and 543) and depth (Lowe and Fritz, 1997). Further breakdowns of biomass is only possible for limited regions within these management areas, including: east and west of 175°E in area 543; Petrel Bank, north of the chain (excluding Petrel Bank), and east and west of 180° south of the chain in 542; and east and west of 174°W in 541 (Fig. 7) as shown in the Table 1.1 below. Differences in stratum biomass estimates between survey years can be very large, as can the CV on a single stratum biomass.

1.5.1.4 Historical Stock Assessment and Biomass Estimates

Atka mackerel did not become a reported species group in the BSAI until 1978 (Table 1.2). Early attempts to evaluate the conditions of Atka mackerel stocks in the Aleutian Islands were severely restricted by limited biological data and lack of measures of relative and absolute stock abundance. In the northeast Pacific, Atka mackerel distribution appeared to be centered in the western Aleutian Islands and Kodiak Island (Wespestad and Ronholt, 1977). Soviet hydroacoustic surveys conducted in 1974 and 1975 in the Aleutian Islands provided the only available biomass estimates (each approximately 100,000 mt). Based on these estimates, the Soviets estimated that MSY would equal one-third of the standing stock, or 33,000 mt. Because neither

Table 1.1. Survey biomass estimates (mt) of Atka mackerel by Aleutian Islands management area and region within area.

Area	Region within area	Survey biomass 1994	Survey biomass 1997	Percent increase or (decrease)
541	177°W - 174°W	74,331	23,117	(69)
	174°W - 170°W	138,242	19,481	(86)
542	Petrel Bank	510	10,016	1864
	177°E - 177°W, north of chain	29,939	76,723	156
	177°E - 180°, south of chain	52,442	58,253	11
	180° - 177°W, south of chain	4,517	49,298	991
543	170°E - 175°E	98,442	43,038	(56)
	175°E - 177°E	225,390	68,012	(70)

Table 1.2. Historical Atka mackerel biomass estimates from stock assessments, and associated TAC levels.

Year	Biomass (mt)	TAC
1978	unknown	24,800
1979	unknown	24,800
1980	unknown	24,800
1981	unknown	24,800
1982	158,000	24,800
1983	182,800	24,800
1984	182,800	23,130
1985	300,000	37,700
1986	300,000	30,800
1987	300,000	30,800
1988	78,000	21,000
1989	unknown	20,285
1990	unknown	21,000
1991	unknown	24,000
1992	868,500	43,000
1993	1,171,000	64,100
1994	816,000	68,000
1995	832,000	80,000
1996	577,800	106,157
1997	450,200	66,700
1998	535,500	64,300

the Soviet data nor the analytical procedures used to estimate biomass and sustainable yield were made available, those estimates were considered provisional.

In the BSAI Fishery Management Plan, the optimum yield (OY) of this species was set at 24,800 mt, 75 percent of the unverified Soviet estimate of MSY. The 1978 allowable catch was set equivalent to the 24,800 mt OY and remained in place until 1984. Stock assessments from 1978 to 1981 contained only biological information (mean length, weight, and age) and catch and CPUE data from observers on Soviet vessels, and did not include formal analyses of abundance trends or yield estimations.

U.S.-derived biomass estimates for the Aleutian Islands Atka mackerel were not provided in the stock assessments until 1982. The first estimate was originally 158,000 mt and was based on demersal trawl surveys conducted cooperatively by the U.S. and Japan in 1980. In 1983, this estimate was increased to 182,800 mt to include Eastern Bering Sea biomass and, in subsequent years, the 1980 Atka mackerel survey biomass was finalized at 197,529 mt. The 1983 and 1984 stock assessments included an analysis of MSY based on the newly available survey biomass (Ronholt 1982,1984). Estimates of MSY ranged from 22,666 to 28,300 mt with a midpoint of 25,500 mt. However, in 1984, the TACs of three species groups (sablefish, Atka mackerel, and squid) were set below their sustainable yield levels so that the aggregate groundfish TAC did not exceed 2 million mt; the resulting TAC for Atka mackerel in 1984 was 23,230, but the TAC was increased mid-season accommodate the expansion of the Atka mackerel joint venture fishery.

The biomass-based Stock Reduction Analysis (SRA) model was used in the 1985, 1986, and 1987 stock assessments to evaluate BSAI Atka mackerel (Kimura and Ronholt 1985; Ronholt and Kimura 1986, 1987). This analysis used the 1983 survey biomass estimate of 300,000 mt to estimate MSY. Based on the updated survey information, MSY was estimated at 38,734 mt. The 1985 TAC was set at 37,700 mt, and again fully utilized by the joint venture fishery. The biomass estimate of 300,000 mt from the 1983 survey was not updated in the 1986 and 1987 stock assessments. However, the Bering Sea/Aleutian Islands Plan Team projected that biomass would decline to 186,700 mt in 1986. Based on this projection and the resulting yield from the SRA analysis, the Plan Team recommended an ABC of 30,800 mt for 1986. Without new information to update the Atka mackerel ABC estimate for 1987, the Plan Team again recommended an ABC of 30,800 mt. In both 1986 and 1987, the NPFMC set the Atka mackerel TAC at the same level.

The 1988 stock assessment included the newly available 1986 survey biomass estimate of 544,754 mt, and used age-structured models for the first time (virtual population analysis (VPA) and least-squares catch-at-age analysis; Kimura and Ronholt 1988). The catch-at-age data were dominated by the strong 1977 year class, which indicated that biomass would be expected to increase through the early 1980s and then decrease. Contrary to this expectation, the survey biomass estimates increased over time. The difference was reconciled by weighting the fits to the catch-at-age analysis by the coefficient of variation (CV) of the survey biomass estimates. Using the estimated CVs from the survey data, the catch-at-age analysis indicated a much lower (relative to the 1986 survey) biomass ranging from 52,000 to 106,000 mt with an average estimate of 78,000 mt. Analyses using a yield-per-recruit model and the delay-difference equation resulted in a revised MSY estimate of 38,800 mt. Because the analysis indicated relatively weak recruitment from 1982-1986, the stock assessment recommended an ABC based on recent levels of recruitment (20,963 mt) rather than sustainable yield estimates as had been done in the past. The Council accepted this recommendation and the 1988 TAC was set at 21,000 mt.

From 1989-1991, the most current survey biomass estimate was from the 1986 survey, and correspondingly, a biomass time series was estimated using the age-structured model only through 1986. In each of these three years, the age-structured model was not updated in the stock assessment, and the same recommended ABC (24,000 mt) was sent to the Plan Team for review. The 1989 TAC for Atka mackerel was reduced to 20,285 mt so that the aggregate groundfish TACs totaled 2 million mt. The 1990 stock assessment noted the appearance of the strong 1984 year class, but TAC was set at 21,000 mt, again so the aggregate groundfish TACs summed to 2 million mt. For 1991, the TAC was set using the new NPFMC overfishing definition for species whose biomass is unknown, which was the average catch from 1978 to 1990 (=24,000 mt).

The 1992 stock assessment utilized the stock synthesis age-structured model which is still currently being used to assess Bering Sea/Aleutian Islands Atka mackerel (Lowe, 1991). The 1992 stock assessment included the newly available biomass estimate (over 600,000 mt) from the 1991 survey. The large biomass indicated by the 1991 survey was consistent with strong recruitment from the 1988 year class. The stock synthesis model projected a 1992 biomass (for ages 3-7) of 868,500 mt, orders of magnitude higher than previous estimates of biomass. As an alternative to estimating F_{msy} which was unknown, the stock assessment estimated the $F_{0.1}$ level. This rate was extremely high (attributed to maximum biomass being reached before full recruitment into the fishery) and considered inappropriate for Atka mackerel yield analyses. As an alternative, the stock assessment recommended a yield of 260,000 mt which was derived by applying a harvest rate equal to the natural mortality rate (0.3) to the current biomass. While the SSC accepted the new analysis and higher biomass estimate, they were reluctant to increase the ABC by several orders of magnitude in one year and recommended a 6-year phase in approach of the higher exploitation rate. According to this scheme, the 1992 ABC was estimated as (0.30/6) x 870,000 = 43,000 mt, and the NPFMC set the 1992 ABC and TAC at this level.

The 1993 stock assessment included a projection of 1993 biomass of 1,171,000 mt from the stock synthesis analysis (Lowe, 1992). This projection was higher than the 1992 projection due to the inclusion of updated 1991 survey data and fish older than age 7 that appeared in fishery catches. Consistent with the 6-year phase-in plan, the stock assessment recommended an ABC of 117,100 mt. The 1993 stock assessment noted that the recommended yield was based on an Aleutian-wide analysis, and raised the issue of disproportionate harvesting of Atka mackerel biomass. It was noted that the bulk of the fishery occurs in the eastern Aleutians (Seguam), whereas the major portion of survey biomass has been consistently found in the western Aleutians. In the absence of a means to apportion ABCs, and the possibility of localized depletion of Atka mackerel and the resulting impact on predator populations, the SSC set the ABC at 32,100 mt, the amount that was determined could be safely taken from the eastern Aleutians (SSC minutes, December 1992). The SSC strongly recommended that the Council develop a plan amendment to allow TACs to be apportioned geographically in the Aleutian Islands. In order to protect Atka mackerel stocks from overharvesting, the Council set the 1993 TAC for BSAI Atka mackerel at 32,100 mt, well below the ABC of 117,100 mt. Amendment 28 to the BSAI Fishery Management Plan divided the Aleutian Islands into three districts. After it became effective in mid-1993, an additional 32,000 mt of Atka mackerel TAC was released to the Central (27,000 mt) and Western (5,000 mt) districts, for a total 1993 Atka mackerel TAC of 64,000 mt.

The 1994 stock assessment included a projection of 1994 biomass of 816,000 mt from the stock synthesis analysis (Lowe, 1993). The analysis showed that Atka mackerel biomass peaked in 1990. Based on a 15% harvest rate (according to the phase-in of the 30% harvest rate), the stock assessment recommended an ABC of 122,400 mt. The Council set the Atka mackerel TAC at 68,000 mt, well below the ABC of 122,400 mt based on industry needs.

The projected 1995 biomass from the stock synthesis analysis in the stock assessment was 832,000 mt (Lowe and Fritz, 1994). Although Atka mackerel biomass was still thought to be declining, the 1995 biomass was similar to the 1994 estimate based on upward revisions of past strong year classes in the 1995 assessment. However, because of the lack of updated survey information (the 1994 survey biomass estimate was not available for the 1995 stock assessment) and fishery data (too few otoliths were collected from the 1993 fishery to update catch-at-age data), the stock assessment authors recommended maintaining the 15% harvest rate resulting in an ABC of 124,800 mt. The Council set the Atka mackerel 1995 TAC at 80,000 mt, again below the ABC of 125,000 mt based on industry needs.

The 1996 stock assessment included the 1994 survey biomass estimate of 623,800 mt, similar in magnitude to the 1991 survey biomass estimate (Lowe and Fritz, 1995). Maturity-at-age data was also available for the first time and allowed better estimation of spawning biomass and the $F_{40\%}$ reference fishing mortality rate.

The projected 1996 biomass was 577,800 mt. The 1996 stock assessment noted that the phase-in fishing mortality rates were now at levels above or approaching the commonly applied reference fishing mortality rates and recommended application of the $F_{40\%}$ fishing mortality rate for BSAI Atka mackerel. The 1996 recommended yield was 116,000 mt. The Council set the 1996 BSAI Atka mackerel ABC and TAC at 116,000 and 106,157 mt, respectively.

The projected 1997 biomass from the stock synthesis analysis was 450,200 mt (Lowe and Fritz, 1996). The 1997 stock assessment incorporated revised reference fishing mortality rates. These rates were considerably lower than those reported in the 1996 stock assessment. Previously, the spawning biomass estimate was calculated at the beginning of the year. Since Atka mackerel are summer-fall spawners, a January 1 date was not a good proxy for the month of peak spawning. Consequently, a change to a more appropriate mid-August assumption to represent peak spawning in the spawning biomass calculation resulted in significantly lower reference fishing mortality rates. The resulting ABC based on a revised estimation of the $F_{40\%}$ rate was 66,700 mt. The Council set the 1997 ABC and TAC at 66,700 mt.

The most recent (1998) stock assessment included the 1997 Atka mackerel survey biomass estimate of 348,000 mt, down about 50% relative to the 1991 and 1994 survey estimates. For 1998 the stock assessment recommended a fishing mortality rate lower than the maximum allowed under the ABC/OFL (overfishing) definitions. The reasons for recommending a rate lower than the previously used $F_{40\%}$ rate were:

> "1) Stock size has been steeply declining since 1991 according to the age-structured analysis, 2) The 1997 Aleutian trawl survey biomass estimate was about 50% lower than the 1991 and 1994 survey estimates, 3) Under an $F_{40\%}$ harvest strategy, female spawning biomass is projected to decline to almost 30% below $B_{40\%}$ within 5 years. While it is acknowledged that $B_{40\%}$ represents the long-term average about which the stock may safely fluctuate, we know little about threshold biomass for Atka mackerel, 4) While the spawner-recruit relationship for Atka mackerel is uncertain, some of its life history and behavioral characteristics (low female fecundity and male nest-guarding) suggest that the relationship may be more direct, particularly at medium population levels, than for other groundfish (e.g., gadid), 5) Estimated local Atka mackerel fishery harvest rates (section 12.2.2) have been much greater (on the order of 3-5 times) than the Aleutian-wide harvest rates estimated from the model. While this pattern of fishing apparently does not affect local fishing success from one year to the next, we are uncertain about the long-term effects on the population and particularly the spawning stock." (Lowe and Fritz 1997).

Based on the above rationale, the stock assessment recommended a harvest rate no greater than that estimated for 1997 (12%) in the face of a declining Atka mackerel stock; this translated to an ABC recommendation of 64,300 mt. The Council set the 1998 ABC and TAC at 64,300 mt.

1.5.1.5 Limitations of Atka mackerel data

To fully characterize Atka mackerel stocks and localized depletion, further information is needed on their temporal and spatial dynamics, their schooling behavior, and the extent to which these are affected by fishing. Information is also needed on areas of dispersion, seasonal and annual variation by site, juvenile life history stages, and the influence of environmental or oceanographic conditions.

Better descriptions or predictions of Atka mackerel biomass and distribution would facilitate management of the fishery to avoid localized depletions. Such descriptions or predictions are limited at this time by natural variability of Atka mackerel biomass by area, and by survey frequency and precision. First, as discussed in the previous section on survey estimation of Atka mackerel biomass, six surveys have been conducted. The resulting estimates have varied three- to four-fold (ca. 200,000 mt to ca. 700,000 mt).

Between the 1994 survey and the 1997 survey, estimated biomass dropped by about half. Thus, biomass estimates based on existing surveys indicate marked variability, which compromises any attempt at predicting biomass in a future year.

Second, existing surveys are conducted every three years which, given the observed variability in results, suggests that significant changes in biomass may occur between surveys.

Third, the surveys as conducted can provide only limited information on fine-scale distribution patterns of Atka mackerel. Table 1.1 above indicates the smallest scale possible for biomass estimation in localized regions. The observed percent change in biomass estimates by region within management areas is extensive. Marked variability, rather than constancy, is the apparent rule.

Atka mackerel is also difficult 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 bottom trawls difficult; and (3) their schooling behavior makes the species susceptible to large variances in catches which greatly affect area-swept estimates of biomass.

Further areal breakdowns of survey biomass cannot be reasonably accommodated without eroding the integrity of the biomass estimates as they were designed to be used. The survey design is based on the technique of stratified random sampling where samples (trawl hauls) are randomly drawn from a defined population (area/depth interval) to estimate certain population characteristics such as abundance. One of the major benefits of stratified random sampling is the most precise estimate of any stratum mean can be obtained from the smallest possible sample size (trawl hauls) in that stratum. The stratum estimates can then be combined into a precise estimate for the whole population. While stratum estimates can be combined to create a total, they cannot be readily divided to provide abundance estimates of smaller areas within a stratum. Once divided, much of the precision associated with the stratum estimate is lost, resulting in high uncertainty in the new estimate. Smaller subarea biomass estimates could only be obtained with ad hoc apportionments and extrapolations which could result in biased and perhaps misleading estimates. Thus, useful biomass estimates for areas within the 10 nm no-trawl zones and inside and outside of critical habitat areas cannot be provided without significant changes in survey techniques and frequency.

1.5.2. Steller Sea Lion

1.5.2.1 Distribution, Status, and Life History

Steller sea lions are presently distributed around the rim of the North Pacific Ocean from northern Japan to the Kuril Islands and Okhotsk Sea, throughout the Aleutian Islands, northward in the Bering Sea to the Pribilof Islands, along the coast of the Gulf of Alaska, and southward to British Columbia, Washington, Oregon, and California. The centers of abundance are considered to be the Gulf of Alaska and Aleutian Islands (NMFS 1992). Steller sea lions are not known to migrate, but may disperse seasonally during the non-breeding season. Unidirectional movements between different sites occur (NMFS 1992), but the movement rate is unknown.

The first reported counts of the Steller sea lion occurred in the late-1950s (Kenyon and Rice 1961), and a review by Merrick et al. (1987) indicated a 78% decline between the late-1950s and 1990. The decline was first noted in the Eastern Aleutian Islands in the early 1970s (Braham et al. 1980), but spread eastward to the western and central Gulf of Alaska and westward to the central and western Aleutian Islands by the mid 1980s. York et al. (1996) report that the rate of decline appeared to increase from the mid to late 1980s, with further eastward spread to Prince William Sound and the eastern Gulf of Alaska. Between 1989 and 1994, the entire U.S. population declined by 24%. However, the declining trend observed in the Aleutian Islands region and Gulf of Alaska was not observed in southeastern Alaska, or further south along the North American west coast (except in central and southern California). In 1997, the Steller sea lion was split for management purposes into western and eastern populations; the division was based primarily on genetic studies (Bickham et al. 1996) indicating separate eastern and western stocks, and the dividing line was set at 144°W longitude (Loughlin 1997). The status of the western population was changed to endangered, while the status of the eastern population was left as threatened.

Estimated numbers for the western population declined by about 81% between the mid 1960s (ca. 177,000) and the mid 1990s (ca. 34,000; NMFS 1995; Fig. 8). Within this population, the extent of decline varies by site or area. From Samalga Pass to Kiska Island, counts of sea lions have dropped from ca. 36,000 in 1979 to just over 5,000 in 1996 (NMFS 1995, unpubl. data; Fig. 9). From Samalga Pass eastward to Amak Island, counts dropped from ca. 15,000 in 1975 to 3,000 plus in 1994. And counts west of Kiska Island have dropped from ca. 14,000 in 1979 to 2,000 plus in 1996. Since the early 1990s, the rate of decline of Steller sea lion counts in these areas appears to have slowed (Fig.9), but it is premature to assume that the decline has stopped.

Potential causes of the Steller sea lion decline include commercial harvest, subsistence harvest, parasitism and disease, toxic substances, entanglement in marine debris, deliberate shooting, predation, disturbance, direct taking in fisheries, and lack of available prey (Loughlin 1987). A total of 45,178 pups were harvested in the eastern Aleutian Islands and GOA between 1963 and 1972 (Merrick et al. 1987). Commercial harvesting ended in 1972, however, and can not be considered a factor at this time. Loss of sea lions through subsistence harvesting may also have contributed to the decline, and may be a more important factor at the current low population levels, but is insufficient to explain the decline observed since the mid 1960s. Parasitism, disease, and toxic substances may be potentially important factors, but the nature and persistence of the decline are not consistent with these potential causes. Pitcher et al. (*In press*) found aborted fetuses in numbers higher than expected, but there is no evidence that this is a widespread phenomenon or of measurable significance to the decline. Entanglement in marine debris has been observed, but at a relatively low rate (0.07 to 0.12 percent; Loughlin et al. 1986). Deliberate shooting has been reported and may have contributed significantly to the early part of the decline. Such shooting may still be occurring, but is not being reported nor quantified. Predation by killer whales has been suggested as one potential cause for the decline. However, killer whale predation is not considered a cause for the observed declines but presently may exacerbate local declines now that the western population is at such low levels (Barrett-Lennard et al. 1996). Steller sea lions are known to be easily disturbed at their rookeries and haulout sites. The consequences of such disturbance are difficult to measure, and although disturbance may have contributed to the decline, more concern is focused on disturbance as an impediment to the study of sea lions than as a primary cause of the decline. Direct taking in fisheries has contributed significantly to the decline (Loughlin and Nelson 1986, Perez and Loughlin 1990), but such taking has been reduced to relatively small numbers since the early and mid 1980s, and does not appear to be a significant determinant of present trends. Lack of available prey is generally considered the most likely cause of the decline.

Efforts to understand the nature of the decline of the western population have focused on, among other things, the life history of Steller sea lions. As is the case for most pinnipeds, most of what is known about the life history of this species is from land-based studies. Relatively little is known about their marine habitats and behaviors. On land, sea lions are found on rookeries and haulout sites, which tend to be areas isolated from access by terrestrial, and perhaps marine, predators. Rookeries are reproductive sites where pupping, nursing, and mating occur; areas where sea lions haul out on land for purposes other than reproductive behaviors are referred to as haulout sites. The most active time on rookeries is from late May to early July, when pups are born. Females mature between the ages of three and six, and thereafter may give birth to a single pup. The annual pupping rate among mature females is unknown, but early studies suggest it may be as low as 60-75% (Belkin 1966, Pitcher and Calkins 1981, Calkins and Goodwin 1988). The sex ratio at birth is reported to be slightly biased toward males (NMFS 1992). After parturition, females begin a cycle of nursing their pups on land and feeding at sea.

On average, feeding trips are on the order of a day and on-land stays are about 1.5 days (Gentry 1970, Higgins et al. 1988, Merrick and Loughlin 1997). The length of the nursing period, which is terminated by weaning of the pup, ranges from 4 to 24 months, but most pups are weaned just prior to the females' next breeding season (Pitcher and Calkins 1981). After weaning, pups face a critical and long transition to independent feeding, during which their foraging success will be an important determinant of their growth and probability of survival. Evidence from modeling studies (York 1994) and observations of sea lions at Marmot Island in the late 1980s and early 1990s (Chumbley et al. 1997) indicate that low survival of young animals (pups and juveniles) may be a key element of the species' decline. However, other aspects of the Steller sea lion life history may also be involved, and the data presently in hand are not sufficient to assess the possibility of changes in, for example, adult female survival or reproduction. The condition of adult females may affect their ability to carry a fetus to full term or, after parturition, to provide sufficient nutrition for a pup. Survival rates of pups, juveniles, and adults, and reproductive rates of adults are largely unknown, but are nonetheless vital elements for understanding the Steller sea lion decline.

1.5.2.2 Steller Sea Lion Foraging Behavior

Steller sea lion foraging behavior has been studied in the eastern Aleutian Islands, the Gulf of Alaska, southeast Alaska, and the Kuril Islands, Russia. Comparison of results (mostly unpublished) suggest that sea lions forage similarly in all areas. For instance, diving behavior and foraging distance from the rookery for adult female Steller sea lions in the eastern Aleutian Islands, the Gulf of Alaska, and in the Kuril Islands showed that females behaved similarly in all areas during the breeding season. Merrick and Loughlin (1997) present data showing that adult females in Alaska had a mean trip distance of 17.1 km (range 2.6-48.7 km) over 30 trips to sea during June and July, 1990-1993. In the Kuril Islands, female Steller sea lions had mean trip distances of 20 km (range 5-263 km) over 63 trips (Loughlin et al., *in press*). Mean dive depth for female Steller sea lions in Alaska during the breeding season was 21 m with 96% of all dives less than 50 m; similar results were obtained for the Kuril Islands. In Alaska, only 3% of adult female dives were deeper than 50 m where Kuril Islands females made 14% of their dives to depths greater than 50 m. Mean dive duration for female sea lions in Alaska during the breeding season was 92 sec and 78% of all dives were less than 120 sec; in the Kuril Islands mean dive duration was 112 sec and 70% of the dives were less than 120 sec.

Merrick and Loughlin (1997) measured foraging effort and found that it did not differ seasonally for postpartum adult females, though females with dependent young may have increased their foraging effort in winter. Also in winter, all adult females made longer foraging trips over larger home ranges and dove deeper. Young-of-the-year exerted less effort and had the shallowest and briefest dives. Winter studies have not been conducted in the Kuril Islands or in southeastern Alaska. For young sea lions, foraging ability seems to develop throughout the year. Since young sea lions are naive foragers during their first few years, and because they are limited in their dives both physiologically and behaviorally, Merrick and Loughlin (1997) concluded that they could be more easily limited by food due to changes in prey distribution.

Recent analysis of morphometric data collected in the GOA provides supporting evidence that sea lion pups and juveniles may suffer from nutritional stress. This study showed that sea lions collected in the 1980s were smaller than those collected in the same geographic area in the 1970s. The 1980s animals were smaller in standard length, mass, and axillary girth (Calkins et al., 1998). The authors propose that these differences support the hypothesis that Steller sea lions were under nutritional stress during the sampling period. Reasons for the nutritional stress were presumed to be linked to reduced food availability or lack of energetically enriched prey.

The ultimate cause for low abundance or availability of prey is a matter of considerable contention; it may be due to natural ecosystem changes, or fisheries, or some combination of the two.

1.5.2.3 Limitations of Data on Sea Lion Vital Rates and Foraging Behavior

Limited information on vital rates (survival and reproduction) of Steller sea lions is a significant impediment to understanding the nature of their decline and to managing their recovery. For large mammals, population growth is most sensitive to the survival rates of adult females. However, juvenile survival is thought to be the most sensitive to changes in the environment, and is therefore considered a major factor regulating marine mammal populations. For the Steller sea lion, two kinds of information indicate that the observed decline is related to juvenile survival: 1) modeling studies using observed age distributions (York 1994), and 2) extremely low resighting rates of animals tagged as pups at Marmot Island (Chumbley et al. 1997). However, limited information on adult reproductive rates also suggests that these rates are depressed, which also may contribute to population decline. Pitcher et al. (*in review*) report annual reproductive rates on the order of 65-70%, which is well below rates observed for other Otariids in the North Pacific (e.g., northern fur seals and California sea lions). In addition, survival rates of adult females are notoriously difficult to measure precisely, but may have major affects on population growth or decline. Thus, the lack of information on Steller sea lion vital rates severely confounds management attempts to enhance the species recovery.

Historical counts of sea lions clearly demonstrate a severe decline, but here, too, the data are insufficient to provide detailed clues about the nature of the decline. Much of the decline occurred during periods when counts were either irregular or infrequent, and better assessments are available only in the last decade. The counts serve only as an index of the total population, and may be subject to considerable measurement error and natural variation. Due to limited resources, counts at a given site are almost never repeated in a given season or year. Counts conducted by aerial survey are constrained by logistics and may occur under suboptimal conditions, thus leading to measurement error. Also, the number of animals on a rookery or haulout site may vary considerably as a function of, for example, time of day or weather conditions, leading to natural variability in the counts. In general, this lack of precision confounds attempts to correlate possible causes of the decline with population trends. Thus, evaluation of changes in sea lion numbers or survival as a result of changes in the management of the Atka mackerel fishery may not be possible.

To fully describe the potential for competition between Steller sea lions and the Atka mackerel fishery (or any other fishery), it would also be necessary to understand the foraging dynamics of sea lions in greater detail than is now possible. Foraging patterns probably vary by individual, size/age, sex, health status, reproductive status, season, year, site, prey type, and prey availability. The concept of foraging success is equally complex, and must be defined in terms of a cost/benefit analysis of energy and nutrients expended versus energy and nutrients gained. The scientific information gathered to date is revealing, but insufficient to describe sea lion foraging with confidence. The general picture that seems to be emerging is that diving patterns of Steller sea lions tend to be relatively shallow and short. Occasional deeper dives indicate that they have considerably greater diving capacity than their average dive would indicate but, in an evolutionary sense, they may be shallow divers because the extensive shallow areas around the Aleutian Islands and in the Bering Sea may have provided sufficient prey to limit the need for development of deeper diving capacity. Studies of other North Pacific pinnipeds indicate, however, that most species exhibit a wide variety of behavior, and that summaries based on a few animals should be interpreted with caution.

The study of Steller sea lion foraging behavior is confounded by a number of factors. Prior to 1987, safe anesthetics were not available for immobilizing animals and telemetry devices were in their early stages of development. Significant improvements occurred with the use of Telazol and the development of satellite-linked time-depth recorders (SLTDR: Loughlin and Spraker 1987; Merrick et al. 1994). However, even with these advancements, study sample sizes remain low. Many of the early SLTDRs malfunctioned and adequate data were not obtained. The National Marine Mammal Laboratory (NMML) has deployed 71 units as of December 1997; 2 on adult males, 50 on adult females (principally in the breeding season), and the remainder on juveniles or pups. Of these, adequate data were obtained and analyzed for 29 and the results presented in Merrick et al. (1994), Merrick (1995), Merrick and Loughlin (1997), and Loughlin et al. (in press). All results were obtained in the Gulf of Alaska, the eastern Aleutian Islands, or Kuril Islands (Russia)

The last deployment by NMML on an adult female was in 1993; in recent years, NMML's emphasis has been on juveniles. The Alaska Department of Fish and Game (ADF&G) and others have monitored a few adult females in southeast Alaska during the breeding season. Because of logistical problems associated with working in the Aleutian Islands in fall and winter, few SLTDRs have been deployed during this period and then only in the eastern Aleutian Islands and Gulf of Alaska. None have been deployed on any sex or age group in the area of the Atka mackerel fishery during the time of year of the fishery. However, as presented above, Steller sea lion foraging behavior appears similar in different geographic areas. Individual variability in sea lion foraging strategies likely overshadows any geographic differences, particularly if comparing similar geographic areas where depth, distance to the continental shelf, and prey distribution and density are similar.

1.5.3 Interactions between the Atka Mackerel Fishery and the Steller Sea Lion

The geographic distribution of the Atka mackerel fishery overlaps considerably with areas that were designated in 1993 as Steller sea lion critical habitat (Fig. 5). This overlap may lead to interactions between the fishery and sea lions. Interactions between marine mammals and fisheries are generally characterized as direct (e.g., entanglement, gear conflict, damage of fishery catch, incidental kill of marine mammals) or indirect (i.e., competition for prey). Direct interactions will not be discussed here, because the evidence suggests that the direct interaction rate between Steller sea lions and the entire BSAI groundfish fishery is very low (Hill and DeMaster 1998), and the intent of this amendment is to reduce indirect interactions or competition for Atka mackerel prey. With respect to such competition, the following can be stated.

- The foraging distributions of the Steller sea lion and the Atka mackerel fishery overlap considerably (see above for distributions of the Steller sea lion and the fishery).

- Atka mackerel are an important prey item for Steller sea lions (Fig. 10). Merrick et al. (1997) found that Atka mackerel were the most common prey item (based on split-sample frequency of occurrence) for Steller sea lions in portions of the central and western Aleutian Islands. Their results were based on scats collected in summer months and assumed to be primarily from adult females. Atka mackerel were also found in 84% of 241 Steller sea lion scats collected in 1989-92 in the Aleutian Islands (92% in the Central Aleutian Islands; NMFS 1992).

- If lack of available prey is an impediment to the recovery of the western population of Steller sea lions, then the evidence for fishery-induced localized depletions of Atka mackerel and the persistent distribution of the fishery within critical habitat support the hypothesis of sea lion - fishery competition and fishery impacts on Steller sea lion population dynamics.

The task of proving or disproving this competition hypothesis with absolute certainty will probably not be possible given the complexities and dynamics of: 1) Steller sea lion foraging patterns and success, and their link to survival and reproductive rates; 2) the temporal and spatial distribution of Atka mackerel and the fishery; and 3) natural changes in food availability. Examination of past trends in estimated Atka mackerel biomass (Fig. 2) and Steller sea lions in the central and western Aleutian Islands (Fig. 9) does not reveal a correspondence between the two. Initial evidence of the Steller sea lion decline was from the eastern

Aleutian Islands, and declining trends in the central and western Aleutians were not confirmed until mid 1980s (Fig. 9), indicating those declines began some time prior to 1985. The declines were particularly severe in the late 1980s, when the estimated biomass of Atka mackerel appeared to be increasing. Atka mackerel biomass peaked in the early 1990s and has been declining since, while sea lion numbers have continued to decline, but at lower rates than observed in earlier years. Thus, a comparison of trends does not support the hypothesis that Atka mackerel biomass is the dominant factor in the decline of Steller sea lions in the central and western Aleutian Islands.

Such a comparison may be misleading, however, in that earlier estimates of Atka mackerel biomass may be less reliable and other more influential factors may confuse or confound any attempt at relating Atka mackerel biomass to sea lion trends. Similarly, total Atka mackerel biomass may not be as important as availability in areas around rookeries and haulouts, which may be affected by the fishery. That is, the appropriate comparison of Atka mackerel biomass and Steller sea lion trends is likely not on a range-wide basis, but rather on a more geographically restricted basis, with limits determined by the temporal and spatial dynamics of the fish stock and foraging behavior of sea lions. At present, such data are not available. As stated earlier, however, this proposal is not based on the notion that the fishery has caused the decline, but rather on NMFS's responsibility to ameliorate conditions which may impede recovery and conservation.

1.5.4 Management History

Management actions pertaining to the Atka mackerel fishery and Steller sea lions include:

- Atka mackerel became a reported species in the BSAI (1978);
- The BSAI FMP became effective (1982);
- The Steller sea lion was listed as threatened under the ESA (December 1990);
- Three-nautical-mile (nm) radius no-entry buffer zones were created around all sea lion rookeries west of 150° W longitude (December 1990);
- Shooting at or near sea lions was prohibited and the number of sea lions that could be killed incidental to commercial fishing was reduced (December 1990);
- The pollock TAC in the GOA was allocated spatially, and conditions were placed on temporal allocations of the TAC (June 1991);
- Year-round 10-nm trawl exclusion zones were created around all rookeries west of 150°W longitude, and 20-nm trawl exclusion zones were created around 6 rookeries in the eastern Aleutian Islands during the BSAI pollock A-season (June 1991, January 1992, and January 1993);
- The recovery plan for the Steller sea lion was published (December 1992);
- Critical habitat for the Steller sea lion was designated in April 1993 (58 FR 17181). Specific areas designated as critical habitat were (1) all rookeries and major haul outs (where greater than 200 sea lions had been counted, but where few pups are present and little breeding takes place), including a) a zone 3,000 feet (914 m) landward and seaward from each site east of 144°W longitude (including those in Alaska, Washington, Oregon and California); and b) a zone 3,000 feet (914 m) landward and 20 nm (36.5 km) seaward of

each site (36 rookeries and 79 haul outs) west of 144°W longitude where the population had declined more precipitously and where the former center of abundance of the species was located; and 2) three aquatic foraging regions within the core of the species' range;

- The Aleutian Islands were divided into three management areas for the purpose of apportioning Atka mackerel TACs (Amendment 28, 1993);

- The Steller sea lion species was split into eastern and western populations and the listing status of the western population was changed to endangered (May 1997); and

- Certain forage fish were combined into a unique complex that could not be commercially harvested (effective April 1998).

When the western population was listed as endangered, no new management measures were imposed. However, NMFS is in the process of evaluating current management efforts, including (but not limited to) the buffer zones around Steller sea lion rookeries and various harvest strategies for groundfish, including Atka mackerel. At the conclusion of these evaluations, NMFS may suggest modifications of current management strategies.

1.5.5 Leslie Depletion Analysis

In previous ESA section 7 consultations on the BSAI FMP, NMFS expressed concern that fisheries could impede sea lion recovery in at least three different ways: 1) fishing could lead to changes in prey composition, reducing the availability of preferred prey, 2) fishing could change the age structure of target species which may be preferred prey, and 3) fishing could lead to areas of localized depletion of prey, thereby reducing the foraging success of sea lions by increasing the energetic costs associated with finding sufficient prey. Fritz (unpubl., Appendix 1) suggests that localized depletions occur as a result of the Atka mackerel fishery. Initially, Fritz evaluated in-season changes in CPUE of the Atka mackerel fishery at three BSAI locations (Seguam Bank, Petrel Bank, and Kiska Island) and one location in the Gulf of Alaska in 1992-95. The abstract of this work states:

> "Leslie regression analyses of Atka mackerel (*Pleurogrammus monopterygius*) fishery catch per unit effort (CPUE) data collected in the Aleutian Islands and Gulf of Alaska in 1992-95 revealed significant reductions during the course of 8 local fisheries lasting between 3 days and 17 weeks. Estimates of harvest rate (catch divided by the initial population size estimate, B_0) ranged between 55% and 91%. Length-frequency distributions and the time-series of catches and effort suggest that the exploited populations were not closed (e.g., immigration was evident) yet the rates of removal (or emigration) apparently far exceeded rates of immigration. Estimates of B_0 from the second year (with periods of fishing separated by at least 15 weeks) were nearly identical to those from the first year. This suggests that in the Aleutian Islands, the fishery utilizes areas preferred by adult Atka mackerel and that these areas are replenished over time. Temporary reductions in the sizes of local Atka mackerel populations could affect other Atka mackerel predators, such as the Steller sea lion (*Eumetopias jubatus*).

The use of the Leslie model (as described by Ricker [1975] and Gunderson [1993]) to estimate stock abundance has been primarily restricted to intensive fishing experiments of relatively sedentary species, such as invertebrates (Ralston 1986; Joll and Penn 1990; Iribarne et al. 1991; Miller and Mohn 1993) or tropical reef fish (Polovina 1986), using standardized gear in well-defined areas. With a time-series of catch and effort data from such experiments, Leslie's model permits estimation of the species' initial abundance and its catchability (proportion of the stock caught with one unit of effort) within the context of certain assumptions, which include that: 1) the population being fished is closed, or alternatively that immigration and growth are equal to emigration from the area plus natural mortality, 2) catchability over the course of the experiment remains constant, and 3) changes in catch per unit effort are directly related to changes in fish density.

These assumptions are reasonable for the Atka mackerel fish stock in the central and western Aleutian Islands. The fish are found in well-defined habitat and the fishery operates at relatively constant locations. The duration of the fishery is relatively short so that natural mortality and migration into and out of the fish stocks are likely limited. Catchability could change over the course of the fishery, but if such changes occur, say as a result of dispersion or altered schooling behavior, those changes could also have detrimental affects on foraging sea lions. Finally, the use of CPUE as direct measure of fish density or abundance may be considered problematic, but CPUE is commonly used as a reliable index of density or abundance. While all of the assumptions of the Leslie model may not be met perfectly in these fisheries, the model is sufficiently reliable to indicate a consistent and meaningful pattern of depletion due to fishing.

The data analyzed were collected by fishery observers and include detailed information on catch composition, haul duration, and haul location. Leslie's method of CPUE analysis uses the resulting time series of catch and effort data to estimate catchability (q) and the biomass of the initial population (B_0) from the following linear equation (Ricker 1975):

$$\frac{C_t}{f_t} = qB_0 - qK_t$$

where C_t and f_t are catch taken (metric tons [mt] of Atka mackerel) and effort expended (hours trawled), respectively, during period t, and K_t is the cumulative catch to the start of period t plus half that taken during the period. Catchability is defined as the proportion of B_0 that is captured with one unit of effort (one hour trawled).

The application of the Leslie model and an example of within-season changes in CPUE during the course of a fishery at a single location (Kiska, from May-July 1994) are illustrated in Figure 11. The time series of Atka mackerel catches by the fleet is shown in Figure 11A (a total of 22,500 mt caught from late March - week 11, to late July - week 29). Haul-by-haul CPUE is shown in Figure 11B, while fleet CPUE pooled by week is shown in Figure 11C. For the Leslie regression line shown in Figure 11C (regression coefficient is significantly different from 0 at $p<0.001$), weekly CPUE is regressed against cumulative catch (K_t as described above). Extending this line to the x-axis (where CPUE=0) yields an estimate of the initial biomass of the fished population given the assumptions of the model. In this case, it was estimated that 32,200 mt of Atka mackerel was present prior to the fishery which caught 22,500 mt, yielding an estimate of the harvest rate of 70%. This is similar to the percentage decline in CPUE estimated from the regression: CPUE during the first week of the fishery was 37.7 mt/hour, and in the last week was 14.7 mt/hour, a decline of 61%.

Subsequent Leslie depletion analyses were completed for 37 time-area fisheries in 1986-97 (Appendix 2). The areas analyzed included east and west of Buldir Island, west of Kiska Island, two areas south of Amchitka Island, north of the Delarof Islands, the east side of Tanaga Pass, and south of Seguam Island (Fig. 5). With an alpha value of 0.05, a total of 17 of the 37 time-area fisheries yielded statistically significant relationships between cumulative catch and CPUE; CPUE increased significantly in one case and declined significantly in 16 cases. In general, the greater the total catch in an area, the more likely it was to yield a significant decline in CPUE.

1.5.6 Comments on the Leslie Depletion Model and Analysis

The results of the Leslie depletion model analyses indicate that CPUE declined significantly in 16 of 37 time/area Atka mackerel fisheries. In only 1 of the 37 did CPUE increase significantly with cumulative catch, a number consistent with random chance. These results indicate that the fishery can create localized depletions of an important Steller sea lion prey. Criticisms of this conclusion can be divided into two general categories: criticisms of the Leslie model itself, and criticisms of the data used in the analysis. Three reviews were completed on the Leslie analysis prior to the preparation of this document. The first two were reviews contracted by Groundfish Forum, and the third was a review and reanalysis contracted by the Alaska Fisheries Science Center. Those reviews are provided in section 8.0 (Agencies and Individuals Consulted).

During the Council review process (NPFMC meeting April, 1998), several comments/questions were also raised about the data used in the analysis. Those comments will be briefly addressed here, with additional detail provided in Appendices.

Comment 1: The analysis may have included hauls directed at other targets, giving a false impression of declining CPUE for Atka mackerel.

Species composition of the hauls from 13 time-area fisheries was investigated to see if declines in CPUE were related to declines in percent composition of Atka mackerel in the haul. Data showing both the aggregate Atka mackerel percentages in sampled hauls by period and vessel, and the fleet CPUE for each period are summarized in Appendix 3; nine of the time-area fisheries had significant declines in CPUE with cumulative catch, while four did not.

The results suggest that the Atka mackerel percentage was not correlated with CPUE. Of the nine fisheries with significant declines, there was no consistent pattern between fleet Atka mackerel haul percentages and CPUE by period. For some time-area fisheries (e.g., Amchitka W 1996, Buldir E 1995 and Petrel Bank 1994), both Atka mackerel percent and CPUE declined (but generally not at the same rate or simultaneously). For others (e.g., Seguam 1993 and Kiska 1994), Atka mackerel percent increased as CPUE decreased, while for some (e.g., Amchitka E 1997), Atka mackerel percent remained at approximately the same level as CPUE declined. In the four fisheries that did not have significant declines in CPUE, no trend was observed in Atka mackerel percentage over time.

The lowest fleet Atka mackerel percentage observed in any single period of the 13 time-area fisheries was 64%. Furthermore, 93% of the periods had fleet Atka mackerel percentages greater than 70%. The pattern was similar for individual vessel percentages by period. While the lowest Atka mackerel percentage observed during any single period on an individual vessel was 34%, 92% of the vessel-periods had Atka mackerel percentages greater than 70%. Therefore, changes in fishing target does not explain the observed declines in CPUE.

Comment 2: The declines in CPUE may have resulted from an increasing number of vessels in a fishery over time, which was not accounted for in the Leslie analyses.

CPUE is a relative index of catch per unit of effort. The measure of effort is in hours trawled and is independent of the number of vessels in the fishery. The number of vessels actively fishing for Atka mackerel varied during the course of the time-area periods analyzed, and changes in the number of vessels did not coincide with the significant declines observed in CPUE (Appendix 3). For example, the number of vessels fishing at Seguam Bank in 1993 went from 4 (periods 3-6) to 12, 17, 21, and 12 in periods 7-10 (see Appendix 3, Figure corresponding to Seguam 1993). The sharp increase in the number of vessels was not discernible in the declining CPUE observed from period 4 to period 10.

Comment 3: The declines in CPUE may have resulted from a pattern of larger vessels entering the fishery first, and then being replaced by smaller vessels with less fishing "power" (i.e., less horsepower, smaller nets). The changing power of the vessels in the fishery accounts for the observed declines in CPUE.

Two kinds of evidence suggest that fishing power is not a sufficient explanation for the observed declines. First, Leslie depletion analyses were rerun for four fisheries using the CPUE data from only one vessel; two of the fisheries which showed significant declines in CPUE (Amchitka West 1996 and Kiska 1996) and two did not (Amchitka West 1995 and Amchitka East 1996). In all four cases, the CPUE declined significantly for the single vessels. These four cases are listed in tables giving site-specific results in Appendix 2.

Second, in his depletion paper, Fritz analyzed depletions in CPUE for Petrel Bank 1993 and Seguam 1993, using all vessels involved in the fisheries. He then reanalyzed the decline in CPUE using only vessels that were at those sites for the entire duration of the fishery (i.e., fishing power for those vessels would not have changed during the course of the fishery. The results using all vessels versus vessels there the entire fishery were virtually identical, indicating that the declines were not the result of changes in vessel power.

Comment 4: The method of binning the data is arbitrary and may lead to spurious results.

The original CPUE data were determined by definition. Fritz chose catch by hour, but could have chosen catch by haul, catch by day, or catch by week, or some other measure. Catch by hour is probably the best method, as it accounts for effort more accurately than catch by haul (which may be 1 hour or three hours) or day (1 haul per day versus 10), and so on. Binning was used to reduce the variance around the regression line while at the same time allowing sufficient points to accurately estimate the slope of the line. These analytical decisions did not have a significant influence on the outcome of the analyses. As described in Appendix 2, analyses were conducted with CPUE data binned by amount of catch, and then the analyses were rerun with CPUE data binned by number of hauls; the results are comparable. The method of binning should not change the general conclusion of declining CPUE.

2.0 GOALS, OBJECTIVES, AND ANALYSES OF ALTERNATIVES

2.1 Goal of the Amendment

The goal of this regulatory amendment is to avoid significant competition between the Atka mackerel fishery and the Steller sea lion.

2.2 Objectives of the Amendment

2.2.1 To avoid fishery-induced localized depletion of Atka mackerel.

2.2.2 To avoid adverse modification of Steller sea lion critical habitat by excessive fishery removal of Atka mackerel.

2.3 Criteria for Evaluating Alternatives

Based on the objectives of the amendment, the chosen alternative must meet two fundamental criteria or this amendment will likely not meet NEPA and ESA requirements:

2.3.1 The alternative must avoid significant localized depletion by some mechanism, including one or more of the following: spatial apportionment, temporal apportionment, or reduced TAC.

2.3.2 The alternative must avoid adverse modification of Steller sea lion critical habitat by reducing the proportion of catch inside such habitat.

Additional criteria will be considered below only for those alternatives that meet these first two criteria.

2.4 Analyses of Alternatives

2.4.1 Alternative 1: No Action: no change in management of the fishery.

This alternative would not avoid localized depletions (criterion 1), nor would it reduce the proportion of the catch within critical habitat (criterion 2). Because it fails to satisfy the two main criteria, it would likely not meet ESA requirements. Therefore, this alternative is not considered acceptable and will not be considered further.

2.4.2 Alternative 2: Seasonal A:B split (50%:50%) in TAC.

This alternative would reduce the probability of localized depletions (criterion 1), but to a limited extent only. At the request of some fishery participants, Leslie analyses were conducted on data from the first half of the fishing season (i.e., until half of the TAC in specific area was caught) to determine if reducing the TAC by 50% (as would be accomplished by a 50:50 seasonal split in TAC without other management measures) would prevent localized depletions. In 8 of 9 cases where significant depletions occurred in the course of a whole season, significant depletions also occurred in the analyses based on half of the data (Appendix 2). These results suggest that a simple seasonal split does not meet the first main criterion or avoiding localized depletions.

This alternative does not reduce the proportion of the catch taken from critical habitat (criterion 2). Because it fails to satisfy the two main criteria, it would likely not meet ESA requirements. Therefore, this alternative is not considered acceptable and will not be considered further.

2.4.3 Alternative 3: **(Preferred)** Seasonal A:B split (50%:50%) in TAC, plus split of TAC to subareas inside and outside of Steller sea lion critical habitat.

This alternative is expected to avoid localized depletion (criterion 1) by splitting the TAC among two seasons and among areas inside and outside of critical habitat. The extent to which localized depletions would be avoided under this alternative will depend, in part, on the fleet distribution within a management area. The probability of localized depletions increases when the fleet concentrates fishing effort geographically, and decreases when the fleet spreads out and distributes effort throughout a management area. Figures 12 and 13 illustrate the effect of fleet concentration/dispersal under alternatives 2 and 3. Localized depletions are still possible under alternative 3, but they are much less likely than under alternative 2. Alternative 3 is also expected to avoid adverse modification of critical habitat (criterion 2) by reducing the proportion of the catch taken from such habitat.

Table 2.3. Example of alternative 3. Releases of TAC in the Atka mackerel fishery, assuming a BSAI TAC of 64,300 mt, a temporal split (50:50) of the fishery into two seasons, and an additional split (40:60) in each season-area for inside and outside critical habitat.

	Regulatory area									
	541		542				543			
Stock distribution	23%		35%				42%			
Seasons	A	B	A		B		A			
Critical habitat			In	Out	In	Out	In	Out	In	Out
TAC distribution	7450	7450	4500	6700	4500	6700	5400	8050	5400	8050

Listed variations of alternative 3 were:

2.4.3.1 Critical habitat split (e.g., 40% inside: 60% outside), in areas 542 and 543 during both seasons. Area 541 would not be split for critical habitat because of the 20-nm no-trawl zone during the A season.

This variation includes a critical habitat split of 40% inside and 60% outside (effectively reduces current inside percent [80%] in half), but the split is imposed only in areas 542 and 543. Most of the fishery in area 541 occurs around Seguam Bank, and 20-nm no-trawl zones around rookeries at Seguam and Amlia Islands already protect critical habitat during the A season.

2.4.3.2 **(Preferred)** Critical habitat split of 40% inside: 60% outside in areas 542 and 543 during both seasons, achieved in incremental changes as shown in the following table. The current 20-nm no-trawl zones around Agligadak and Seguam rookeries would remain in effect for both A and B seasons. CDQ vessels would be exempt from the A:B season split, but would abide by the percent limits in the table. The Atka mackerel jig fishery in area 541/Bering Sea would be exempt from seasonal and critical habitat splits. The effectiveness and impact of the amendment would be reviewed annually. This variation imposes the reduction of TAC inside critical habitat in an annual incremental manner. This approach could achieve the same result as the first option, but would require four years to do so. The incremental implementation of this option would allow fisheries a period of adjustment to the shift of TAC out of critical habitat.

Minimum percent of annual Atka mackerel TAC taken outside of Steller sea lion critical habitat		
	Aleutian Islands District	
Year	Western (543)	Central (542)
Current	15	5
1999	35	20
2000	43	33
2001	52	46
2002	60	60

2.4.3.3 Critical habitat split of 0% inside: 100% outside.

The third variation would be to close critical habitat to fishing (effectively a 0% inside: 100% outside split). This option would ensure that localized depletions do not occur inside critical habitat, and would ensure that critical habitat is not adversely affected.

All three variations are expected to satisfy both criteria, although the incremental reduction of proportion of catch inside critical habitat would be satisfied only after a two- to four-year period. The purpose of the incremental shift out of critical habitat is to allow the fishing fleet a period of time to adjust its fishing practice.

Therefore, alternative 3 and the listed variations are considered likely to meet ESA requirements. Further considerations pertinent to Alternative 3 include the effects of seasonal and geographical dispersion of the fishery.

2.4.3.4 Seasonal considerations

From a biological point of view, the two primary considerations with respect to season are 1) the life history of the Atka mackerel and the need to avoid the spawning period, and 2) the life history of the Steller sea lion and the need to avoid the winter period when pregnant and lactating adult females face increased energy demands and young-of-the-year are beginning to wean and learn to forage independently.

While Atka mackerel spawn more than one time per year, in Alaskan waters, spawning peaks in August (McDermott and Lowe 1997). Lowe and Fritz (1997) report:

> "In certain areas and months, female Atka mackerel greatly outnumbered males in fishery catches (Fritz and Lowe, unpubl. manuscript, AFSC). While reasons for this are not known, this may be related to their reproductive and spawning behavior. In Russian waters, male Atka mackerel have been observed guarding nests of fertilized demersal eggs (Zolotov 1933). Therefore, catches composed predominately of females may be the result of a sexually segregated population, possibly during nest-guarding periods after spawning. In the Aleutian Islands, females are more likely to outnumber males in fishery catches in late summer and fall than during winter, but there is considerable variability in the sex ratios geographically within the same season. More research on

seasonal and tidal distribution patterns and rates of seasonal, geographic and ontogenetic maturity are necessary before these observations can be fully explained."

The peak of the pupping season for Steller sea lions is in early June. Pups nurse for a minimum of four months and may wean from that point onward until the age of about 24 months. The early weaning pups are therefore beginning a critical transition to foraging independence beginning in October or November, but lasting through the winter months, perhaps until March.

To allow a sufficient no-fishing interval between the A and B season (i.e., disperse the fishery over time), to avoid the peak of the Atka mackerel spawning period, and to avoid the winter period critical to Steller sea lions, the B-season might be best conducted from 1 September to 1 November.

A small percent of the Atka mackerel TAC is allocated to CDQ vessels, and the allocation to these vessel would be exempt from the seasonal split because subdivision of that allocation would likely make fishing for Atka mackerel economically infeasible.

2.4.3.5 Geographical considerations

2.4.3.5.1 Area Available to the Fishery

Trawl surveys conducted by NMFS indicate that Atka mackerel fish stocks are available to the fishery almost exclusively at depths above 200 m. Assuming that the fishery is conducted at depths of 200 m or less, the total area available (i.e., less than 200 m depth but outside of no-trawl zones) is about 20,000 km^2. Of that area, about 13,828 km^2 (69%) is within Steller sea lion critical habitat and 6,267 km^2 (31%) is outside of critical habitat (Fig. 14). The main locations outside of critical habitat that are available for fishing are south of Atka Island (management area 541), Petrel Bank (area 542), Tahoma Reef (area 543), the area between Buldir and Kiska Islands (area 543), and Stalemate Bank (area 543).

Locations where surveys indicate the presence of fish stocks (based on the 1991 and 1994 surveys; Fig. 1), but where the fishery currently does not operate include south of Atka Island and Stalemate Bank (Fig. 5).

2.4.3.5.2 CPUE inside and outside of critical habitat

Trawl surveys conducted by NMFS in 1991 and 1994 provide a general view of Atka mackerel biomass distribution throughout the region fished (Fig. 1). These surveys are not designed to estimate Atka mackerel biomass inside and outside of critical habitat. However, fishing inside and outside of critical habitat can be compared on the basis of past CPUE values. Tables 2.4 and 2.5 present the CPUE for the fishery and for trawl surveys conducted 1993-97 by year and management area for the period from 1993 to 1997. For this period, 71% of the catch occurred inside of critical habitat, and 29% occurred outside. Inside critical habitat, CPUE was 16.6 mt, while outside critical habitat, CPUE was 16.2 mt. NMFS trawl survey data for 1991 and 1994 combined indicate that CPUE was higher outside of critical habitat (3.4 mt) than inside (1.8 mt), particularly in areas 541 and 543.

While the expectation is that CPUE will decline if the fishery is required to shift to locations outside of critical habitat, the available information does not automatically lead to that conclusion, and it is not yet clear that any decline in CPUE will be significant.

Table 2.4. Catch per unit effort of the Atka mackerel fishery (CPUE=metric tons of Atka mackerel per hour trawled) and observed tons of Atka mackerel caught inside and outside of Steller sea lion critical habitat by management area (541, 542, and 543) in the Aleutian Islands, 1993-97.

		541			542		
Year	**Data**	**Inside**	**Outside**	**% Inside**	**Inside**	**Outside**	**% Inside**
1993	CPUE (mt/hr)	17.9	27.5		9.0	14.5	
	Tons	16,369	9,618	63%	1,906	15,470	11%
	# Hauls	599	237		188	399	
1994	CPUE (mt/hr)	15.1	21.8		17.1	13.4	
	Tons	5,123	5,084	50%	17,041	9,189	65%
	# Hauls	120	107		501	296	
1995	CPUE (mt/hr)	15.0	25.0		22.9	7.6	
	Tons	2,430	5,703	30%	30,164	463	98%
	# Hauls	57	100		706	23	
1996	CPUE (mt/hr)	13.9	17.4		15.5	9.1	
	Tons	10,070	9,184	52%	18,762	3,313	85%
	# Hauls	219	194		515	110	
1997	CPUE (mt/hr)	23.1	25.2		19.0	13.4	
	Tons	6,840	4,898	58%	11,971	588	95%
	# Hauls	100	68		245	15	
1993-1997	CPUE (mt/hr)	16.8	22.5		18.3	13.1	
	Tons	40,832	34,488	54%	79,844	29,023	73%
	# Hauls	1,095	706		2,155	843	

		543			Aleutian Islands		
Year	**Data**	**Inside**	**Outside**	**% Inside**	**Inside**	**Outside**	**% Inside**
1993	CPUE (mt/hr)	11.6	4.7		15.9	16.7	
	Tons	1,045	554	65%	19,321	25,642	43%
	# Hauls	36	30		823	666	
1994	CPUE (mt/hr)	26.8	19.4		18.6	15.6	
	Tons	8,559	52	99%	30,723	14,325	68%
	# Hauls	216	2		837	405	
1995	CPUE (mt/hr)	14.1	12.3		19.3	18.1	
	Tons	11,234	2,000	85%	43,827	8,167	84%
	# Hauls	313	79		1,076	202	
1996	CPUE (mt/hr)	13.9	15.1		14.4	14.4	
	Tons	22,332	5,941	79%	51,164	18,438	74%
	# Hauls	561	141		1,295	445	
1997	CPUE (mt/hr)	13.4	13.6		16.2	18.5	
	Tons	17,974	3,011	86%	36,786	8,497	81%
	# Hauls	401	67		746	150	
1993-1997	CPUE (mt/hr)	14.7	12.9		16.6	16.2	
	Tons	61,145	11,558	84%	181,821	75,070	71%
	# Hauls	1,527	319		4,777	1,868	

Table 2.5. Catch per unit effort (CPUE=metric tons of Atka mackerel per hour trawled), tons of Atka mackerel caught, and number of non-zero Atka mackerel hauls (# Hauls w/ AM) and total hauls taken during the NMFS Aleutian Islands bottom trawl groundfish surveys inside and outside of Steller sea lion critical habitat by management area (541, 542, and 543) in 1991 and 1994.

		541		542	
Year	Data	Inside	Outside	Inside	Outside
1991	CPUE (mt/hour)	0.4	0.0	2.0	1.3
	Tons	4.5	0.0	34.1	5.7
	# Hauls w/ AM	23	2	43	13
	Total Hauls	116	26	81	24
	% w/ AM	20%	8%	53%	54%
1994	CPUE (mt/hour)	3.2	8.6	0.9	0.1
	Tons	43.2	25.4	22.0	0.1
	# Hauls	31	6	55	4
	Total Hauls	123	31	114	17
	% w/ AM	25%	19%	48%	23%
1991 & 1994	CPUE (mt/hour)	2.0	6.5	1.4	0.9
	Tons	47.7	25.4	56.1	5.8
	# Hauls	54	8	98	17
	Total Hauls	239	57	195	41
	% w/ AM	23%	14%	50%	41%

		543		Aleutian Islands	
Year	Data	Inside	Outside	Inside	Outside
1991	CPUE (mt/hour)	2.0	3.4	1.5	1.9
	Tons	17.8	10.0	56.5	15.6
	# Hauls	27	12	93	27
	Total Hauls	44	21	241	71
	% w/ AM	66%	57%	38%	38%
1994	CPUE (mt/hour)	4.7	4.0	2.1	4.6
	Tons	22.3	17.6	87.5	43.1
	# Hauls	16	14	102	24
	Total Hauls	56	25	293	73
	% w/ AM	28%	56%	35%	33%
1991 & 1994	CPUE (mt/hour)	2.9	3.7	1.8	3.4
	Tons	40.1	27.5	144.0	58.8
	# Hauls	43	26	195	51
	Total Hauls	100	46	534	144
	% w/ AM	43%	56%	36%	35%

2.4.3.5.3 Length distribution of the catch inside and outside of critical habitat

The dominant feature of the size distribution of Atka mackerel by area is that they grow faster in the eastern portions of their Alaskan range than in the west (Lowe et al. in press). Their length distribution varies annually due to variance in the size of recruiting yearclasses, and spatially due to variability in the distribution of those yearclasses. These variances are apparent in Figures 15 and 16, which illustrate length-frequency data collected on fishing vessels in 1996 and 1997 in the Aleutian Islands, western Gulf of Alaska, and southern Bering Sea. In 1996, two distinct size modes were present in most areas fished. In 543 (western Aleutian Islands) and the western portions of 542 (Petrel Bank and Amchitka), the larger mode was centered at approximately 40 cm while the smaller mode was at 31-35 cm. In eastern 542 (Delarofs) and in 541 (Seguam), the smaller size mode was similar in size to that observed in the west, but the larger mode was 1-2 cm longer. East of Seguam, Atka mackerel smaller than 40 cm were rare in fishery samples, and modal lengths increased to between 45-47 cm. In 1997, a single size mode of Atka mackerel was present in the areas fished, and the modal length increased from 35-37 cm in 543 and the western portions of 542 to 39-40 cm in east 542 and 541.

Within each management area, limited data are available to address the question of size differences in Atka mackerel encountered by the fishery inside and outside of Steller sea lion critical habitat. In 543, areas fished around Buldir Island and west of Kiska Island are within critical habitat, while areas on Tahoma Reef are outside (Fig. 5). In 1996, the smaller size mode was encountered more frequently on Tahoma Reef than around Buldir Island, suggesting that size outside critical habitat may be smaller. However, this small mode dominated the length-frequency distribution at Kiska Island. In 1997, all three areas had similar length-frequency distributions. In 542, Petrel Bank is outside of critical habitat and can be compared with areas fished near Amchitka Island, the Delarofs, and west of Kiska. Petrel Bank had a similar length-frequency distribution to Amchitka, but Atka mackerel were generally smaller at both locations than at the Delarofs and near Seguam to the east. This was observed in both 1996 and 1997 (though without Petrel Bank in 1997). These observations suggest that within a management area, any differences in length distribution of Atka mackerel inside and outside of critical habitat are small compared to those observed between western and eastern fished areas even within a single management area (e.g., 542).

2.4.3.5.4 Bycatch inside and outside of critical habitat

Prohibited species bycatch rates by the Atka mackerel target fishery inside and outside of Steller sea lion critical habitat are summarized for 1994, 1996, and 1997 in Tables 2.6 and 2.7. The years 1994, 1996, and 1997 were chosen because 1996 and 1997 represent the two most recent complete years of data, and 1994 is the most recent year during which significant Atka mackerel fishing effort occurred outside of critical habitat in area 542. Halibut and salmon bycatch rates by the fishery were low both inside and outside of critical habitat in the Aleutian Islands (541-543), and there was no trend by management area or with respect to critical habitat. King crab bycatch rates by the fishery have generally been higher in areas 542 and 543 than in 541, but there is no consistent trend with respect to critical habitat. For instance, in 1994 in management area 542, the king crab bycatch rate outside of critical habitat (on Petrel Bank) exceeded 0.1 crab/mt of Atka mackerel, while that inside critical habitat was 0. However, in 1996 and 1997, king crab bycatch rates were higher inside critical habitat than outside. In 1996 in 543, almost 0.2 crab/mt were caught inside critical habitat (west of both Buldir and Kiska Islands), while the "outside" rate was 0 (Tahoma reef). In 1997 in 542, 0.16 crab/mt were caught inside critical habitat (at the Delarof Islands and west of Kiska Island), while none were caught outside (though only 588 mt of Atka mackerel was observed outside of critical habitat at Petrel Bank compared with over 12,000 mt inside). In area 543 in 1997, the highest rate of crab bycatch, almost 0.5 crab/mt, was observed inside critical habitat, primarily west of Kiska Island. The rate outside of critical habitat in area 543 in 1997 was only 0.02 crab/mt (on Tahoma reef).

Table 2.6. Bycatch rates of Pacific halibut, king crab (includes blue, golden, brown, and red), and salmon (all species) in the Atka mackerel target fishery inside and outside of Steller sea lion critical habitat in the BSAI region in 1994, 1996, and 1997. Bycatch rates are calculated per ton of Atka mackerel caught and are in the units of kg of halibut, numbers of crab, and numbers of salmon.

1994	**Management Area**						
Inside Critical Habitat	516	517	519	541	542	543	**Grand Total**
Atka mackerel mt		1	1	5,030	16,826	8,441	30,299
Halibut kg/mt		0.0064	0.0172	0.0015	0.0020	0.0010	0.0016
King crab num/mt		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Salmon num/mt		0.0000	0.0000	0.0000	0.0162	0.0000	0.0090
Outside Critical Habitat							
Atka mackerel mt		49		5,060	9,133	49	14,290
Halibut kg/mt		0.0000		0.0013	0.0098	0.0000	0.0068
King crab num/mt		0.0000		0.0000	**0.1095**	0.0000	0.0700
Salmon num/mt		0.0000		0.0000	0.0996	0.0000	0.0637
1996							
Inside Critical Habitat							
Atka mackerel mt			270	10,023	18,541	22,218	51,052
Halibut kg/mt			0.0000	0.0077	0.0006	0.0007	0.0020
King crab num/mt			0.0000	0.0000	0.0000	**0.1971**	0.0858
Salmon num/mt			0.0000	0.0000	0.0096	0.0000	0.0035
Outside Critical Habitat							
Atka mackerel mt	10	19		9,141	3,287	5,791	18,248
Halibut kg/mt	0.0000	0.0093		0.0037	0.0059	0.0000	0.0029
King crab num/mt	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
Salmon num/mt	0.0000	0.0000		0.0000	0.0751	0.0000	0.0135
1997							
Inside Critical Habitat							
Atka mackerel mt			27	6,797	12,002	17,911	36,736
Halibut kg/mt			0.0000	0.0058	0.0003	0.0012	0.0017
King crab num/mt			0.0000	0.0000	0.1599	0.4817	0.2871
Salmon num/mt			0.6307	0.0306	0.0075	0.0000	0.0086
Outside Critical Habitat							
Atka mackerel mt				4,846	588	2,895	8,330
Halibut kg/mt				0.0016	0.0010	0.0000	0.0010
King crab num/mt				0.0000	0.0000	0.0219	0.0076
Salmon num/mt				0.0000	0.0000	0.0200	0.0070

Table 2.7. Bycatch rates of other groundfish species (Pacific cod, walleye pollock, Pacific ocean perch (POP), and other rockfish) in the Atka mackerel target fishery inside and outside of Steller sea lion critical habitat in the BSAI region in 1994, 1996, and 1997. Bycatch rates are calculated per ton of Atka mackerel caught. The other rockfish bycatch is separated by species and management area for 1997.

Year	Critical habitat and species	Management Area 516	517	519	541	542	543	Grand Total
1994	*Inside Critical Habitat*							
	Atka mackerel mt		1	1	5,030	16,826	8,441	30,299
	Cod mt/mt		0.0000	0.0000	0.1304	0.1341	0.1831	0.1472
	Pollock mt/mt		0.0000	0.0000	0.0055	0.0070	0.0056	0.0064
	POP mt/mt		0.0000	0.0000	0.0122	0.0088	0.0070	0.0089
	Rockfish mt/mt		0.0000	0.0000	0.0015	0.0101	0.0250	0.0128
	Outside Critical							
	Atka mackerel mt		49		5,060	9,133	49	14,290
	Cod mt/mt		0.0420		0.0681	0.0386	0.0000	0.0489
	Pollock mt/mt		0.0039		0.0005	0.0005	0.0000	0.0005
	POP mt/mt		0.1650		0.0213	0.0013	0.0043	0.0090
	Rockfish mt/mt		0.0000		0.0201	0.0129	0.0482	0.0155
1996	*Inside Critical Habitat*							
	Atka mackerel mt			270	10,023	18,541	22,218	51,052
	Cod mt/mt			0.0072	0.1613	0.0462	0.0886	0.0871
	Pollock mt/mt			0.1105	0.0017	0.0045	0.0065	0.0054
	POP mt/mt			0.0103	0.0027	0.0267	0.0100	0.0146
	Rockfish mt/mt			0.1720	0.0182	0.0452	0.0482	0.0419
	Outside Critical							
	Atka mackerel mt		19		9,141	3,287	5,791	18,248
	Cod mt/mt	0.1978	0.0310		0.1173	0.0465	0.0159	0.0723
	Pollock mt/mt	0.4914	0.0000		0.0037	0.0003	0.0065	0.0043
	POP mt/mt	0.0000	0.0035		0.0056	0.0052	0.0456	0.0182
	Rockfish mt/mt	0.0000	0.1593		0.0214	0.0400	0.0676	0.0395
1997	*Inside Critical Habitat*							
	Atka mackerel mt			27	6,797	12,002	17,911	36,736
	Cod mt/mt			0.0385	0.0405	0.0300	0.0343	0.0340
	Pollock mt/mt			0.3146	0.0004	0.0037	0.0015	0.0023
	POP mt/mt			0.0000	0.0052	0.0189	0.0171	0.0155
	Rockfish mt/mt			0.0111	0.0077	0.0220	0.0334	0.0249
	Outside Critical							
	Atka mackerel mt				4,846	588	2,895	8,330
	Cod mt/mt				0.0524	0.0047	0.0082	0.0336
	Pollock mt/mt				0.0004	0.0014	0.0006	0.0005
	POP mt/mt				0.0023	0.0025	0.1495	0.0535
	Rockfish mt/mt				0.0147	0.0261	0.0720	0.0354
	Rockfish Bycatch by Species and Management Area in 1997							
	Atka mackerel mt			27	11,643	12,590	20,806	45,066
	Northern rockfish			0.0111	0.0097	0.0206	0.0370	0.0253
	Sharpchin rockfish			0.0000	0.0000	0.0000	0.0000	0.0000
	Rougheye rockfish			0.0000	0.0001	0.0009	0.0014	0.0009
	Shortraker rockfish			0.0000	0.0001	0.0000	0.0002	0.0001
	Other Rockfish mt/mt			0.0000	0.0008	0.0006	0.0003	0.0000

Bycatch rates of other groundfish species by the Atka mackerel target fishery inside and outside of Steller sea lion critical habitat are summarized for 1994, 1996, and 1997 in Table 2.7. The predominant bycatch groundfish species by weight were Pacific cod, walleye pollock, and various rockfish, including Pacific ocean perch and northern rockfish. There is no consistent pattern with respect to critical habitat in bycatch rates of other groundfish species by the Atka mackerel fishery. Cod bycatch rates have been as high as 15% (in 1994, BSAI-wide), but were generally less than 10%. Bycatch rates of pollock were low (each time/area cell less than 1%). Bycatch rates of Pacific ocean perch have generally been less than 2%, but have been as high as 15% in some time/area cells (1997, 543, outside critical habitat). Examination of the other rockfish bycatch by species in 1997 suggests that northern rockfish comprises most of this; rates were as high as 4% in area 543 in 1997, and the aggregate BSAI rate for the Atka mackerel fishery was 2.5%.

The data in Tables 2.6 and 2.7 represent summaries of haul-by-haul observer data. As such, they represent "natural" bycatch of prohibited and other groundfish species in the Atka mackerel fishery. The practice of "topping off" with other groundfish species, which can appear as high bycatch in weekly aggregated data (e.g., the blend), does not influence these results. The target fishery was determined on a haul-by-haul basis according to the dominant species in the observer's species composition sample.

2.4.3.5.5 The Atka mackerel jig fishery in area 541/Bering Sea

A small portion of the Atka mackerel TAC is allocated to a jig fishery in area 541/Bering Sea. The allocation was 127 t in 1998. This size and localized nature of this fishery indicates that it could be exempted from seasonal or geographic splits of the Atka mackerel TAC because its effect on Steller sea lions, if any, should be negligible.

2.4.4 Alternative 4: Seasonal split in all three regulatory areas, or in critical habitat in management areas 542, 543, or both, plus setting of maximum TAC in any season/area based on estimates of *initial* biomass and application of a target harvest rate.

Alternative 4 is expected to avoid localized depletion (criterion 1) using information derived from previous observations of localized depletions at different sites within each management area. This alternative is also expected to avoid adverse modification of critical habitat by reducing the proportion of the catch that can be taken out of critical habitat (criterion 2).

Alternative 4 would make the best use of the available scientific and commercial data to predict levels at which localized depletion might occur and ensure that time-area TACs do not exceed levels that could cause such depletions. This alternative would reduce fishery catch within critical habitat, and may eliminate the need for seasons in some areas, which could reduce fishery operations costs. This approach is currently based on the Leslie depletion model, which also provides additional information useful for evaluation of the fishery and its impact. However, whenever possible, the Leslie model should be refined or replaced to provide the most accurate and reliable description of the effects of the fishery on Atka mackerel stocks.

The utility of alternative 4, however, may be somewhat compromised by annual variability in the distribution and site-specific abundance of Atka mackerel stocks. Estimates of the catch possible at any given site would be dependent on past stock and fishery assessments. The predictive value of those past data will depend on the amount of annual variation; that is, as variation in stock distribution and abundance increases, past data become less effective at predicting safe levels of fishing.

Table 2.8. Example of alternative 4. Releases of TAC in the Atka mackerel fishery, assuming a BSAI TAC of 64,300 mt, an inside/outside critical habitat split of 40%/60%, a seasonal split (50/50) for seasons when necessary, and a maximum catch per season-area based on 18% of biomass from Leslie regression results.

	Regulatory area							
	541		542		543			
Stock distribution	23%		35%		42%			
Critical habitat			In	Out	In		Out	
TAC distribution	14,900		9,000	13,400	10,800		16,100	
Seasonal maximum	8,500		12,600		6,200			
Seasons	A	B	A only	A only	A	B	A	B
TAC	7,450	7,450	9,000	13,400	5400	5400	8050	8050

2.4.5 Alternative 5: Seasonal split and geographic rotation. Establish TAC for each regulatory area, begin with a time-limited season (e.g., 5 days) for 1/3 of TAC in regulatory area 541, then close area 541 and move to area 542 for a second time-limited season on 1/3 of TAC for that area, and then shift to area 543. When all three areas were fished, then return to area 541 and start the cycle again.

Alternative 5 would probably avoid localized depletion (criterion 1) to a considerable extent but, as described, would not reduce the proportion of the catch taken from critical habitat (criterion 2). This alternative would likely not meet ESA requirements, is therefore not acceptable, and will not be considered further.

2.4.6 Alternative 6: Voluntary fleet distribution of effort throughout regulatory areas throughout year.

Alternative 6 may or may not reduce the probability of localized depletion (criterion 1). This alternative does not include any mechanism to reduce the proportion of catch within critical habitat (criterion 2), nor does it provide a mechanism to ensure compliance with any voluntary arrangement, and would likely not meet ESA requirements. This alternative is therefore not acceptable and will not be considered further.

2.5 Analysis Summary

The extent to which the different alternatives satisfy the two main criteria is summarized in Table 2.9. Only alternatives 3 and 4 satisfy both criteria and should be considered as viable alternatives for this amendment. Additional considerations with respect to these alternatives are based on seasonal and geographic adjustments to the fishery, as well as the potential impacts on 'small entities.' The B season should avoid spawning of Atka mackerel and the winter period critical to the Steller sea lion, and should temporally disperse the fishery to allow Atka mackerel recovery between seasons. The period from 1 September to 1 November meets these requirements.

Spatial considerations include the characteristics of areas inside and outside of critical habitat, including area available, expected CPUE, fish size, and bycatch. The area outside of critical habitat comprises about 31% of the total area < 200 m deep and beyond the trawl exclusion zones. Overall, the CPUE observed in the fishery to date is similar inside and outside critical habitat. However, about 29% of the fishery occurred outside critical habitat from 1993 to 1997, and CPUE outside may well decline with a geographical shift of

Table 2.9. Summary of analysis of alternatives with respect to the two main criteria of avoiding localized depletion and adverse modification of critical habitat.

Alternative	Criterion 1 Localized depletion	Criterion 2 Adverse modification
1. Status Quo	No	No
2. Split seasonally	Partial	No
3. **(Preferred)** Split seasonally and inside/outside critical habitat	Yes	Yes
4. Split inside/outside critical habitat and seasonally based on CPUE analysis	Yes	Yes
5. Geographic rotation	Partial	No
6. Voluntary dispersal	Unassured	Unassured

the fishery. Bycatch rates are generally thought to be low in the Atka mackerel fishery, and a summary of bycatch of prohibited species and other groundfishes does not reveal a consistent difference in bycatch inside versus outside of critical habitat.

The key distinguishing factor between alternatives 3 and 4 is the extent to which recent fishery data is used to establish future local TACs. The utility and reliability of past data as an indicator of future effort has not been demonstrated and is compromised by the annual numerical and spatial variability of the Atka mackerel stocks taken in the fishery.

3.0 ENVIRONMENTAL IMPACTS OF THE ALTERNATIVES

An environmental assessment (EA) is required by the National Environmental Policy Act of 1969 (NEPA) to determine whether the action considered will result in significant impact on the human environment. If the action is determined not to be significant based on an analysis of relevant considerations, the EA and resulting finding of no significant impact (FONSI) would be the final environmental documents required by NEPA. An environmental impact statement (EIS) must be prepared for major Federal actions significantly affecting the human environment.

An EA must include a brief discussion of the need for the proposal, the alternatives considered, the environmental impacts of the proposed action and the alternatives, and a list of document preparers. The purpose and need for the proposal are described in section 1, the alternatives considered are presented in section 2, and the list of preparers is in section 9. This section contains the discussion of the environmental impacts of the alternatives including impacts on threatened and endangered species and marine mammals.

3.1 Environmental Impacts of the Alternatives

The environmental impacts generally associated with fishery management actions are effects resulting from (1) harvest of fish stocks which may result in changes in food availability to predators and scavengers, changes in the population structure of target fish stocks, and changes in the marine ecosystem community structure; (2) changes in the physical and biological structure of the marine environment as a result of fishing practices, e.g., effects of gear use and fish processing discards; and (3) entanglement/entrapment of non-target organisms in active or inactive fishing gear.

A summary of the effects of the annual groundfish TAC amounts on the biological environment and associated impacts on marine mammals, seabirds, and other threatened or endangered species are discussed in the final environmental assessment for the annual groundfish TAC specifications.

The potential environmental impacts of the alternatives fall into two categories: those that would result from temporal redistribution of the fishery and those that would result from geographic redistribution. The temporal distribution of the fishery has become compressed since the late 1980s. Prior to that time, fishing occurred primarily in spring-summer months, but in the 1990s the fishery has occurred primarily from January to April, with brief summer openings to allow complete removal of TAC. The potential consequences of a temporal split and the creation of a B season would depend largely on the time of year that the B season occurred. From a stock perspective, fishing during the spawning period (peaking in August) could be most disruptive, although fishing has occurred during this period in the past and, again, does so currently for short periods. In past years, fishing in the spawning season led to an increase in the ratio of females to males in the catch, but this increase was of no known consequence to the stock. Note also that the actual spawning grounds are very shallow, presumably located in very rough habitat, and not accessible to the current large-scale commercial fisheries.

The potential environmental impacts of geographic redistribution of the fishery would result from a reduction of fishing effort inside Steller sea lion critical habitat and a corresponding increase in effort outside critical habitat. The Atka mackerel fishery is conducted using bottom trawls, and a reduction of trawling inside critical habitat could have a positive impact on bottom substrate and communities in that region. No significant negative impacts are expected as a result of reduced effort inside critical habitat. Outside critical habitat, two types of impacts might be expected. The first involves a broader distribution of bottom trawling; more intense trawling would likely occur in areas already fished (e.g., Petrel Bank and Tahoma Reef), and additional impacts would likely occur from trawling in new areas or areas not traditionally fished (e.g., south of Atka Island or at Stalemate Bank). The sum total of area affected may be the same or greater if fishing in new areas resulted in decreased CPUE. The second type of potential impact outside of critical habitat could occur if fishing at the periphery of Atka mackerel schools or habitat resulted in increased bycatch of other species. The Atka mackerel fishery generally has low levels of bycatch, and analyses for 1994, 1996, and 1997 indicate that fishing outside of critical habitat resulted in less bycatch in two years and more bycatch in one year. Thus, these data do not support the contention that bycatch will increase significantly if the fishery is forced outside of critical habitat.

Both temporal and geographic redistribution of the fishery could also result in changes in predator-prey relations other than those with the Steller sea lion. Atka mackerel is prey for a number of species including northern fur seals, harbor seals, Dall's porpoise, thick-billed murres, horned puffins, tufted puffins, Pacific halibut, Pacific cod, and arrowtooth flounder (Livingston, AFSC Quarterly Report, Oct-Dec 1996). Frost and Lowry (1981) report that Atka mackerel are also important prey of endangered humpback whales. At present, there is no basis for suggesting that any of the alternatives (especially those that reduce the chance for localized depletions of Atka mackerel) would have significant negative impacts on these species.

Thus, none of the alternatives are expected to have significant detrimental impacts on the environment.

3.2 Impacts on Endangered, Threatened or Candidate Species

Endangered and threatened species under the ESA that may be present in the GOA and BSAI include:

Endangered

Western population Steller sea lion	*Eumetopias jubatus*
Northern right whale	*Balaena glacialis*
Sei whale	*Balaenoptera borealis*
Blue whale	*Balaenoptera musculus*
Fin whale	*Balaenoptera physalus*
Humpback whale	*Megaptera novaeangliae*
Sperm whale	*Physeter macrocephalus*
Snake River sockeye salmon	*Oncorhynchus nerka*
Short-tailed albatross	*Diomedea albatrus*

Threatened

Eastern population Steller sea lion	*Eumetopias jubatus*
Snake R. spring and summer chinook salmon	*Oncorhynchus tshawytscha*
Snake R. fall chinook salmon	*Oncorhynchus tshawytscha*
Spectacled eider	*Somateria fischeri*
Steller's eider	*Polysticta stelleri*

The status of the ESA section 7 consultations required to assess the impact of the groundfish fisheries on endangered, threatened, or candidate species is updated annually. A new consultation has been initiated to assess the impact of the Atka mackerel fishery on Steller sea lion foraging success. This new consultation was initiated because of the new information about fishery-induced localized depletion (Fritz, unpubl.).

None of the alternatives considered in this amendment is expected to have a significant impact on endangered, threatened, or candidate species other than the Steller sea lion. The goal and objectives of the amendment (sections 2.1 and 2.2 above) are to prevent competition between the fishery and Steller sea lions by avoiding 1) significant fisheries-induced localized depletions of Atka mackerel, and 2) adverse modification of Steller sea lion critical habitat by areal redistribution of the fishery.

The first (*status quo*), alternative would not achieve either of the objectives, and therefore could likely result in significant impacts on the Steller sea lion through competition for prey.

The second alternative (temporal split only) would likely reduce some of the potential for localized depletions, although such depletions could still occur if, for example, fishing effort became even more focused or concentrated in A and B seasons. Review of analyses in Appendix 2 indicates that some statistically significant reductions in CPUE occurred, even when the total catch was well below half of the TAC for an area (see Buldir Island, east and west, in 1995). In addition, a temporal split does not result in any change to the distribution of fishery catch inside and outside of critical habitat.

The third **(preferred)** alternative (with option 2; temporal split plus incremental implementation of an areal split inside and outside of Steller sea lion critical habitat and specific exemptions of certain 'small entities' from the regulation) would, by definition, reduce the proportion of catch taken from within critical habitat. This alternative would also likely reduce the potential for localized depletions by facilitating greater areal distribution of the fishery at any particular site in any given season. While this alternative would not ensure that localized depletions would not occur at particular areas (see Figs. 12 and 13), comparisons of potential TAC releases with catch levels that resulted in significant declines in CPUE (Appendix 2) suggest that the likelihood of localized depletion under alternative 3 would be greatly reduced. To reduce potential economic impacts to small entities, this alternative also would exempt small vessels using jig gear from aspects of the proposed regulation and would exempt CDQ groups from the A-B season split.

The fourth alternative would also reduce the probability of localized depletion to an insignificant level, and would reduce the proportion of catch taken from Steller sea lion critical habitat. This alternative is based on analysis of past fishery data, which may compromised as a predictor of future trends, because of considerable numerical and spatial variability in the annual distribution of Atka mackerel stocks. While the Leslie depletion analyses reported by Fritz and discussed in this document may provide a reliable method to evaluate localized depletion in past fisheries, it has not yet been established that such information can be used reliably to predict TAC levels for future fisheries.

The fifth alternative would reduce the probability of localized depletions by moving fishing vessels from one area to another as a portion of each area's TAC is caught. This alternative does not reduce the catch inside critical habitat.

The sixth alternative provides no structure or basis for ensuring that localized depletions will not occur, or that removal from critical habitat areas does not result in adverse modification of those areas. As it would be imposed on a voluntary basis, this alternative does not ensure compliance by all fishery participants.

Only alternatives 3 and 4 will satisfactorily avoid 1) fishery-induced localized depletions of Atka mackerel and 2) adverse modification of Steller sea lion critical habitat by excessive removal of an important prey item. Thus, alternatives 3 **(preferred)** and 4 are not expected to have significant detrimental effects on the Steller sea lion, whereas all other alternatives (1, 2, 5, and 6) are expected to have significant detrimental effects.

3.3 Impacts on Marine Mammals

Marine mammals not listed under the ESA that may be present in the GOA and BSAI include cetaceans, [minke whale (*Balaenoptera acutorostrata*), killer whale (*Orcinus orca*), Dall's porpoise *(Phocoenoides* *dalli*), harbor porpoise (*Phocoena phocoena*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), and the beaked whales (e.g., *Berardius bairdii* and *Mesoplodon spp.*)] as well as pinnipeds [northern fur seals (*Callorhinus ursinus*), and Pacific harbor seals (*Phoca vitulina*)] and the sea otter (*Enhydra lutris*).

None of the alternatives is expected to have a significant impact on these marine mammals.

3.4 Coastal Zone Management Act

Implementation of each of the alternatives would be conducted in a manner consistent, to the maximum extent practicable, with the Alaska Coastal Management Program within the meaning of section 30(c)(1) of the Coastal Zone Management Act of 1972 and its implementing regulations.

3.5 Conclusions or Finding of No Significant Impact

Alternatives 3 (preferred) and 4 are not likely to significantly affect the quality of the human environment, and the preparation of an environmental impact statement for the proposed action is not required by section 102(2)(C) of the National Environmental Policy Act or its implementing regulations if either alternative 3 (preferred) or 4 is chosen. An environmental impact statement would be required if any one of alternatives 1, 2, 5, or 6 is chosen.

Assistant Administrator for Fisheries, NOAA

JAN 15 1999

Date

4.0 REGULATORY IMPACT REVIEW: ECONOMIC AND SOCIOECONOMIC IMPACTS OF THE ALTERNATIVES

4.1 Introduction

In section 1.4 of the EA for this issue, six alternatives--one of which contains three sub-alternatives--for managing the Aleutian Islands fishery for Atka mackerel are presented. These alternatives incorporate various combinations of apportionments by season and area--inside and outside of critical habitat areas (CHAs)--for purposes of reducing the effects of this fishery on steller sea lion populations. Thorough analysis of the tradeoffs of these alternatives would require more information than is presently available regarding the seasonal and geographic distribution of Atka mackerel throughout the Aleutian Islands, as well as the financial implications for participating vessels of different types of management restrictions. As a result, the objectives of this chapter will be to provide an overview of recent participation in this fishery, and to the extent possible, identify alternative fisheries where effort might increase as a result of greater restrictions in the Atka mackerel fishery, discuss the potential impacts on fleet efficiency, as well as considerations that may be important for minimizing adverse impacts for operations that depend upon Atka mackerel for a significant part of their income.

4.2 Description of the Atka Mackerel Fishery and Fleet

Blend data and weekly production reports for 1993-97 were used to develop annual participation profiles, reflecting all fishing off Alaska, for vessels that had at least one week where Atka mackerel was a target in Areas 541, 542, or 543 during the same year. Product price data from 1996 were used to estimate product values for 1997. Table 4.1 provides an overview of the numbers of participating vessels and their general level of dependence upon Atka mackerel for these five years. Examination of individual vessel histories revealed a clear stratification in participation in the fishery. Nine of the 24 vessels participating in one or more years were designated as "core" vessels, on the basis of having earned 30% or more of their revenue from Atka mackerel in at least three of the four years from 1994 to 1997. For the years 1995-97, Table 4.1 indicates that whenever a core vessel participated, it earned more than 30% of its revenue from Atka mackerel, and that no non-core vessels achieved this standard during those years.

Figures 1-4 provide additional detail regarding the participation of these two groups, and the evolution of the fishery. Figure 1 shows the number of weeks each core vessel targeted Atka mackerel in Areas 541, 542, or 543, during these 5 years. A generally upward trend is revealed from 1993-96, with a reduction in 1997. This pattern is consistent with the pattern of removals reported in Table 4.2a. Figure 2 shows a similar pattern for the percentage of core vessel revenue associated with all species caught during Atka mackerel target weeks. Figures 4.3 and 4.4 illustrate the lower levels of participation in, and dependence on, the Aleutian Atka mackerel fishery by non-core vessels over this time period.

Table 4.2a reports the amounts of Atka mackerel that were retained or discarded, by year and weekly target designation, in areas 541-543. The upper panel reflects all vessels, including those that did not have an Atka mackerel target week in the specified year. The lower panel includes only the catch of the nine core vessels. Table 4.2b reports the percentage of each total-catch cell that was attributable to the nine core vessels. From 1994 on, the core vessels have accounted for at least 99% of the retained Atka mackerel catch in area 541, while annual percentages have ranged from 56% to 100% in the other two areas.

Within the three Aleutian areas during 1996, four vessels fished for Atka mackerel only in Area 542, two vessels fished in Areas 542 and 543, with the remaining nine vessels fishing in all three areas. During 1997, two vessels fished only in Area 542, two vessels fished in Areas 542 and 543, with the remaining eight vessels fishing in all three areas. Additional information regarding the seasonal, geographical, and targeting patterns of fishery participation by vessels that targeted Atka mackerel is presented in Tables 4.3 and 4.4. Table 4.3 shows the number of vessels with weekly targets of Atka mackerel and other species, by month and area, for vessels having at least one target week for Atka mackerel in Areas 541, 542, or 543 during the same year. Table 4.4 provides the number of target weeks associated with the corresponding "vessel" cells in Table 4.3. In general, vessels have tended to move sequentially in a westward direction along the Aleutians, beginning their fishing for Atka mackerel in Area 541 in January and February. Some also target other species in that area by February or March. By March, those fishing for Atka mackerel have moved into Areas 542 and 543, with fishing continuing in 543 in April or beyond, depending on the available TAC. Throughout March and April, some vessels also target other species in these westward areas. With the high TACs in 1996, Atka mackerel fishing resumed in all three areas during July and August. The pattern of fishery participation in 1993 was quite different than in other years, probably as a result of several factors. More fishing for Atka mackerel occurred in the Gulf of Alaska from January through March than in subsequent years, with the Aleutian fishery focusing on Area 542 during August-October.

4.3 Potential effects on alternative fisheries

Table 4.5 provides annual summaries of the product values, by species/group, for core and non-core vessels during 1995-97. Prominent alternative species for core vessels include yellowfin sole, rockfish, rock sole, and Pacific cod. Pollock has consistently been the primary alternative for the fringe participants in the Atka mackerel fishery, with an increasing trend in the percentage of revenue earned from pollock. The reduction in TAC from 1996 to 1997 provides an opportunity to observe industry response to reduced access to Atka mackerel. Atka mackerel earnings for core vessels fell by roughly $30 million, however, two-thirds of this loss was offset by higher earnings from other species, principally yellowfin and rock soles.

Table 4.6 provides additional detail regarding the location of selected species catches in 1995-97, by core and non-core vessels, as well as the fishery targets that were designated for the weeks in which they were caught. Of note is that more than 90% of the Pacific cod retained by core vessels in areas 541-543 was caught during weeks where Atka mackerel was the designated target. And the amount of retained Pacific cod in these areas fell by an even greater percentage than did Atka mackerel between 1996 and 1997. Thus, there is an apparent positive correlation between the amount of time spent fishing for Atka Mackerel in Areas 541-543, and the amount of Pacific cod caught by these vessels. However, determining the extent to which these species were caught coincidently would require analysis of haul-by-haul data, which is not possible within the time constraints of this preliminary analysis.

In summary, the extent to which management alternatives under consideration will lead to less effort in this fishery is not clear. Some alternatives could make full harvest of the TAC economically unviable. If a reduction in Atka mackerel effort were caused, recent fishery participation suggests that while harvest of Pacific cod might fall, core vessels are likely to direct more effort towards yellowfin and rock soles in other areas, while fringe participants may direct more effort towards pollock. To the extent that overall or early-season effort is diverted from the Atka mackerel fishery, the attainment of TACs and/or prohibited species caps in these other fisheries may be accelerated with distributional reductions in harvest and income for vessels currently participating in those fisheries.

In 1997, the eight core vessels in the BSAI Atka mackerel fishery accounted for 81 percent of the total Atka mackerel catch in areas 541, 542 and 543 combined. Therefore, the effects of the alternatives on the participation of these vessels in other fisheries will be critical in determining the effects of the alternatives on other fisheries.

Comparisons were made between the factory trawlers in the Atka mackerel fishery and in other BSAI bottom trawl fisheries because any redistribution of effort from the Atka mackerel fishery to other fisheries is expected to be principally to other fisheries dominated by factory trawlers. The comparisons of physical characteristics are in Table 4.7 and comparisons by catch level classes are in Table 4.8.

In the last four years (1994-97), there was substantially less participation in the Atka mackerel fishery than in most other BSAI bottom trawl fisheries by vessel in the smallest three length classes (less than 125 ft, 125-150 ft and 151-200 ft). In the Atka mackerel fishery, there were more vessels in the 200-250 ft length class than in any other length class and the same was generally true for the Pacific cod and yellowfin sole fishery. For the other bottom trawl fisheries, there were often at least as many vessels in the 150-200 ft length class. With the exception of the yellowfin sole fishery, more vessels in the Atka mackerel fishery were in the top two total catch classes (501-10,000 mt and greater than 10,000 mt) than in the other bottom trawl fisheries.

More detailed comparisons were made between the core Atka mackerel factory trawlers in the rock sole fishery and the other factory trawlers in the rock sole fishery because the rock sole fishery is a likely target for factory trawlers that may be partially displaced from the Atka mackerel fishery by some of the alternatives being considered. These comparisons are made in Table 4 9. In each of the three years (1995-97), the mean length, net registered tons and horsepower were substantially greater for the core Atka mackerel vessels than for other factory trawlers in the rock sole fishery and the mean catch capacity per vessel that was estimated using data for all three years was about 22 percent greater for the core vessels.

It is very difficult to predict the effect each alternative would have on the level of participation by the core Atka mackerel vessels in the BSAI Atka mackerel fishery. It is even more difficult to predict the effects on their levels of participation in other BSAI and GOA fisheries. The increases in fishing costs that probably would be associated with some of the alternatives would tend to decrease participation in the Atka mackerel fishery and increase participation in other fisheries. However, other factors, such as changes in product prices for Atka mackerel and other groundfish, could mitigate or intensify any such redistribution of effort from the Atka mackerel fishery to other fisheries. Therefore, the following estimate of what could happen with the more restrictive alternatives is one of many scenarios that could be considered.

The estimates of what would have happened in 1997 are based on: 1) catch and bycatch rate data for Atka mackerel fishery core vessels and other factory trawlers in the 1997 roe rock sole fishery and 2) a specific scenario concerning effort switching earlier and more fully from the Atka mackerel fishery to the rock sole fishery.

In 1997, one of the core factory trawlers for 1993-96 did not participate in the Atka mackerel fishery; therefore, there were eight core factory trawlers in the 1997 Atka mackerel fishery. The participation of these eight factory trawlers in select BSAI bottom trawl fisheries was as follows:

Actual deployment of core vessels

Week ending	Atka mackerel	Pacific cod	Rock sole
1/25	8	0	0
2/01	8	0	0
2/08	8	0	6
2/15	1	0	6
2/22	1	4	4
3/01	5	0	0
3/08	8	0	0

Therefore, the core vessels were fully deployed in the Atka mackerel fishery (area 541) during the first two weeks of the trawl fishing year. The third week was a transition week with six of the core vessels participating in the Atka mackerel and roe rock sole fisheries. In the fourth and fifth weeks most of the core vessels were out of the Atka mackerel fishery and fully deployed in the rock sole and Pacific cod fisheries. The transition back into the Atka mackerel fishery, now in area 542, began the sixth week and was completed by the seventh week.

The alternatives with A and B seasons and with inside/outside critical habitat apportionments could have changed the 1997 deployment of the core vessels substantially had any of them been in place in 1997. The A season TAC for area 541 could have been taken by early in the second week, in which case the redeployment to the rock sole fishery would have happened a week sooner. If in addition, the A season and the inside/outside split for the area 542 TAC had postponed the transition into the Atka mackerel fishery in area 542 by at least one week and if all the core Atka mackerel vessels had been deployed in the rock sole fishery beginning with the transition after the earlier closure of the Atka mackerel fishery in area 541, the deployment would have been as follows:

Alternative (assumed) deployment of core vessels

Week ending	Atka mackerel	Pacific cod	Rock sole
1/25	8	0	0
2/01	8	0	8
2/08	0	0	8
2/15	0	0	8
2/22	0	4	8
3/01	0	0	8

The estimates of what the catch and bycatch of the core vessels would have been in the rock sole fishery are based on the following: 1) the mean catch per non-core vessel by week; 2) an adjustment factor to reflect the higher mean weekly catch per core vessel; 3) separate bycatch rates by week for the core and non-core vessels; and 4) the use of week three bycatch rates for core vessels as estimates of what their week two bycatch rates would have been.

One set of estimates was made for each of two catch rate adjustments. The lower adjustment of 1.22 is based on the difference between the estimated weekly catch capacity per vessel for core and non-core vessels based on data for 1995-97 (see Table 4.9). The higher adjustment of 1.41 is based on the difference in catch per core and non-core vessel during the week in which the core vessels were more fully deployed in the rock sole fishery, that was the week ending February 15.

With this set of assumptions and a zone 1 bairdi allowance of 296,052 crab for the rock sole and other flatfish fisheries, the 1997 rock sole fishery would have been closed in zone 1 toward the end of the fourth week, if the bairdi allowances had been in place at that time. Because of a delay in implementing the PSC allowances in 1997, the rock sole fishery continued for almost two additional weeks. If the bairdi allowance and one of the more restrictive alternatives had been in place and if the latter had caused the redeployment summarized above, the bairdi allowance would have been taken by late in the third week. Estimates of the catch and bycatch in the rock sole fishery and the catch excluding that of the core vessels are presented in Table 4.10.

The estimates indicate that increased participation in the roe rock sole fishery by the core vessels from the Atka mackerel fishery would have done the following: 1) closed the roe rock sole fishery almost a week earlier; 2) decreased the total catch and the catch of the non-core vessels; 3) increased the catch of the core vessels from the Atka mackerel fishery; 4) decreased halibut bycatch; and 5) increased red king crab bycatch. These changes are due to the higher bycatch rates for bairdi and red king crab and lower halibut bycatch rates for the core vessels from the Atka mackerel fishery.

4.4 Potential effects on fleet efficiency

Of the information that is presently available, that which is most informative regarding efficiency impacts is CPUE data from the fishery and trawl surveys. And these data are not comprehensive enough to clearly identify the magnitude of effects that would accompany any of the alternatives. As a result, it is probably safest to assume that individual operations are currently fishing in areas where they expect to find the highest CPUEs, relative to the costs of searching for and/or transiting to alternative locations, and that significant changes in the fishing locations where most fish are harvested are likely to lower the fleet's overall CPUE. Some operations may not find acceptable returns with lower CPUEs, and shift to other target species, while those that remain are likely to expend more time and money harvesting a given quantity of fish.

In Area 543, CPUE data from both fishery and survey sources suggest catch rates outside of CHAs that are comparable to those inside. However, from 1993-1997, 84% of the Atka mackerel catch in this area has occurred inside CHAs. If equal amounts of fish were caught "inside" and "outside", it is likely that CPUEs outside CHAs would fall considerably if fishing were to continue at recently used locations. If productive new locations are identified, the effect on CPUE is less clear. One such alternative site in Area 543 is Stalemate Bank, which lies much farther west than current fishing grounds. This location was fished regularly in earlier years by foreign fleets, but has been largely ignored by the domestic fishery, very likely because of additional transit costs and concerns relating to exposure during sudden storms. However, if fishing opportunities are structured properly, this location could hold some potential to offset reductions in catch/profits from inside CHAs. Over the past three years, an even higher percentage of catch in Area 542 has occurred inside CHAs, and "outside" CPUEs have been dramatically lower than those inside. As a result, shifting a large percentage of catch to "outside" areas may be expected to impose a greater economic penalty in Area 542 than in Area 543.

Based on the evidence of localized depletions from the Leslie regression analysis, dispersing fishing effort over time at some locations could lead to increased average CPUEs for the total amount of fish removed from current individual fishing grounds. However, even if realized, higher average CPUEs inside CHAs might not compensate for additional transit costs to return to a series of sites, later in the year, or the potentially lower CPUEs that could be associated with shifting a larger fraction of catch to "outside" areas.

4.5 Considerations for achieving habitat objectives while minimizing adverse impacts on the fleet

In general, if actions are taken to mitigate the potential for localized depletions in sea lion feeding areas, they should allow the industry the greatest possible flexibility in meeting habitat-related objectives, while encouraging as much fishing as possible to occur outside of CHAs. Alternatives whose purpose is to distribute TAC between areas inside and outside of CHAs should be specified in terms of maximum percentages that would be allowed inside CHAs. If fishery conditions were able to support an even higher percentage of catch from areas outside the CHAs, it should not be prevented by having assigned a specific percentage to outside areas that cannot be exceeded.

In concert with this philosophy, for options which include both geographic and seasonal dispersion of catch, it may be preferable to exempt fishing outside the CHAs from the seasonal apportionment process. Stalemate

Bank, at the western edge of area 543 provides an illustration of why this flexibility may be useful in lessening the impact of changes on the industry. Although this location was regularly fished by foreign fleets and has yielded high CPUEs during recent trawl surveys, those who might choose to fish this site would be subject to greater transit costs and exposure to storms. If access to traditional domestic fishing sites within CHAs is restricted, some vessels might find a single trip to Stalemate Bank for a larger amount of fish to be profitable, where two lengthy trips for smaller amounts of fish would not be. Additionally, they might not be willing to risk fishing in the area at all until assured of reasonably good weather. If only fishing inside the 543 CHAs were closed after their "A" season maximum had been reached, the entire "B" season allowance could conceivably be caught by vessels fishing "outside" locations during the spring/summer. This would facilitate less harvest inside CHAs while providing additional incentive for some vessels to explore Stalemate Bank and other "outside" fishing grounds prior to the opening of a "B" season.

4.6 Net benefit considerations

Cost information, including fixed and variable operating cost statistics, is a crucial element of an effective net benefit analysis. Cost data for the BSAI groundfish harvesting and processing sectors are not currently available to NMFS. For this reason, NMFS cannot complete a quantitative cost/benefit examination of the preferred alternative, nor derive comparative net benefit conclusions about the several competing alternatives and sub-options. This fact has been recognized, and reinforced, by the Council's Scientific and Statistical Committee.

Changes in net benefits to the nation cannot be determined with a gross revenue analysis. However, given that the total economic value of the Atka mackerel fishery varied from approximately \$38 million to \$68 million from 1995-1997 (Table 4.5) and this action will not eliminate the fishery or even reduce the annual TAC, we can conclude that the net benefits to the US economy would not decrease by \$100 million annually once costs were included in the calculation. Therefore, the Council's preferred alternative does not constitute a 'significant' action under E.O. 12866, recognizing that there may be distributional economic impacts among the various sectors of the groundfish industry.

4.7 Conclusion

The alternatives which have been identified to reduce adverse fishing-related effects on sea lion survival exist in a context of considerable uncertainty. The effects that incremental, or even large-scale, changes in fishing activity would have on sea lion survival cannot be predicted with confidence at this time. Thus, it is difficult to assess the benefit trade-offs associated with management alternatives. In addition, the manner in which fishery CPUE and profitability would be affected by large-scale changes in the spatial and/or temporal distribution of fishing opportunities are not well understood. Nevertheless, some general conclusions can be drawn regarding impacts on the industry. Alternatives that shift greater proportions of catch to fishing grounds outside of critical habitat areas are likely to lower fishery CPUEs, raising industry costs and/or redirecting effort to other, more profitable fisheries. Alternatives which would disperse harvest over two or more seasons, could lead to increases in fishery CPUE, but are also likely to increase the costs of participants, who would have to transit to fishing grounds in each area multiple times in order to harvest the same amount of fish. Currently, alternatives do not specify the timing of split seasons, and as a result it is not possible to identify conflicts that may arise for participants, with regard to other present fishing opportunities. The alternatives also do not clearly address how targeting for other species within CHAs will be affected, and the extent to which existing fishing standards would restrict continued catch of Atka mackerel in other target fisheries once areas are closed to Atka mackerel targeting. Finally, structuring management action to preserve as much flexibility for industry adaptation as possible may be an important determinant of the extent to which fishery participants are adversely affected by the action.

4.7 Enforcement and Vessel Monitoring Systems

4.7.1 Purpose and Need

The benefits of catch limits inside and outside of Steller sea lion critical habitat will be realized only if fishing vessels adhere to the spatial boundaries of the fishery, as established under this amendment. The areas fished and the restricted areas are relatively small and determination of precise location during fishing operations will be essential to the determination of whether or not the vessel is fishing inside or outside of critical habitat or in no-trawl zones. Precise locations at any given point in time can be determined from Global Positioning System (GPS) coordinates read by the on-board observer, but continuous "manual" monitoring would require extensive time by the observer, making it difficult for the observer to accomplish other objectives. Manual monitoring would also likely involve greater measurement error.

Surveillance flights by the U.S. Coast Guard will presumably continue, but such flights are not sufficiently frequent for full evaluation of vessel locations during the fishing period, and determination of precise location could be difficult from overflying aircraft, especially under adverse conditions. Sufficient numbers of vessels have violated no-trawl and buffer exclusions zones to conclude that such violations occur. Precise measurements of vessel location are essential for the purposes of enforcement and for analysis of fisheries data to determine if this amendment effectively achieves its two main objectives of avoiding fishery-induced localized depletions and reducing the proportion of the Atka mackerel TAC taken from within Steller sea lion critical habitat.

4.7.2 Description of VMS and expected costs

Vessel Monitoring System (VMS) is an automated, real-time, satellite-based tracking system coupled with a GPS unit that obtains accurate position reports of vessels at sea. That is, real-time vessel location information is sent automatically from a transceiver on board the fishing vessel.

The cost of a VMS is approximately $3,500 to $5,000 per vessel for the initial purchase of the equipment, including the transceiver and antenna. Installation of the equipment costs may be ca. $1,000, and communication charges for required automated position reports are about $2.50 per day. Repair and maintenance costs may approach $1,000 per year. Additional costs could include the purchase of an optional personal computer and transmission costs for text messages (approximately $0.01 per character) that are sent or received by the vessel.

4.7.3 VMS Specifications

Specifications and criteria for VMS were provided by NMFS in the Federal Register, 59 FR 15180, March 31, 1994. The following will be required components for a VMS:

1. It shall be tamper-proof, i.e., shall not permit the input of false positions. It shall be password protected to prevent unauthorized reconfiguration of the transceiver.

2. It shall be fully automatic and operational at all times, regardless of weather and environmental conditions. It shall automatically generate position reports during power up, power down, antennae disconnection and antenna blockage.

3. It shall be capable of tracking vessels throughout their range and shall provide position accuracies that meet current industry standards. All systems certified by NMFS must be accurate to within 400 m (1,300 ft).

4. It shall have the capability of transmitting and storing information, including vessel identification, date-time, latitude, longitude, speed and bearing.

5. It shall provide accurate position transmissions, the interval between which can be determined by NMFS and set or changed remotely. In addition, the VMS shall allow NMFS to poll individual vessels or any set of vessels at any time and receive position reports in real time.

6. It shall incorporate a low-cost reporting mode over the signal channel to allow the transmission of the vessel identifier and the location of the vessel. Communications shall include, but not be limited to, transmitting and receiving telex and full or compressed data messages to and from shore. The VMS shall allow NMFS to initiate communications or data transfer at any time.

7. It shall include a fully integrated International Maritime Satellite (Inmarsat)-C and GPS Transceiver.

Table 4.1.--Overview of fishery participation by vessels having at least one Atka mackerel target week in the specified year, 1993-97.

Year / % of rev. from Atka mack. / core group	Number of Vessels	Mean revenue-all areas: From Atka mackerel	Mean revenue-all areas: From other species	Mean % of vessel revenue from A. mackerel caught in Areas 541,542, and 543: 541	542	543	Total	Mean % of revenue from all species caught in A. mackerel target weeks in Areas 541,542, and 543: 541	542	543	Total
1993											
0.1-30.0%	8	944,650	6,030,330	2.2	5.2	0.1	7.5	2.3	5.9	0.2	8.3
30.1-100%	5	6,580,327	7,426,106	0.2	21.3	3.1	24.6	0.2	22.5	3.2	25.9
Non-core	7	718,842	5,933,359	2.5	5.5	0.1	8.1	2.6	5.9	0.2	8.7
Core -9	6	5,904,490	7,306,610	0.2	18.3	2.5	21	0.2	19.7	2.7	22.5
Total	13	3,112,218	6,567,167	1.4	11.4	1.2	14.1	1.5	12.3	1.3	15.1
1994											
0.1-30.0%	10	1,185,628	9,499,971	2.6	7.1	0.5	10.2	2.9	8.2	0.6	11.7
30.1-100%	4	5,081,014	6,497,998	10	22.4	9	41.4	11	27.4	10.5	48.9
Non-core	5	582,507	9,936,232	0	5.7	0	5.7	0	6	0	6
Core -9	9	3,251,979	7,923,393	7.4	14.7	4.5	26.6	8.1	17.9	5.4	31.4
Total	14	2,298,596	8,642,264	4.8	11.5	2.9	19.2	5.2	13.7	3.4	22.3
1995											
0.1-30.0%	8	592,949	9,683,615	0	5.1	1.7	6.8	0	5.7	2.1	7.8
30.1-100%	9	4,339,780	5,707,970	9.9	25.6	8.5	43.9	10.1	27	9.5	46.6
Non-core	8	592,949	9,683,615	0	5.1	1.7	6.8	0	5.7	2.1	7.8
Core -9	9	4,339,780	5,707,970	9.9	25.6	8.5	43.9	10.1	27	9.5	46.6
Total	17	2,576,566	7,578,862	5.2	15.9	5.3	26.5	5.3	17	6.1	28.3
1996											
0.1-30.0%	6	461,349	7,905,278	0	4.6	1.1	5.7	0	4.7	1.1	5.8
30.1-100%	9	7,303,619	4,758,538	21	15.1	23.4	59.4	24.3	16.5	25.8	66.6
Non-core	6	461,349	7,905,278	0	4.6	1.1	5.7	0	4.7	1.1	5.8
Core -9	9	7,303,619	4,758,538	21	15.1	23.4	59.4	24.3	16.5	25.8	66.6
Total	15	4,566,711	6,017,234	12.6	10.9	14.5	37.9	14.6	11.8	15.9	42.3
1997											
0.1-30.0%	4	573,108	13,596,266	0	3	1.8	4.8	0	3	1.8	4.8
30.1-100%	8	4,460,161	7,696,902	11.3	7.5	16.7	35.5	11.6	8.7	18.3	38.6
Non-core	4	573,108	13,596,266	0	3	1.8	4.8	0	3	1.8	4.8
Core -9	8	4,460,161	7,696,902	11.3	7.5	16.7	35.5	11.6	8.7	18.3	38.6
Total	12	3,164,477	9,663,357	7.5	6	11.8	25.3	7.7	6.8	12.8	27.4

Table 4.2a.–Retained and discarded Atka mackerel in Areas 541, 542 and 543, 1993-97.

		Weekly target designation						
		Atka mackerel		Other species		Total	Total	Total
Area	Year	Retained	Discarded	Retained	Discarded	Retained	Discarded	Catch
All vessels								
541	93	1,248	273	365	323	1,613	596	2,209
541	94	12,552	1,739	625	342	13,177	2,081	15,258
541	95	11,791	1,371	4	693	11,795	2,064	13,859
541	96	22,685	3,919	114	671	22,799	4,590	27,389
541	97	14,528	969	448	193	14,976	1,162	16,138
542	93	20,035	6,445	102	318	20,137	6,763	26,900
542	94	35,386	4,967	388	263	35,774	5,230	41,004
542	95	40,832	9,005	387	164	41,219	9,169	50,388
542	96	28,096	4,910	381	137	28,477	5,047	33,524
542	97	17,164	1,514	1,180	132	18,344	1,646	19,990
543	93	1,999	237	0	0	1,999	237	2,236
543	94	7,056	1,861	1	5	7,057	1,866	8,923
543	95	13,530	3,294	108	34	13,638	3,328	16,966
543	96	34,055	6,525	1,144	522	35,199	7,047	42,246
543	97	24,893	3,214	1,032	399	25,925	3,613	29,538
541-543	93	23,282	6,955	467	641	23,749	7,596	31,345
541-543	94	54,994	8,567	1,014	610	56,008	9,177	65,185
541-543	95	66,153	13,670	499	891	66,652	14,561	81,213
541-543	96	84,836	15,354	1,639	1,330	86,475	16,684	103,159
541-543	97	56,585	5,697	2,660	724	59,245	6,421	65,666
Nine core vessels								
541	93	141	11	222	19	363	30	393
541	94	12,552	1,739	570	136	13,122	1,875	14,997
541	95	11,670	1,371	0	262	11,670	1,633	13,303
541	96	22,685	3,919	15	581	22,700	4,500	27,200
541	97	14,528	969	447	74	14,975	1,043	16,018
542	93	15,465	4,417	23	0	15,488	4,417	19,905
542	94	24,222	4,541	270	64	24,492	4,605	29,097
542	95	31,148	8,341	70	114	31,218	8,455	39,673
542	96	21,122	4,440	369	116	21,491	4,556	26,047
542	97	9,897	1,448	284	66	10,181	1,514	11,695
543	93	1,931	223	0	0	1,931	223	2,154
543	94	7,056	1,861	0	0	7,056	1,861	8,917
543	95	10,378	3,019	91	33	10,469	3,052	13,521
543	96	31,624	6,408	962	459	32,586	6,867	39,453
543	97	21,445	3,074	662	163	22,107	3,237	25,344
541-543	93	17,537	4,651	245	19	17,782	4,670	22,452
541-543	94	43,830	8,141	840	200	44,670	8,341	53,011
541-543	95	53,196	12,731	161	409	53,357	13,140	66,497
541-543	96	75,431	14,767	1,346	1,156	76,777	15,923	92,700
541-543	97	45,870	5,491	1,393	303	47,263	5,794	53,057

Table 4.2b.--Percentage of retained and discarded Atka mackerel in Areas 541, 542 and 543, accounted for by 9 core vessels, 1993-97.

Area	Year	Weekly target designation: Atka mackerel Retained	Atka mackerel Discarded	Other species Retained	Other species Discarded	Total Retained	Total Discarded	Total Catch
541	93	11%	4%	61%	6%	23%	5%	18%
541	94	100%	100%	91%	40%	100%	90%	98%
541	95	99%	100%	0%	38%	99%	79%	96%
541	96	100%	100%	13%	87%	100%	98%	99%
541	97	100%	100%	100%	38%	100%	90%	99%
542	93	77%	69%	23%	0%	77%	65%	74%
542	94	68%	91%	70%	24%	68%	88%	71%
542	95	76%	93%	18%	70%	76%	92%	79%
542	96	75%	90%	97%	85%	75%	90%	78%
542	97	58%	96%	24%	50%	56%	92%	59%
543	93	97%	94%	--	--	97%	94%	96%
543	94	100%	100%	0%	0%	100%	100%	100%
543	95	77%	92%	84%	97%	77%	92%	80%
543	96	93%	98%	84%	88%	93%	97%	93%
543	97	86%	96%	64%	41%	85%	90%	86%
541/2/3	93	75%	67%	52%	3%	75%	61%	72%
541/2/3	94	80%	95%	83%	33%	80%	91%	81%
541/2/3	95	80%	93%	32%	46%	80%	90%	82%
541/2/3	96	89%	96%	82%	87%	89%	95%	90%
541/2/3	97	81%	96%	52%	42%	80%	90%	81%

Table 4.3.--Number of vessels with weekly targets of Atka mackerel and other species, by month and area, for vessels having at least one target week for Atka mackerel in Areas 541, 542, or 543 during that year, for 1993-97.

	Area							
	541		542		543		Other	
Year /	Target		Target		Target		Target	
Month	At. mack.	Other	At. mack.	Other	At. mack.	Other	At. mack.	Other
1997								
1	8	.	.	.	.	.	.	2
2	8	6	1	.	.	.	.	11
3	.	10	12	3	10	6	.	1
4	.	.	1	2	9	1	.	5
5	.	.	.	.	.	.	.	8
6	.	.	.	.	.	.	.	8
7	.	.	.	.	.	.	.	8
8	.	.	.	.	.	.	.	10
9	.	.	.	.	.	.	.	12
10	.	.	.	.	.	.	.	12
11	.	.	.	.	.	.	.	8
1996								
1	9	.	.	.	.	.	.	5
2	9	.	5	1	.	.	.	11
3	.	9	14	10	3	7	.	9
4	.	.	11	2	9	7	.	3
5	.	.	.	1	5	.	.	4
6	.	.	.	.	3	.	.	6
7	8	.	4	.	8	.	8	9
8	5	.	5	.	7	.	.	10
9	.	.	.	.	1	.	.	14
10	.	1	.	.	.	.	.	13
11	.	2	.	1	.	.	.	5
1995								
1	9	.	.	.	.	.	.	8
2	9	9	7	.	.	.	.	12
3	1	6	16	6	1	2	.	7
4	.	7	11	1	5	1	.	10
5	.	3	.	5	13	2	.	10
7	.	.	4	.	.	.	.	13
8	.	.	.	.	.	.	.	16
9	.	.	.	.	.	.	.	16
10	.	.	.	.	.	.	1	13
11	.	.	.	.	.	.	.	2

Table 4.3.--Number of vessels with weekly targets of Atka mackerel and other species, by month and area, for vessels having at least one target week for Atka mackerel in Areas 541, 542, or 543 during that year, for 1993-97 (continued).

Year /	Area							
	541		542		543		Other	
	Target		Target		Target		Target	
Month	At. mack.	Other	At. mack.	Other	At. mack.	Other	At. mack.	Other
1994								
1	7	1	.	.	.	.	.	11
2	7	4	3	.	.	.	.	12
3	.	10	8	2	2	2	8	10
4	1	7	9	4	2	.	.	8
5	.	5	8	.	4	.	.	12
6	.	2	6	.	4	.	.	8
7	1	2	10	1	2	.	.	10
8	.	.	.	.	.	.	.	14
9	.	.	.	.	.	.	.	14
10	.	2	.	.	.	.	1	14
11	.	.	.	.	.	.	.	11
12	.	.	.	.	.	.	.	2
1993								
1	.	.	.	.	.	.	2	10
2	1	1	.	.	.	.	7	11
3	1	2	.	1	.	.	8	11
4	.	2	.	1	.	1	.	12
5	.	1	.	.	.	.	.	10
6	.	.	.	.	.	.	.	10
7	.	.	.	.	.	.	.	11
8	1	7	9	3	.	.	.	11
9	1	.	9	.	1	.	.	8
10	.	3	6	3	.	.	.	9
11	.	1	1	1	1	.	.	6
12	.	.	.	.	1	.	.	5

Table 4.4.--Number of target weeks for Atka mackerel and other species, by month and area, by vessels having at least one target week for Atka mackerel in Areas 541, 542, or 543 during that year, for 1993-97.

Year / Month	Area 541 Target At. mack.	Area 541 Target Other	Area 542 Target At. mack.	Area 542 Target Other	Area 543 Target At. mack.	Area 543 Target Other	Area Other Target At. mack.	Area Other Target Other
1997								
1	8	.	.	.	.	.	.	2
2	16	6	3	.	.	.	.	37
3	.	11	28	7	22	9	.	1
4	.	.	1	2	31	1	.	6
5	.	.	.	.	.	.	.	40
6	.	.	.	.	.	.	.	23
7	.	.	.	.	.	.	.	32
8	.	.	.	.	.	.	.	25
9	.	.	.	.	.	.	.	48
10	.	.	.	.	.	.	.	36
11	.	.	.	.	.	.	.	33
1996								
1	17	.	.	.	.	.	.	7
2	25	.	6	1	.	.	.	32
3	.	16	40	13	3	12	.	16
4	.	.	26	2	14	7	.	5
5	.	.	.	1	18	.	.	14
6	.	.	.	.	10	.	.	23
7	16	.	5	.	15	.	8	20
8	7	.	7	.	21	.	.	24
9	.	.	.	.	1	.	.	54
10	.	1	.	.	.	.	.	41
11	.	3	.	1	.	.	.	5
1995								
1	17	.	.	.	.	.	.	13
2	9	9	23	.	.	.	.	40
3	1	13	37	10	2	2	.	13
4	.	13	28	2	10	2	.	36
5	.	3	.	5	31	2	.	10
7	.	.	11	.	.	.	.	44
8	.	.	.	.	.	.	.	58
9	.	.	.	.	.	.	.	77
10	.	.	.	.	.	.	1	39
11	.	.	.	.	.	.	.	2

Table 4.4.--Number of target weeks for Atka mackerel and other species, by month and area, by vessels having at least one target week for Atka mackerel in Areas 541, 542, or 543 during that year, for 1993-97 (continued).

Year / Month	Area 541 Target At. mack.	Area 541 Target Other	Area 542 Target At. mack.	Area 542 Target Other	Area 543 Target At. mack.	Area 543 Target Other	Other Target At. mack.	Other Target Other
1994								
1	10	2	.	.	.	.	.	20
2	17	5	6	.	.	.	.	35
3	.	25	13	3	3	3	8	25
4	1	12	24	5	9	.	.	31
5	.	5	19	.	6	.	.	34
6	.	2	7	.	7	.	.	23
7	1	4	25	1	2	.	.	26
8	.	.	.	.	.	.	.	52
9	.	.	.	.	.	.	.	56
10	.	2	.	.	.	.	2	65
11	.	.	.	.	.	.	.	31
12	.	.	.	.	.	.	.	5
1993								
1	.	.	.	.	.	.	4	21
2	1	1	.	.	.	.	13	40
3	2	6	.	1	.	.	15	32
4	.	2	.	2	.	1	.	44
5	.	1	.	.	.	.	.	43
6	.	.	.	.	.	.	.	36
7	.	.	.	.	.	.	.	52
8	1	10	18	5	.	.	.	19
9	1	.	26	.	1	.	.	25
10	.	5	13	4	.	.	.	37
11	.	1	1	1	4	.	.	20
12	.	.	.	.	3	.	.	9

Table 4.5.--Annual product revenues and revenue shares for all vessels having at least one target week for Atka mackerel in Areas 541-543 during the specified years, 1995-97.

Vessel group / Species	1995			1996			1997		
	# of ves.	Total value of products ($)	% of value	# of ves.	Total value of products ($)	% of value	# of ves.	Total value of products ($)	% of value
9 core vessels									
Atka mackerel	9	39,058,023	43%	9	65,732,575	61%	8	35,681,290	37%
Pollock	9	3,211,805	4%	7	2,226,572	2%	8	2,440,020	3%
Pacific cod	9	4,256,702	5%	9	6,590,297	6%	8	5,348,451	5%
Flathead sole	9	1,312,492	1%	9	850,491	1%	8	1,066,896	1%
Rock sole	9	4,874,510	5%	9	3,070,154	3%	8	8,481,744	9%
Yellowfin	9	17,940,425	20%	8	18,272,926	17%	8	31,361,553	32%
Rockfish	9	14,343,922	16%	9	10,016,934	9%	8	11,008,427	11%
Other	9	5,436,093	6%	9	1,808,248	2%	8	1,868,147	2%
Total non-mack.		51,375,948	57%		42,835,622	39%		61,575,239	63%
All species		90,433,971	100%		108,568,197	100%		97,256,529	100%
Non-core vessels									
Atka mackerel	8	4,743,596	6%	6	2,768,095	5%	4	2,292,434	4%
Pollock	8	48,010,032	58%	5	35,599,905	71%	4	54,368,929	96%
Pacific cod	8	2,460,086	3%	4	1,275,878	3%	1	16,136	0%
Flathead sole	5	1,159,745	1%	3	104,361	0%	0	0	0%
Rock sole	5	8,136,492	10%	3	3,307,035	7%	0	0	0%
Yellowfin	6	9,246,940	11%	2	1,358,821	3%	0	0	0%
Rockfish	6	6,265,637	8%	3	4,017,969	8%	0	0	0%
Other	5	2,189,990	3%	3	1,926,300	4%	0	0	0%
Total non-mack.		77,468,923	94%		47,590,269	95%		54,385,064	96%
All species		82,212,519	100%		50,358,364	100%		56,677,498	100%
All vessels									
Atka mackerel	17	43,801,619	25%	15	68,500,670	43%	12	37,973,724	25%
Pollock	17	51,221,836	30%	12	37,826,477	24%	12	56,808,948	37%
Pacific cod	17	6,716,788	4%	13	7,866,175	5%	9	5,364,587	3%
Flathead sole	14	2,472,237	1%	12	954,852	1%	8	1,066,896	1%
Rock sole	14	13,011,002	8%	12	6,377,190	4%	8	8,481,744	6%
Yellowfin	15	27,187,365	16%	10	19,631,747	12%	8	31,361,553	20%
Rockfish	15	20,609,559	12%	12	14,034,903	9%	9	11,008,427	7%
Other	14	7,626,084	4%	12	3,734,548	2%	8	1,868,147	1%
Total non-mack.		128,844,871	75%		90,425,891	57%		115,960,303	75%
All species		172,646,490	100%		158,926,561	100%		153,934,027	100%

Note: Vessels designated as core participants earned more than 30% of revenue from Atka mackerel in at least 3 of 4 years from 1994-97.

Table 4.6.–Retained and discarded catch of major species, by year, area and target designation, for core and non-core groups of vessels, 1995-97.

Year / Vessel group / Species group / Disposition	Area 541		Area 542		Area 543		Areas 541-543			Other areas		Total
	Weekly target		Weekly target		Weekly target		Weekly target			Weekly target		
	A. mck.	Other	A. mck.	Other	A. mck.	Other	A. mck.	Other	All	A. mck.	Other	All
1995												
9 Core vessels												
Atka mackerel												
Retained	11,670	0	31,148	70	10,378	91	53,196	161	53,357	1	62	53,420
Discard	1,371	262	8,341	114	3,019	33	12,731	409	13,140	0	15	13,155
Pacific cod												
Retained	178	72	1,523	15	834	5	2,535	92	2,627	0	4,900	7,527
Discard	76	21	596	10	404	1	1,076	32	1,108	1	3,377	4,486
Rock sole												
Retained	1	4	25	0	0	0	26	4	30	0	5,558	5,588
Discard	14	14	42	0	13	0	69	14	83	0	4,088	4,171
Yellowfin												
Retained	0	0	2	0	0	0	2	0	2	0	24,504	24,506
Discard	0	0	2	0	0	0	2	0	2	0	4,900	4,902
Rockfish												
Retained	7	5,475	375	635	396	219	778	6,329	7,107	0	7,441	14,548
Discard	424	189	1,579	131	930	31	2,933	351	3,284	0	1,210	4,494
All non-mackerel												
Retained	187	6,410	1,959	657	1,229	224	3,375	7,291	10,666	0	51,168	61,834
Discard	617	914	2,723	190	1,527	40	4,867	1,144	6,011	1	28,255	34,267
Non-core vessels												
Atka mackerel												
Retained	122	0	9,684	311	3,152	17	12,958	328	13,286	0	50	13,336
Discard	0	257	663	28	275	1	938	286	1,224	0	3	1,227
Pollock												
Retained	0	5,624	0	2,964	0	0	0	8,588	8,588	0	62,179	70,767
Discard	0	89	25	53	14	0	39	142	181	0	8,885	9,066
Rock sole												
Retained	0	0	0	0	0	0	0	0	0	0	4,217	4,217
Discard	0	2	28	2	15	1	43	5	48	0	5,740	5,788
Rockfish												
Retained	0	1,019	323	1,288	93	88	416	2,395	2,811	0	3,182	5,993
Discard	1	124	381	129	349	3	731	256	987	0	598	1,585
All non-mackerel												
Retained	0	7,151	457	4,260	251	91	708	11,502	12,210	0	88,137	100,347
Discard	3	321	956	230	556	9	1,515	560	2,075	0	29,652	31,727

Note: Vessels designated as "core" earned more than 30% of revenue from Atka mackerel in at least 3 of 4 years from 1994-97.

Table 4. 6.–Retained and discarded catch of major species, by year, area and target designation, for core and non-core groups of vessels, 1995-97 (continued).

Year / Vessel group / Species group / Disposition	Area 541		Area 542		Area 543		Areas 541-543			Other areas		Total
	Weekly target		Weekly target		Weekly target		Weekly target			Weekly target		
	A. mck.	Other	A. mck.	Other	A. mck.	Other	A. mck.	Other	All	A. mck.	Other	All
1996												
9 Core vessels												
Atka mackerel												
Retained	22,685	15	21,122	369	31,624	962	75,431	1,346	76,777	1094	46	77,917
Discard	3,919	581	4,440	116	6,408	459	14,767	1,156	15,923	62	16	16,001
Pacific cod												
Retained	2994	434	995	67	2486	119	6,475	620	7,095	3	2,084	9,182
Discard	708	7	350	28	541	22	1,599	57	1,656	63	884	2,603
Rock sole												
Retained	3	1	4	0	4	0	11	1	12	0	3,910	3,922
Discard	59	3	32	2	24	1	115	6	121	0	3,643	3,764
Yellowfin												
Retained	0	0	0	0	0	0	0	0	0	0	25,260	25,260
Discard	0	0	0	0	0	0	0	0	0	0	3,952	3,952
Rockfish												
Retained	27	2,459	1138	1301	1262	4340	2,427	8,100	10,527	39	3,250	13,816
Discard	686	386	1,623	197	2737	750	5,046	1,333	6,379	69	235	6,683
All non-mackerel												
Retained	3025	3,538	2,224	1372	3,830	4461	9,079	9,371	18,450	43	38,814	57,307
Discard	1748	780	2,662	310	3,778	862	8,188	1,952	10,140	191	23,177	33,508
Non-core vessels												
Atka mackerel												
Retained	0	0	6,973	0	2,431	183	9,404	183	9,587	0	0	9,587
Discard	0	0	470	15	118	60	588	75	663	0	0	663
Pollock												
Retained	0	1,071	0	2,513	0	0	0	3,584	3,584	0	60,614	64,198
Discard	0	4	13	131	1	5	14	140	154	0	5,343	5,497
Rock sole												
Retained	0	0	0	0	0	0	0	0	0	0	1,594	1,594
Discard	0	0	19	1	0	1	19	2	21	0	1,774	1,795
Rockfish												
Retained	0	0	17	479	1	999	18	1,478	1,496	0	3,554	5,050
Discard	0	5	313	10	127	188	440	203	643	0	785	1,428
All non-mackerel												
Retained	0	1,144	71	2,996	3	999	74	5,139	5,213	0	71,620	76,833
Discard	0	25	964	158	212	220	1,176	403	1,579	0	13,622	15,201

Note: Vessels designated as "core" earned more than 30% of revenue from Atka mackerel in at least 3 of 4 years from 1994-97.

Table 4.6.--Retained and discarded catch of major species, by year, area and target designation, for core and non-core groups of vessels, 1995-97 (continued).

Year / Vessel group / Species group / Disposition	Area 541 Weekly target A. mck.	Area 541 Weekly target Other	Area 542 Weekly target A. mck.	Area 542 Weekly target Other	Area 543 Weekly target A. mck.	Area 543 Weekly target Other	Areas 541-543 Weekly target A. mck.	Areas 541-543 Weekly target Other	Areas 541-543 All	Other areas Weekly target A. mck.	Other areas Weekly target Other	Total All
1997												
9 Core vessels												
Atka mackerel												
Retained	14,528	447	9,897	284	21,445	662	45,870	1,393	47,263	0	276	47,539
Discard	969	74	1,448	66	3,074	163	5,491	303	5,794	0	42	5,836
Pacific cod												
Retained	374	44	138	27	656	11	1,168	82	1,250	0	5,722	6,972
Discard	198	8	183	10	163	5	544	23	567	0	1,116	1,683
Rock sole												
Retained	3	0	2	0	5	0	10	0	10	0	11,113	11,123
Discard	17	1	10	0	13	1	40	2	42	0	6,389	6,431
Yellowfin												
Retained	0	0	0	0	0	0	0	0	0	0	57,175	57,175
Discard	1	0	0	0	0	0	1	0	1	0	3,554	3,555
Rockfish												
Retained	24	2,948	1427	917	1504	2106	2,955	5,971	8,926	0	5,937	14,863
Discard	181	106	714	95	1706	301	2,601	502	3,103	0	978	4,081
All non-mackerel												
Retained	410	3,531	1,599	944	2,195	2118	4,204	6,593	10,797	0	84,871	95,668
Discard	515	279	1,164	163	2,122	376	3,801	818	4,619	0	33,665	38,284
Non-core vessels												
Atka mackerel												
Retained	0	0	7,267	896	3,448	369	10,715	1,265	11,980	0	0	11,980
Discard	0	45	66	48	139	230	205	323	528	0	0	528
Pollock												
Retained	0	1,132	0	3,544	0	922	0	5,598	5,598	0	87,020	92,618
Discard	0	23	8	22	13	6	21	51	72	0	1,639	1,711
Rock sole												
Discard	0	0	3	1	1	0	4	1	5	0	129	134
Rockfish												
Retained	0	2	0	0	0	3	0	5	5	0	0	5
Discard	0	32	82	18	264	3	346	53	399	0	3	402
All non-mackerel												
Retained	0	1,182	15	3,544	0	925	15	5,651	5,666	0	87,070	92,736
Discard	0	59	291	324	344	17	635	400	1,035	0	2,583	3,618

Note: Vessels designated as "core" earned more than 30% of revenue from Atka mackerel in at least 3 of 4 years from 1994-97.

Table 4.7 BSAI factory trawler fleet, number, mean length, mean net registered tons, and mean horsepower by fishery and length class, 1995-97.

Number of vessels

	Vessel length class (feet)				
Target	<125	125-150	151-200	201-250	>250
Pacific cod					
1993	5	4	13	18	8
1994	4	2	8	10	10
1995	7	4	11	11	7
1996	8	3	12	13	3
1997	10	3	8	15	6
Flathead. sole					
1995	2	3	7	6	1
1996	7	3	5	3	-
1997	7	3	5	3	-
Rock sole					
1993	7	4	12	12	3
1994	3	2	9	12	4
1995	8	4	12	8	4
1996	8	3	8	9	2
1997	8	3	9	7	2
Yellowfin					
1993	4	3	8	12	5
1994	3	4	10	13	5
1995	6	4	12	15	7
1996	7	3	8	9	7
1997	8	2	9	8	5
Flat, other					
1993	4	3	9	7	3
1994	4	1	8	3	1
1995	6	4	7	5	-
1996	6	2	5	2	-
1997	4	1	2	-	1
Atka mack.					
1993	1	4	6	9	3
1994	1	1	2	9	2
1995	-	-	7	8	2
1996	-	2	3	10	2
1997	-	-	1	8	3

Table 4.7 Continued.

Mean length

	Vessel length class (feet)				
	<125	125-150	151-200	201-250	>250
Target					
Pacific cod					
1993	110	140	175	219	291
1994	112	145	176	219	292
1995	108	140	180	223	278
1996	113	142	182	225	274
1997	108	142	181	222	286
Flathead. sole					
1995	114	141	183	217	278
1996	114	142	174	229	-
1997	117	142	176	221	-
Rock sole					
1993	109	140	173	215	294
1994	117	145	177	216	301
1995	110	140	183	216	322
1996	113	142	181	224	335
1997	115	142	182	224	310
Yellowfin					
1993	114	141	178	217	295
1994	117	140	178	215	310
1995	113	140	183	221	314
1996	114	142	181	222	314
1997	115	145	182	223	.314
Flat, other					
1993	114	142	176	221	283
1994	112	150	176	223	302
1995	111	140	178	222	-
1996	116	145	174	213	-
1997	118	140	172	-	334
Atka mack.					
1993	124	141	184	216	274
1994	124	150	183	214	267
1995	-	-	187	214	316
1996	-	145	191	222	281
1997	-	-	200	222	313

Table 4.7 Continued.

Mean net registered tons

	Vessel length class (feet)				
	<125	125-150	151-200	201-250	>250
Target					
Pacific cod					
1993	128	187	532	739	1339
1994	140	131	590	840	1751
1995	126	195	531	961	1367
1996	142	205	619	849	979
1997	134	205	696	755	1615
Flathead. sole					
1995	134	142	559	857	2150
1996	143	205	514	497	-
1997	152	205	552	688	-
Rock sole					
1993	120	187	525	731	1621
1994	135	131	653	780	1327
1995	130	195	652	909	2757
1996	142	205	696	757	2028
1997	150	205	687	574	2848
Yellowfin					
1993	124	131	620	709	1250
1994	135	195	619	763	2516
1995	116	195	652	871	2279
1996	143	205	653	663	2150
1997	150	131	687	676	2415
Flat, other					
1993	121	205	510	696	1557
1994	140	132	661	973	1582
1995	126	195	573	985	-
1996	155	131	549	932	-
1997	149	130	504	-	1773
Atka mack.					
1993	136	166	734	661	1065
1994	136	132	1019	771	1857
1995	-	-	706	924	1923
1996	-	131	942	737	1101
1997	-	-	1162	573	1581

Table 4.7 Continued.

Mean horse power

	Vessel length class (feet)				
	<125	125-150	151-200	201-250	>250
Target					
Pacific cod					
1993	1,108	1,710	2,639	3,726	4,852
1994	1,100	2,000	2,463	3,764	5,469
1995	1,007	1,725	2,724	3,706	5,035
1996	1,088	1,867	2,619	3,432	4,425
1997	1,022	1,867	2,579	3,381	6,060
Flathead. sole					
1995	1,050	1,767	2,900	3,420	5,300
1996	1,129	1,867	2,610	3,300	-
1997	1,240	1,867	2,690	2,625	-
Rock sole					
1993	1,002	1,710	2,634	3,546	5,350
1994	1,183	2,000	2,463	3,244	4,425
1995	1,032	1,725	2,713	3,236	7,533
1996	1,088	1,867	2,579	3,175	6,100
1997	1,185	1,867	2,594	3,210	7,050
Yellowfin					
1993	1,147	1,747	3,034	3,623	4,690
1994	1,183	1,685	2,480	3,439	6,340
1995	1,084	1,725	2,713	3,862	6,217
1996	1,129	1,867	2,707	3,150	5,852
1997	1,185	2,000	2,594	3,175	6,690
Flat, other					
1993	1,173	1,867	2,396	3,275	5,525
1994	1,100	2,200	2,471	2,625	-
1995	1,028	1,725	2,578	3,112	-
1996	1,205	2,000	2,750	3,000	-
1997	1,275	1,800	2,500	-	-
Atka mack.					
1993	1,450	1,735	3,370	3,281	4,917
1994	1,450	2,200	3,200	3,490	5,650
1995	-	-	2,900	3,436	6,125
1996	-	2,000	2,150	3,436	6,000
1997	-	-	-	3,508	6,083

Table 4.8 Number of BSAI factory trawlers by catch class and fishery, 1995-97.

Target	Catch class in metric tons of catch					
	< 100	100-500	501-1,000	1,001-5,000	5,001-10,000	> 10,000
Pacific cod						
1993	11	8	8	21	-	-
1994	6	8	8	12	-	-
1995	4	8	6	22	-	-
1996	7	10	8	14	-	-
1997	9	9	8	16	*	-
Flathead. sole						
1995	8	6	1	4	-	-
1996	4	4	2	8	-	-
1997	1	5	2	10	-	-
Rock sole						
1993	3	5	7	20	3	-
1994	2	4	3	18	3	-
1995	2	7	4	23	-	-
1996	4	4	4	18	*	-
1997	-	3	1	25	*	-
Yellowfin						
1993	2	1	2	15	12	*
1994	-	2	3	12	11	7
1995	-	3	7	24	10	*
1996	2	-	3	14	12	3
1997	-	-	-	12	11	8
Flat, other						
1993	9	7	2	8	*	-
1994	3	4	3	7	-	-
1995	4	6	5	7	-	-
1996	3	5	3	4	-	-
1997	1	4	3	*	-	-
Atka mack.						
1993	1	3	5	10	4	*
1994	2	1	1	6	5	*
1995	-	2	3	2	10	*
1996	1	3	2	1	3	7
1997	-	-	2	2	8	-

Note: If fewer than 3 vessels were in the top catch class, the number of vessel was replaced with a * and the number of vessels in the previous catch class was increased by that number of vessels.

Table 4.9 Comparisons of mean vessel characteristics for the core Atka mackerel fleet and other vessels in the BSAI rock sole fishery, 1995-97.

		Mean		
		Length	NRT	HP
1995	Non-core	177	759	2,639
	Core	208	828	3,210
1996	Non-core	165	553	2,265
	Core	223	731	3,210
1997	Non-core	162	597	2,378
	Core	221	648	3,210

1995-97 Weekly catch capacity	
Non-core	503
Core	615

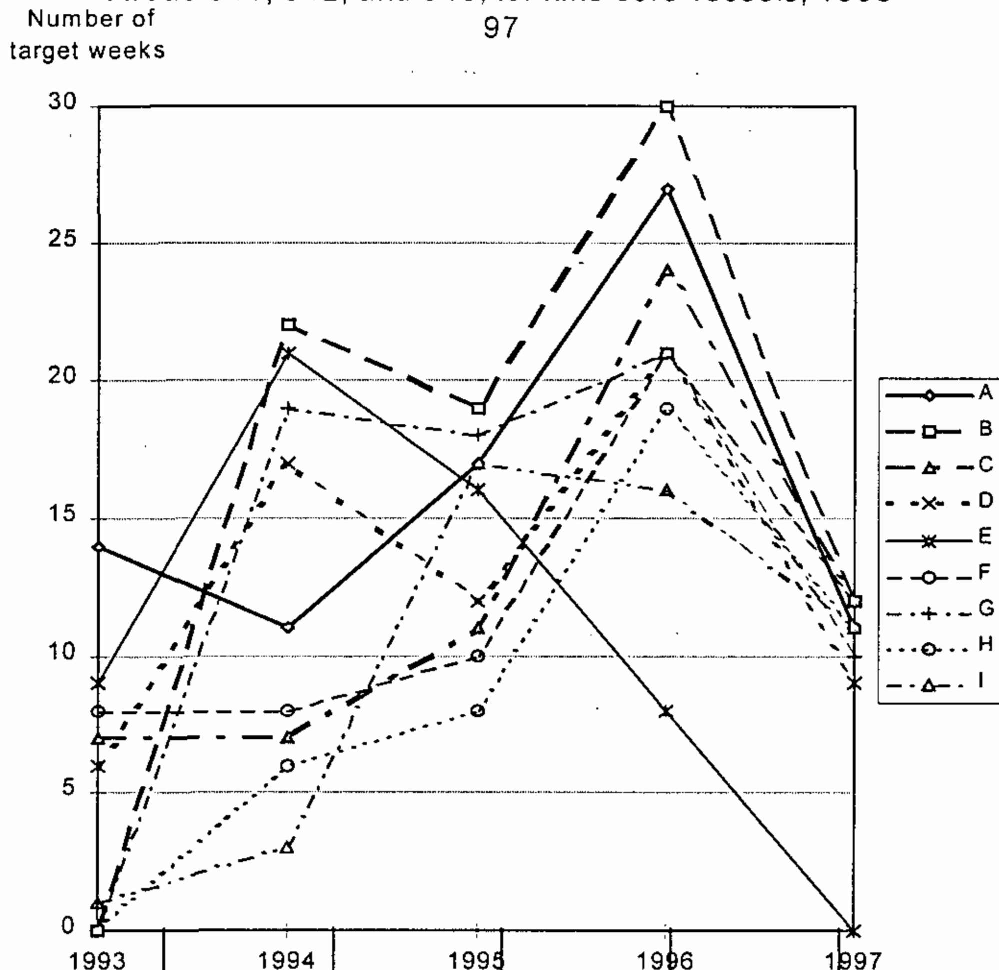
Note: Length over all in feet, net registered tons (NRT), horsepower (HP), and weekly catch capacity in metric tons. Catch capacity is based on the mean catch per week for the top four weeks for each vessel for the three-year period. The core vessels refer to the 9 core vessels from the Atka mackerel fishery and the non-core vessels refer to the other vessels in the BSAI rock sole fishery.

Table 4.10 Estimates of what the catch and bycatch would have been in the 1997 BSAI roe rock sole fishery with a 296,000 bairdi PSC allowance and with the actual and assumed deployments of the core Atka mackerel vessels in the rock sole fishery.

	Deployment		
	Actual	Assumed (1)	Assumed (2)
Catch (mt)			
total	30,617	26,216	25,979
non-core vessels	25,457	19,370	18,672
core vessels	5,160	6,846	7,307
Bycatch			
Halibut (mt)	451	390	385
bairdi (no)	296,057	296,069	296,069
red king crab (no)	37,783	38,710	38,813

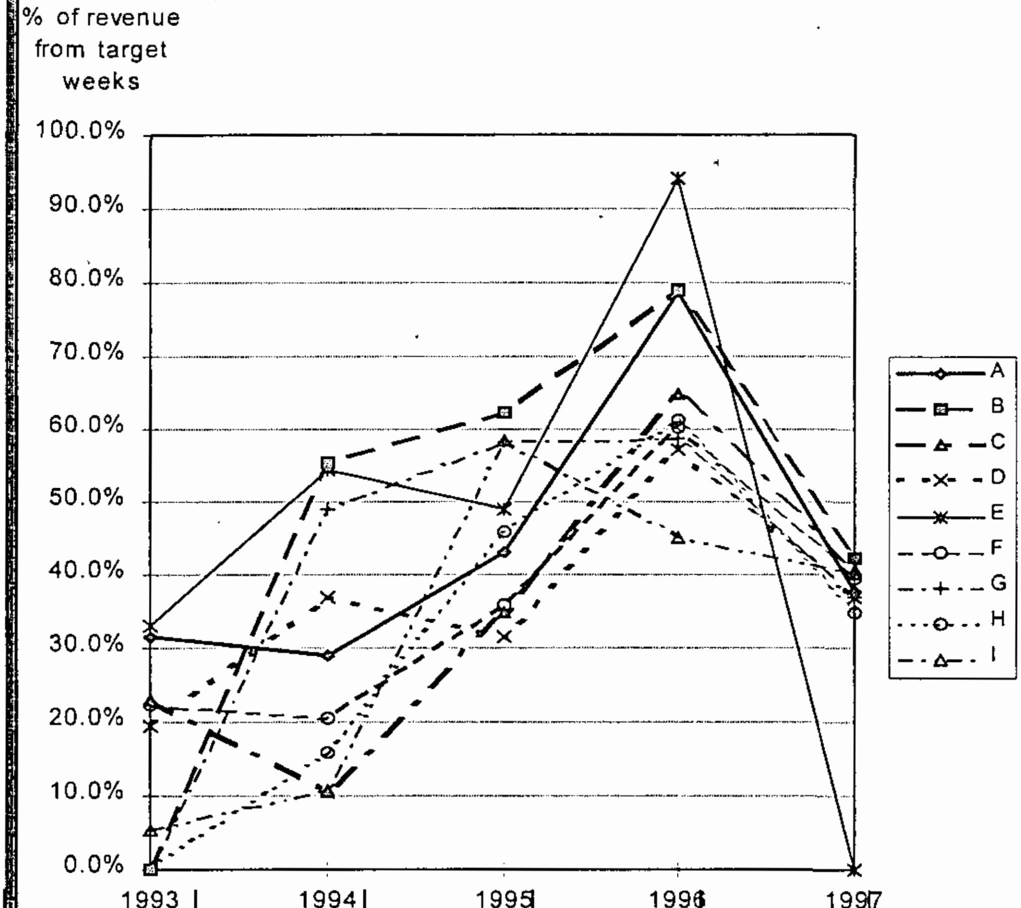
Note: Assumed (1) and (2) are for the catch per vessel week adjustments of 1.22 and 1.41, respectively.

Figure 1.--Number of Atka mackerel target weeks in Areas 541, 542, and 543, for nine core vessels, 1993 97



Vessel	1993	1994	1995	1996	1997
A	14	11	17	27	11
B	0	22	19	30	12
C	7	7	11	24	12
D	6	17	12	21	9
E	9	21	16	8	0
F	8	8	10	21	12
G	0	19	18	21	10
H	0	6	8	19	11
I	1	3	17	16	11

Figure 2.--Percentage of annual earnings from all fish caught during Atka mackerel target weeks in Areas 541, 542, and 543, for nine core vessels, 1993-97



Vessel	1993	1994	1995	1996	1997
A	31.5%	28.9%	43.2%	78.7%	37.8%
B	0.0%	55.3%	62.3%	79.1%	42.3%
C	23.2%	10.5%	34.9%	64.8%	40.7%
D	19.6%	36.9%	31.5%	57.1%	37.0%
E	33.1%	54.4%	49.1%	94.2%	0.0%
F	22.2%	20.6%	35.9%	60.3%	39.5%
G	0.0%	49.1%	58.2%	58.6%	36.8%
H	0.0%	16.0%	46.0%	61.4%	34.9%
I	5.5%	10.7%	58.4%	45.1%	40.2%

Figure 3.--Number of Atka mackerel target weeks in Areas 541, 542, and 543, for 15 non-core vessels, 1993-97

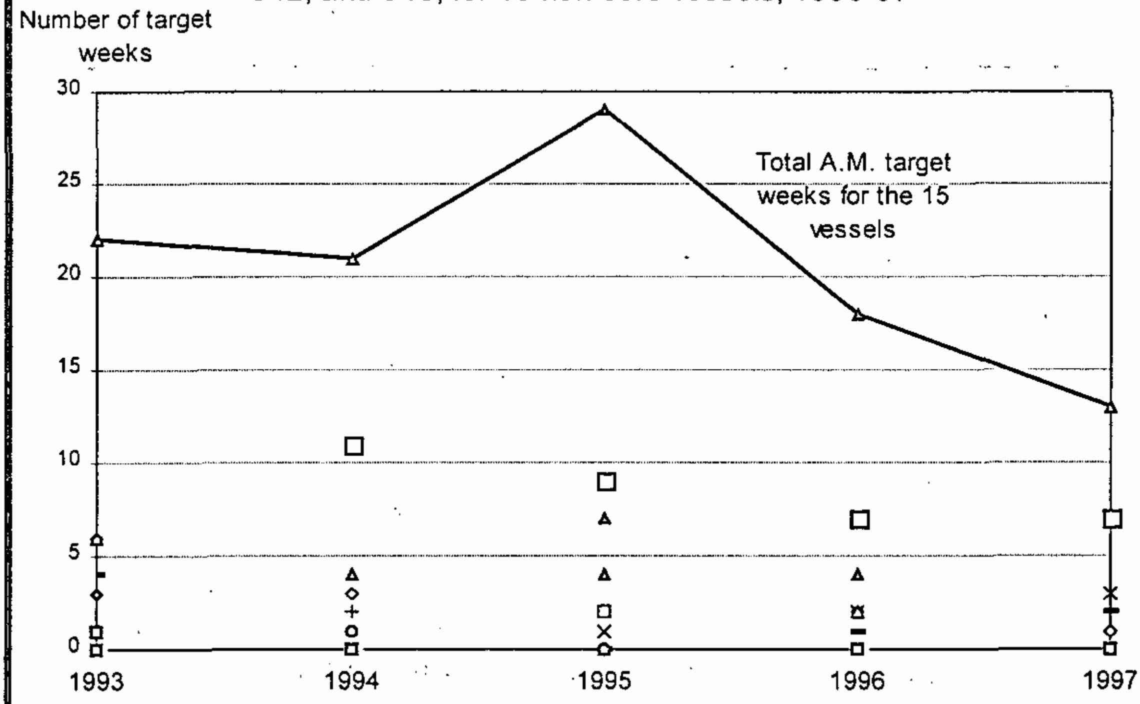
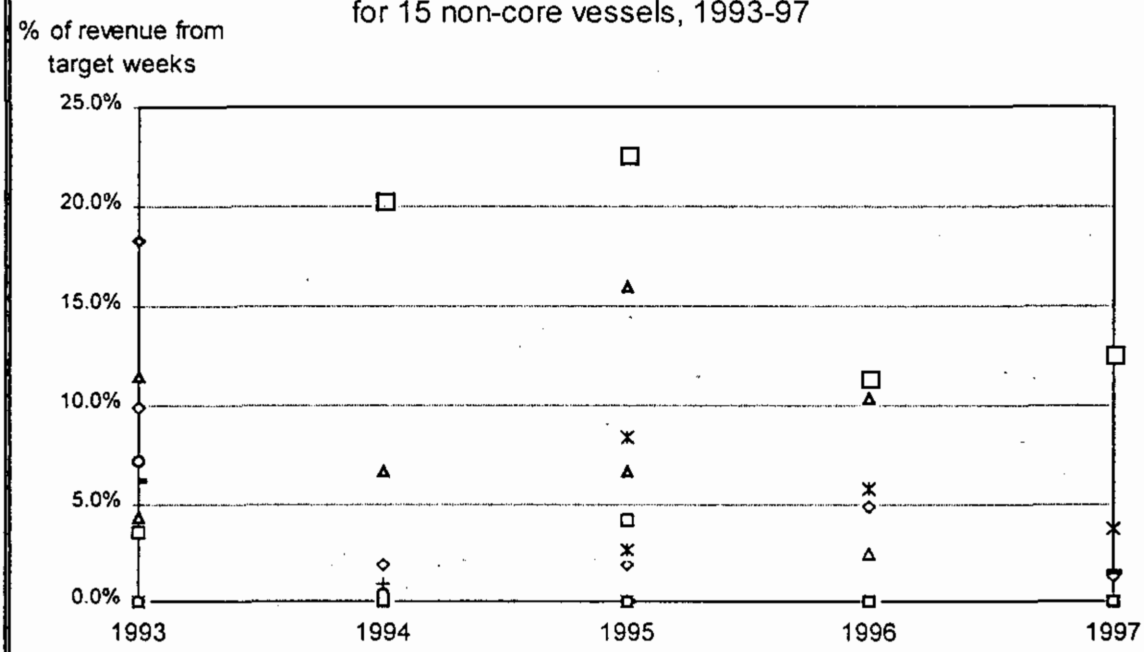


Figure 4.--Percentage of annual earnings from all fish caught during Atka mackerel target weeks in Areas 541, 542, and 543, for 15 non-core vessels, 1993-97



5.0 INITIAL REGULATORY FLEXIBILITY ANALYSIS

The Regulatory Flexibility Act (RFA) first enacted in 1980 was designed to place the burden on the government to review all regulations to ensure that, while accomplishing their intended purposes, they do not unduly inhibit the ability of small entities to compete. The RFA recognizes that the size of a business, unit of government, or nonprofit organization frequently has a bearing on its ability to comply with a federal regulation. Major goals of the RFA are: (1) to increase agency awareness and understanding of the impact of their regulations on small business, (2) to require that agencies communicate and explain their findings to the public, and (3) to encourage agencies to use flexibility and to provide regulatory relief to small entities. The RFA emphasizes predicting impacts on small entities as a group distinct from other entities and on the consideration of alternatives that may minimize the impacts while still achieving the stated objective of the action.

On March 29, 1996, President Clinton signed the Small Business Regulatory Enforcement Fairness Act. Among other things, the new law amended the RFA to allow judicial review of an agency's compliance with the RFA. The 1996 amendments also updated the requirements for a final regulatory flexibility analysis, including a description of the steps an agency must take to minimize the significant economic impact on small entities. Finally, the 1996 amendments expanded the authority of the Chief Counsel for Advocacy of the Small Business Administration (SBA) to file *amicus* briefs in court proceedings involving an agency's violation of the RFA.

5.1 Requirement to Prepare an IRFA

If a proposed rule is expected to have a significant economic impact on a substantial number of small entities, an initial regulatory flexibility analysis must be prepared. The central focus of the IRFA should be on the economic impacts of a regulation on small entities and on the alternatives that might minimize the impacts and still accomplish the statutory objectives. The level of detail and sophistication of the analysis should reflect the significance of the impact on small entities. Under 5 U.S.C., Section 603(b) of the RFA, each IRFA is required to address:

- A description of the reasons why action by the agency is being considered;
- A succinct statement of the objectives of, and the legal basis for, the proposed rule;
- A description of and, where feasible, an estimate of the number of small entities to which the proposed rule will apply (including a profile of the industry divided into industry segments, if appropriate);
- A description of the projected reporting, recordkeeping and other compliance requirements of the proposed rule, including an estimate of the classes of small entities that will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;
- An identification, to the extent practicable, of all relevant Federal rules that may duplicate, overlap or conflict with the proposed rule;
- A description of any significant alternatives to the proposed rule that accomplish the stated objectives of the Magnuson-Stevens Act and any other applicable statutes and that would minimize any significant economic impact of the proposed rule on small entities. Consistent with the stated objectives of applicable statutes, the analysis shall discuss significant alternatives, such as:

1. The establishment of differing compliance or reporting requirements or timetables that take into account the resources available to small entities;

2. The clarification, consolidation, or simplification of compliance and reporting requirements under the rule for such small entities;

3. The use of performance rather than design standards;

4. An exemption from coverage of the rule, or any part thereof, for such small entities.

5.2 What is a Small Entity?

The RFA recognizes and defines three kinds of small entities: (1) small businesses, (2) small non-profit organizations, and (3) and small government jurisdictions.

Small businesses. Section 601(3) of the RFA defines a 'small business' as having the same meaning as 'small business concern' which is defined under Section 3 of the Small Business Act. 'Small business' or 'small business concern' includes any firm that is independently owned and operated and not dominate in its field of operation. The SBA has further defined a "small business concern" as one "organized for profit, with a place of business located in the United States, and which operates primarily within the United States or which makes a significant contribution to the U.S. economy through payment of taxes or use of American products, materials or labor...A small business concern may be in the legal form of an individual proprietorship, partnership, limited liability company, corporation, joint venture, association, trust or cooperative, except that where the form is a joint venture there can be no more than 49 percent participation by foreign business entities in the joint venture."

The SBA has established size criteria for all major industry sectors in the US including fish harvesting and fish processing businesses. A business involved in fish harvesting is a small business if it is independently owned and operated and not dominant in its field of operation (including its affiliates) and if it has combined annual receipts not in excess of $ 3 million for all its affiliated operations worldwide. A seafood processor is a small business if it is independently owned and operated, not dominant in its field of operation, and employs 500 or fewer persons on a full-time, part-time, temporary, or other basis, at all its affiliated operations worldwide. A business involved in both the harvesting and processing of seafood products is a small business if it meets the $3 million criterion for fish harvesting operations. Finally a wholesale business servicing the fishing industry is a small businesses if it employs 100 or fewer persons on a full-time, part-time, temporary, or other basis, at all its affiliated operations worldwide.

The SBA has established "principles of affiliation" to determine whether a business concern is "independently owned and operated." In general, business concerns are affiliates of each other when one concern controls or has the power to control the other, or a third party controls or has the power to control both. The SBA considers factors such as ownership, management, previous relationships with or ties to another concern, and contractual relationships, in determining whether affiliation exists. Individuals or firms that have identical or substantially identical business or economic interests, such as family members, persons with common investments, or firms that are economically dependent through contractual or other relationships, are treated as one party with such interests aggregated when measuring the size of the concern in question. The SBA counts the receipts or employees of the concern whose size is at issue and those of all its domestic and foreign affiliates, regardless of whether the affiliates are organized for profit, in determining the concern's size. However, business concerns owned and controlled by Indian Tribes, Alaska Regional or Village Corporations organized pursuant to the Alaska Native Claims Settlement Act (43 U.S.C. 1601), Native Hawaiian Organizations, or Community Development Corporations authorized by 42 U.S.C.

9805 are not considered affiliates of such entities, or with other concerns owned by these entities solely because of their common ownership.

Affiliation may be based on stock ownership when (1) A person is an affiliate of a concern if the person owns or controls, or has the power to control 50% or more of its voting stock, or a block of stock which affords control because it is large compared to other outstanding blocks of stock, or (2) If two or more persons each owns, controls or has the power to control less than 50% of the voting stock of a concern, with minority holdings that are equal or approximately equal in size, but the aggregate of these minority holdings is large as compared with any other stock holding, each such person is presumed to be an affiliate of the concern.

Affiliation may be based on common management or joint venture arrangements. Affiliation arises where one or more officers, directors or general partners controls the board of directors and/or the management of another concern. Parties to a joint venture also may be affiliates. A contractor and subcontractor are treated as joint venturers if the ostensible subcontractor will perform primary and vital requirements of a contract or if the prime contractor is unusually reliant upon the ostensible subcontractor. All requirements of the contract are considered in reviewing such relationship, including contract management, technical responsibilities, and the percentage of subcontracted work.

Small organizations. The RFA defines "small organizations" as any nonprofit enterprise that is independently owned and operated and is not dominant in its field.

Small governmental jurisdictions. The RFA defines small governmental jurisdictions as governments of cities, counties, towns, townships, villages, school districts, or special districts with populations of less than 50,000.

5.3 What is a Substantial Number of Small Entities?

In determining the scope, or 'universe', of the entities to be considered in making a significance determination, NMFS generally includes only those entities, both large and small, that can reasonably be expected to be directly or indirectly affected by the proposed action. If the effects of the rule fall primarily on a distinct segment, or portion thereof, of the industry (e.g., user group, gear type, geographic area), that segment would be considered the universe for the purpose of this criterion. NMFS then determines what number of these directly or indirectly affected entities are small entities. NMFS generally considers that the 'substantial number' criterion has been reached when more than 20% of those small entities affected by the proposed action are likely to be significantly impacted by the proposed action. This percentage is calculated by dividing the number of small entities impacted by the action by the total number of small entities within the universe. The 20% criterion represents a general guide; there may be instances when, in order to satisfy the intent of the RFA, an IRFA should be prepared even though fewer than 20% of the small entities are significantly impacted.

5.4 What is a Significant Economic Impact?

NMFS has determined that an economic impact is significant for the purposes of the RFA if a regulation is likely to result in:

- more than a 5% decrease in annual gross revenues,
- annual compliance costs (e.g., annualized capital, operating, reporting) that increase total costs of production by more than 5%,

- compliance costs as a percent of sales that are 10 or more percent higher for small entities than compliance costs for large entities,

- capital costs of compliance that represent a significant portion of capital available to small entities, considering internal cash flow and external financing capabilities, or

- the regulation is likely to result in 2 or more percent of the small entities affected being forced to cease business operations.

Note that these criteria all deal with adverse or negative economic impacts. NMFS and certain other Federal agencies interpret the RFA as requiring the preparation of an IRFA only for proposed actions expected to have significant adverse economic impacts on a substantial number of small entities over the short, middle, or long term. Most regulatory actions are designed to have net benefits over the long term; however, such actions are not shielded from the RFA's requirement to prepare an IRFA if significant adverse economic impacts on a substantial number of small entities are expected in the short or longer term. Thus, if any action has short-term significant adverse impacts on a substantial number of small entities, even though it will benefit small entities in the long term, an IRFA must be prepared.

5.5 Affected small entities in the Atka mackerel Fishery

Companies. The actions being considered for the BSAI Atka mackerel fishery would have direct effects on fewer than 15 fishing vessels all of which are expected to be factory trawlers. In 1997, 12 factory trawlers participated in the BSAI Atka mackerel fishery and eight of these vessels accounted for 81% of the retained catch in that fishery. All of the factory trawlers in the Atka mackerel fishery are owned by seafood companies with annual receipts that exceed the $3 million threshold established by SBA for "small" fish harvesting businesses. The combined annual receipts for the companies involved in the Atka mackerel fishery are not known. However, based on the value of fish these companies harvest in Alaska, the annual worldwide receipts for the companies involved in the Atka mackerel fishery is estimated to range from $5 million to over $3 billion. In 1998, 1 percent of the Atka mackerel TAC in Area 541 (127 mt) was allocated to vessels using jig gear. However, as of September 12, 1998, NMFS has not received any Atka mackerel catch reports by vessels using jig gear in Area 541 and the entire 127 mt TAC allocation remains unharvested. Up to 10 vessels using jig gear had expressed interest in fishing for Atka mackerel in Area 541 and all of these vessels are "small" entities. However, the preferred alternative would exempt vessels using jig gear from the A-B season split, critical habitat restrictions, and VMS requirements. Therefore, all small entities using jig gear to fish for Atka mackerel would be unaffected by the proposed action.

Communities and groups. Because, very little BSAI Atka mackerel is delivered to on-shore processors and because the principal participants in this fishery are not residents of Alaska fishing communities, with the exception of the CDQ communities, few small communities would be affected directly. With the expansion of the CDQ program to include all BSAI groundfish and crab, the 50 plus CDQ communities would be affected by actions that affect the Atka mackerel CDQ. However, the effects on these communities are not expected to be significant because Atka mackerel is expected to account for less than 5% of the value of the CDQs to these communities, none of the actions would eliminate all of value of the Atka mackerel CDQs, and the CDQs are but one source of income for these communities. Nevertheless, to further reduce the potential impacts of this action on CDQ groups, the Council's preferred alternative would exempt CDQ groups from the A-B season split so that CDQ groups are not forced to fish small amounts of Atka mackerel CDQ during two separate time periods.

5.6 Small entities indirectly affected by the proposed action

A much larger number of entities would be affected indirectly if the proposed actions result in the factory trawlers, that have dominated the Atka mackerel fishery, switching effort from the Atka mackerel fishery to other groundfish fisheries. If the fishing capacity of the eight factory trawlers that were the core of the Atka mackerel fleet in 1997 were diverted to other fisheries, these vessels could take substantially larger shares of the catch in the BSAI rock sole, Pacific cod, flathead sole, or other flatfish fishery or the GOA flatfish fisheries. Much of any such increase in catch by the core Atka mackerel fleet would be at the expense of other factory trawlers in the BSAI and both catcher vessels and other factory trawlers in the GOA. In 1996, 67 factory trawlers participated in BSAI and GOA Pacific cod fisheries and 42 factory trawlers participated in the various BSAI and GOA flatfish fisheries. In 1996, 180 trawl catcher vessels participated in the Pacific cod fisheries of the BSAI and GOA and 62 trawl catcher vessels participated in the various flatfish fisheries of the BSAI and GOA. Due to inshore/offshore TAC allocations for Pacific cod in the GOA and TAC splits between catcher vessels and catcher processors in the BSAI, catcher vessels participating in the Pacific cod fishery will be unaffected if Atka mackerel factory trawlers shift into the Pacific cod fishery. However, catcher vessels fishing for flatfish in the BSAI and GOA could face impacts if effort shifts away from Atka mackerel as a result of this action. As explained in the RIR section of this document, the extent to which these shifts may occur is impossible to quantify or predict.

Most of factory trawlers operating in the BSAI and GOA Pacific cod and flatfish fisheries are owned by or affiliated with "large" entities. In addition, up to half of the catcher vessels fishing in the BSAI are believed to be owned by or affiliated with large entities. However, in a written comment to the Council submitted for this action, an industry representative for flatfish and Pacific cod factory trawlers indicated that more than 30 percent of the factory trawlers in the BSAI flatfish and Pacific cod fisheries expected 1998 annual gross revenues to be less than $3 million. NMFS does not have information to confirm or refute this figure. Furthermore, the ownership characteristics of these vessels has not been analyzed to determine if they are independently owned and operated or affiliated with a larger parent company. Because NMFS cannot quantify the number of small entities that may be indirectly affected by this action, or quantify the magnitude of those effects, NMFS cannot make a finding of non-significance under the RFA.

5.7 Measures taken to reduce impacts on small entities

The Council considered and adopted a series of exemptions to reduce the impacts of this action on small entities. The preferred alternative contains the following elements to reduce impacts on small entities

- Vessels using jig gear would be exempted from all aspects of the proposed action.
- CDQ groups would be exempted from the A-B season split to prevent having to fish for small Atka mackerel CDQ amounts during two times of the year.
- Vessels using hook-and-line gear would be exempt from the closure to fishing inside critical habitat. The critical habitat closures would affect vessels using trawl gear only.
- Both jig and hook and line vessels would be exempted from the VMS requirements contained in this action.

6.0 SUMMARY AND CONCLUSIONS

This regulatory amendment is intended to avoid significant competition between the endangered and declining western population of Steller sea lions and the Atka mackerel fishery in the Bering Sea and Aleutian Islands (BSAI) region. The amendment focuses on two main issues: 1) fishery-induced localized depletion of prey for Steller sea lions, and 2) the degree to which a known important prey item can be removed from Steller sea lion critical habitat without adversely modifying that habitat. Management concern about the potential for localized depletion has been expressed in previous ESA section 7 consultations on the BSAI Fishery Management Plan (FMP). The concern was initially based on the hypothesis that the species' decline is due to lack of available prey, which could be exacerbated by fishery-induced localized depletions of prey. Recent statistical evaluations of catch per unit effort (CPUE) at various sites in the 1990s have indicated that the Atka mackerel fishery has led to localized depletions of Steller sea lion prey (Fritz, unpubl., Appendix 1), thereby increasing evidence for competition.

The second issue is based on the statutory requirement of the ESA that Federal actions within the critical habitat of a listed species not jeopardize the survival and recovery of the species or adversely modify its critical habitat. The single most important feature of critical habitat for the Steller sea lion is its prey base. Since 1977, the portion of catch (prey) taken annually within Steller sea lion critical habitat has varied from 15% to 98%, with an average of 71%. A marked increase in the annual catch in the 1990s, and the high percent of the catch generally taken within Steller sea lion critical habitat has resulted in a marked increase in the amount (tons) of fish taken from areas considered essential to the recovery and conservation of the Steller sea lion, again increasing concerns that the fishery competes with Steller sea lions.

The amendment includes six different alternatives ranging from no change in management to voluntary dispersal of fishery effort by fishing participants. The other four alternatives are all based on time and/or area management of the fishery. None of these alternatives involves a reduction in TAC or a change to the manner in which the overall TAC is set. The key distinguishing features of these alternatives are 1) whether they involve a seasonal split, 2) whether they involve an apportionment of the TAC inside and outside of critical habitat, 3) the extent to which they use past commercial and scientific data to establish TACs for subareas and seasons, and 4) the number of TAC releases associated with each alternative.

Selection of the appropriate alternative must be based on an evaluation of whether or not each possible alternative meets the primary criteria of avoiding significant localized depletions and avoiding adverse modification of Steller sea lion critical habitat. Alternative 1 fails to meet either of these criteria. Alternative 2 would likely result in partial avoidance of localized depletion, but analyses suggest that such depletions would still occur. Alternative 2 also fails to reduce the proportion of the TAC removed from critical habitat. Alternatives 3 **(preferred)** and 4 are expected to meet both criteria. Alternative 5 may avoid localized depletion but does not reduce the proportion of the catch within critical habitat. And alternative 6 does not provide sufficient assurance that either of these criteria would be met.

The two key elements of the debate about this amendment pertain 1) to whether the Leslie depletion analyses provide a reliable indication of localized depletion (i.e., it has been argued that the data used and the analysis methods may be faulty), and 2) to determination of an acceptable level of removal from critical habitat (i.e., one that does not constitute adverse modification). With respect to the Leslie depletion analyses, both the data and analysis methods have been reviewed within NMFS and by outside scientists. The data appear to be the best available for this analyses and also appear to provide a good measure of CPUE. Methods of aggregating the data (binning) were criticized, but these methods should not have a significant effect on the general conclusions from the analyses. The assumptions of the statistical model may not be met perfectly, but perfect congruence of real data and statistical models is unrealistic given the complex nature of the problem under investigation. The pertinent question is not whether the assumptions are met perfectly, but whether any deviations from the assumptions of the model cause a meaningful change in the general conclusions. The evidence presented to date does not indicate such a meaningful change, and the conclusion of localized depletions is reasonable.

The second point of debate is the acceptable level of removal of a known prey item from critical habitat. The answer to this question is unknown. Atka mackerel are a known important prey item for Steller sea lions, the critical habitat areas where the fishery occurs are in close proximity to Steller sea lion rookeries and haulouts, and the best available evidence suggests that the decline of Steller sea lions is due to lack of available prey. An accurate, reliable description of the relations between Steller sea lions, Atka mackerel, and the fishery is not possible at this time due to limited information on Steller sea lion foraging and the spatial, temporal, and population dynamics of Atka mackerel stocks. Still, given the 80% decline of the endangered western population of Steller sea lions, and the requirements of the ESA, some judgement must be exercised about the removal of such prey from critical habitat. Alternatives 3 **(preferred)** and 4 include a reduction of prey in critical habitat, and therefore appear to be the only feasible alternatives at this time.

In June 1998, the Council selected alternative 3 (option 2) as the preferred alternative. Alternative 3 (option 2) requires the following:

- Splitting of the BSAI Atka mackerel fishery into A (1 January to 15 April) and B (1 September to 1 November) seasons,

- Reduction of the percent of the Atka mackerel Total Allowable Catch (TAC) taken from Steller sea lion critical habitat over a 4-year period in the western and central Aleutian Islands management districts as follows:

Minimum percent of annual Atka mackerel TAC taken outside of Steller sea lion critical habitat		
	Aleutian Islands District	
Year	Western (543)	Central (542)
Current	15	5
1999	35	20
2000	43	33
2001	52	46
2002	60	60

- Extension of the 20-nm trawl exclusion zone around Seguam and Agligadak rookeries in management district 541 to include both the A and B seasons,

- Installation of equipment for vessel monitoring (consistent with standards established in the final rule) for all vessels participating in the Atka mackerel fishery,

- Exemption of Community Development Quota (CDQ) fishing vessels from the A/B season split, but such vessels would still be required to adhere to percentage limits for fishing inside of Steller sea lion critical habitat,

- Exemption of the Atka mackerel jig fishery from these actions, and

- Annual review of the impact and effectiveness of these measures by the National Marine Fisheries Service (NMFS) and the Council. The Council also recommended that NMFS conduct research with other parties and industry to develop a research plan to determine effects of these management measures by area.

Based upon the foregoing analysis, NMFS cannot "certify" that the proposed action will not have a 'significant impact' on a 'substantial number' of small entities, as defined under the Regulatory Flexibility Act. Therefore, this document contains the required elements of an "Initial Regulatory Flexibility Analysis".

Cost data (including fixed and variable operating cost information) are required in order to perform a "net benefit analysis". Cost data for the BSAI groundfish harvesting and processing sectors are not currently available for use in this analysis. For this reason, a quantitative cost/benefit examination cannot be completed for the preferred alternative, nor can comparative net benefit conclusions be derived for the several competing alternatives and sub-options. Nonetheless, while changes in net benefits to the nation cannot be quantitatively determined, given that, 1) the ***total*** economic value of the Atka mackerel fishery varied from approximately *$38 million to $68 million* from 1995 through 1997 [Table 4.5] and, 2) the proposed action will not eliminate the fishery, nor even reduce the annual TAC, it is reasonable to conclude that the net benefit to the US economy would not decrease by $100 million annually, once all costs were included in the calculation. Therefore, the Council's preferred alternative does not constitute a 'significant' action, under E.O. 12866, recognizing that there may be distributional economic impacts among the various sectors of the groundfish industry.

5.8 Final Regulatory Flexibility Analysis

The analytical requirements of the Regulatory Flexibility Act (RFA) apply only to regulatory actions for which prior notice and comment is required under the Administrative Procedure Act. Public comments on this proposed regulatory amendment were invited from November 9, 1998, through December 9, 1998 (63 FR 60288, November 9, 1998). NMFS prepared an initial regulatory flexibility analyses (IRFA) which indicated that this action could have a significant impact on a substantial number of small entities under the RFA. Although most of the potential impacts of this action would affect entities other than small entities under the RFA, NMFS has insufficient data to precisely quantify the number of small entities that will be affected or the full extent of those effects. Therefore, NMFS determined that it could not certify that the action will not have a significant impact on a substantial number of small entities under the RFA and prepared this FRFA. This FRFA is comprised of the entire environmental assessment, regulatory impact review, the IRFA that was prepared for public review and the proposed regulation in September 1998, the preamble to the published proposed rule (63 FR 60288, November 9, 1998), and the final regulation publication in the Federal Register. The RFA requires that each FRFA contain:

- A succinct statement of the need for, and objectives of, the rule;
- A summary of the significant issues raised by the public comments in response to the IRFA, the agency's response to those comments, and a statement of any changes made to the rule as a result of the comments;
- A description and estimate of the number of small entities to wich the rule will apply;
- A description of the reporting, recordkeeping, or other compliance requirements of the rule; and
- A description of the steps the agency has taken to minimize the significant economic impact on small entities consistent with the stated objectives of applicable statutes, including a statement of factual, policy, policy, and legal reasons for selecting the alternative adopted in the final rule.

Need for and objectives of the rule. The problem statement, and the purpose of and need for the action are given in sections 1.1 and 1.2 of this analysis, respectively. The purpose and need for the action also is summarized in the preamble to the proposed rule.

Summary of significant issues IRFA raised in public comments. One letter of comment was received during the comment period on the proposed rule that raised significant issues in response to the IRFA. That comment is summarized and responded to in the preamble to the final regulation published in the Federal Register. No changes were made to the final rule as a result of that IRFA comments. The comment summary and the agency response follows:

> Comment 10. In the analysis presented to the Council, NMFS incorrectly determined that there were no small entities (pursuant to the Regulatory Flexibility Act (RFA)) affected by the management measures being developed. In the proposed rule, NMFS attempted to remedy this error by admitting that some impacted entities could be "small entities," as defined by the RFA. NMFS should have made this determination during development of the measures as it may have changed the outcome of the Council decision. Despite a current finding of significant impact on small entities, the analyses of impacts should have been prepared in conjunction with the development of proposed measures instead of in hindsight. NMFS continues to miss the point on impacts on communities in the AI that are by definition "small entities" by maintaining that the issue is impact on Community Development Quota (CDQ) communities. Dutch Harbor and Adak are not CDQ communities but are clearly small entities which depend heavily on income from services provided to vessels participating in the Atka mackerel fishery. Further discrepancy exists between the meaning of "small entity" as used in the analysis of impacts of the pollock inshore-offshore allocations developed at the same time as the analysis of Atka mackerel management measures.

Response. During the development of alternatives, NMFS prepared an analysis of the potential economic impacts of various Steller sea lion conservation measures. This initial analysis indicated that this measure would not result in significant economic impacts on a substantial number of small entities because most of the entities that would be directly affected by the measures were not considered "small entities" under the RFA. For fishing firms, a "small entity" would have receipts of less than $3 million dollars annually. The initial analysis indicated that catcher/processor vessels dominate the Atka mackerel fishery and these vessels did not appear to meet this "small entity" criterion. NMFS presented this analysis to the Council and public. Public testimony presented to the Council included comments on the impacts on small entities and challenged the tentative view that the conservation measures would not have a significant economic impact under the RFA. NMFS later determined that a definite certification of no significant impact on a substantial number of small entities could not be made due to a lack of empirical information. Therefore, NMFS prepared an initial regulatory flexibility analysis (IRFA) that was available for public review and comment at the time the proposed rule was published for public review. A final regulatory flexibility analysis (FRFA) was prepared for the final rule.

The Council process for recommending conservation and management measures is public and iterative, and designed to incorporate new information as it emerges through this process. Compliance with the RFA is primarily an agency responsibility. NMFS is satisfied that the public was adequately notified of the potential small entity impacts, and that the final agency decision to implement this rule has taken these potential impacts into consideration. For example, exemption of small entity jig gear vessels from the rule and the phased-in approach to reducing Atka mackerel catches within CH serve to mitigate economic impacts of the rule on all directly affected entities.

For purposes of the RFA, NMFS must identify small entities that are expected to comply with the rule, i.e. those that would be directly or indirectly regulated by the rule. For this rule, those small entities include those small businesses, small organizations, and small governmental jurisdictions as described in the FRFA (section 5.2). Although the fishing ports of Alaska are small entities, they are not regulated by this action. CDQ groups, on the other hand, are small entities that are directly regulated by this action. Most of the vessels that have participated in the Atka mackerel fishery recently have had total annual receipts in excess of $3 million, and few are small entities. Similarly, few of the factory trawlers in the BSAI pollock fishery should have been identified as small entities for the purposes of the IRFA for the inshore-offshore allocation (Amendment 51 to the FMP). For this action, a summary of the analysis of entities affected indirectly is presented in the preamble to the proposed rule. Due to public comment indicating that the rule could have adverse economic impacts on small entities, including governmental jurisdictions, and without empirical information to demonstrate conclusively that significant impacts on a substantial number of small entities would not occur, NMFS prepared an IRFA and FRFA for this action.

Description and estimate of the number of small entities. Sections 5.5 and 5.6 of this analysis, respectively, describe the affected small entities in the Atka mackerel fishery and the small entities indirectly affected by the proposed action.

Reporting, recordkeeping, or other compliance requirements. No new reporting, recordkeeping or other compliance requirements are imposed by this action. A plain language guide to compliance with this rule by affected small entities is published in the Federal Register preamble to the final rule as required by the Small Business Regulatory Enforcement Fairness Act of 1996.

Measures taken to minimize significant economic impacts on small entities. Section 5.7 of this analysis describes measures taken to reduce impacts on small entities. The reasons for selecting the alternative adopted and implemented by the final rule were that other alternatives (a) would not have been as effective in reducing the proportion of the annual Atka mackerel catch taken from within designated critical habitat to prevent potential jeopardy to the continued existence of the endangered Steller sea lion population and adverse modification of its critical habitat, as required by the Endangered Species Act, or (b) would have been unnecessarily burdensome on those entities affected by the action.

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8.0 AGENCIES AND INDIVIDUALS CONSULTED

8.1 Overview

Any detailed statistical analysis requires assumptions and decisions about analysis models and methods. The important question is not whether such assumptions/decisions are made, but rather how they affect the conclusions. Such assumptions/decisions were made in the Leslie depletion analyses completed by Fritz (in prep. Do trawl fisheries off Alaska create localized depletions of Atka mackerel (*Pleurogrammus monopterygius*)? Available National Marine Fisheries Service, Alaska Region, P.O. Box 21668, Juneau, AK 99802-1668, Attn: Tim Ragen). In the following pages, we provide the Sullivan and Hoenig/Kirkley reviews of that paper and our responses to the questions they raise. (These two reviews were completed under contract to the Groundfish Forum). Note that the paper reviewed by Sullivan and by Hoenig and Kirley included only analyses of fisheries at four sites, one of which is in the Gulf of Alaska. Subsequently, additional analysis have been completed for 37 time-area fisheries, with statistically significant reduction in CPUE in 16 cases. We also provide a review by Smith (contracted by the Alaska Fisheries Science Center) which includes some re-analysis of the data.

The Groundfish Forum requested that an explanation of the Sullivan and Hoenig/Kirkley reviews be included in this document. The following is excerpted from a letter to Richard Lauber from John Gauvin, dated April 28, 1998:

> "After discussing the above paper [the Fritz depletion paper] with some population dynamics biologists and statistics experts, Groundfish Forum arranged for two independent reviews of the paper to help resolve questions pertaining to the methods and applicability of the model for Atka mackerel. We contacted several NMFS scientists to obtain names of independent scientists with a great deal of experience with DeLury/Leslie models and statistical treatments of applications of these models. Although every scientist we contacted was willing to review the paper, only a few could do so within our narrow timeframe. The author of the first review was Dr. Patrick Sullivan, a population dynamics scientist employed at the International Pacific Halibut Commission. The second review was undertaken by the team lead by Dr. Hoenig from the Virginia Institute of Marine Science (VIMS). Dr. Hoenig recently came to VIMS from the Department of Fisheries and Oceans/Canada where he was responsible for conducting stock assessments employing both open and closed depletion models.

All reviewers were paid an hourly fee by the Groundfish Forum (at the standard for their profession) for time spent preparing the reviews. More importantly, all are willing to work with the industry and NMFS to resolve problems raised in the reviews and assist us in finding acceptable diagnostics for localized depletion so that the effectiveness of future measures can be evaluated."

8.2 Sullivan review

The following is the body of the Sullivan review, dated March 31, 1998.

Here are some comments on the manuscript entitled "Do trawl fisheries off Alaska create localized depletions of Atka mackerel (*Pleurogrammus monopterygius*)?" by L. W. Fritz as per your request.

The manuscript describes a Leslie-Delury type depletion analysis applied to commercial fishery data for Atka mackerel. My first impression of this work was that it was a conventional application of a method commonly used in assessing fish abundance. But, upon reviewing some related papers and in looking at statistical output

provided to the Groundfish Forum by the manuscript's author, I realized the analysis had several serious shortcomings that may misrepresent the conclusions drawn in answer to the title question.
First, the paper only presents analyses where statistically significant declines exist. On examining computer outputs (provided by the author to Groundfish Forum), I soon came to realize that there exist nearly twice as many other analyses (for the same study areas, for sometimes the same and sometimes different years) that show *no* significant decline in CPUE over the period of the fishery. In any paper addressing the question of the *significance* of depletion in an area, both the non-significant as well as the significant results should be shown for the areas and times surveyed. Without the uniform presentation and treatment of all the relevant data the reader will draw the biased conclusion that such analyses always show a decline, whereas in this case the majority of the data show no decline.

Second, although a decline over time is observed intra-annually for the data presented in the manuscript, the relative density of Atka mackerel appears to return to (or in some instances above) the nominal value by the following year (see any of the depletion figures accompanying the text). This would imply a decline locally (and only for certain times and areas), and not globally. How local this phenomena is, if it exists at all, becomes the central issue. The argument, made in the manuscript, is inconsistent on this, arguing first that the depletion is local (via the Leslie model) and then that it is more global (that is that mackerel are migrating in from adjacent areas, specifically sea lion habitat areas). If depletion is indeed local and movement to replace harvest is slow, then the local effect should not greatly affect adjacent areas. If, on the other hand, re-population is quick, then it is important to know from where the mackerel are recruited and whether this affects density globally. It is implied in the manuscript that re-population locally is slow, but that mackerel, when they are recruited, are recruited from the trawl exclusion zones.

There is no information in the manuscript to support this however. Historic fishing records (Fritz and Lowe manuscript), on the other hand, would seem to indicate that mackerel populations exist elsewhere (locally in deeper waters for example), which could easily provide an alternative source of new recruits to harvested areas. There is not enough information provided in the manuscript to address this critical point.

There are a number of other technical and biological issues that I think must play an important role and should be considered as well.

Based on data provided in the manuscript it appears that fishing occurred in and around the Atka mackerel spawning period during the years covered by the study. McDermott and Lowe (manuscript) have found that sex segregation occurs during the spawning period. As these authors note this likely could affect the results drawn from analyses conducted using trawl CPUE for this species. For example, the females may aggregate in areas accessible to the fishery as part of their spawning behavior. If they then depart as part of this same behavior, the result would be a decline in CPUE that is unrelated to fishery removals. And even if the decline is real it may only represent a portion of the population (i.e. only females) and thus not reflect the population as a whole. Furthermore, it appears that the females increase in size more dramatically than do the males during this time period (Fritz and Lowe manuscript). I speculate that this may in part be due to reproductive development. I am curious to what degree changes seen in CPUE (tons per effort expended) over the intra-annual time period reflect changes in individual size rather than changes in population size.

Another more technical issue is the process of pooling the data to form data points for the regression. This process appears to vary from one data set to the next depending upon the intensity of fishing in that area. This pooling of data to form regression points can affect trends and significance of outcomes, but to what degree it affects the conclusions drawn is not clear based on what was presented in the manuscript.

A bit off the central topic of the manuscript, it seems to me that the Steller sea lion population began its decline well before the Atka mackerel fishery began to build and during a time when the mackerel population remained steady or increased. If that is the case, then Atka mackerel may not be the limiting component of the system.

I hope these comments help to clarify some of the scientific and statistical issues raised by this manuscript. Please let me know if you require further comment or clarification.

Fritz, L. W. and S. A. Lowe. Seasonal distributions of Atka mackerel (Pleurogrammus monopterygius) in commercially-fished areas of the Aleutian Islands and Gulf of Alaska.

McDermott, S. F., and S. Lowe. The reproductive cycle and sexual maturity of Atka mackerel (Pleurogrammus monopterygius).

(End of Sullivan review.)

8.3 Responses to Sullivan review

(Reviewer's comment is given first (*in italics*), followed by the response.)

8.3.1 *"First, the paper only presents analyses where statistically significant declines exist."*

The paper never suggested that localized depletion occurred in every time-area fishery, nor did the paper suggest that such depletions occurred a certain portion of the time. The pertinent question was whether or not they occurred, and the paper and subsequent analyses show that they do. In all presentations of these analyses, the analyst (Fritz) has been careful to state the number of time-area cases evaluated and the number of significant cases. It should also be noted that simply because a regression was not statistically significant does not mean that depletion was not occurring. It simply means the data are not sufficient to demonstrate that depletion with 95% confidence.

8.3.2 *The manuscript argues inconsistently on local versus global depletion.*

The focus of the manuscript is on localized depletion. The manuscript discusses evidence for migration of fish into a fished area (based on a change in the size distribution of the catch at one site), and also discusses possible implications for larger areas. The manuscript does not attempt to make a case that global depletion occurs, but rather discusses the implications of movement into and out of the fished areas. This is not only reasonable material for a discussion section, but it pertinent to a consideration of further study to understand the implications of localized depletion.

8.3.3 *"It is implied in the manuscript that ...mackerel, when they are recruited, are recruited from the trawl exclusion zones."*

No such implication is made; Fritz only suggests the possibility. The manuscript states: "...since evidence suggests that Atka mackerel immigrated into the fished area, the area occupied by the original population and from which Atka mackerel were removed may have been larger than that actually fished and MAY HAVE (emphasis added) included areas inside trawl-exclusion zones."

8.3.4 *Large natural movements of aggregated females off the fishing grounds may have given the appearance of a decrease in CPUE. Also, the apparent decline may have been due to changes in body size with changes in reproductive status over time.*

In Alaskan waters, the spawning period is in July to October (McDermott and Lowe 1997). If all the time-area analyses occurred during that period, then these explanations could be possible. However, the time periods evaluated ranged from January to November (Fig. 17); i.e., over a wide range of time when it is unlikely that mackerel would be exhibiting a consistent movement off the fishing ground. Thus, these explanations would probably not be likely. In addition, it is difficult to imagine that a 80 to 90 percent decrease in CPUE could be accounted for by a change (decrease) in body size of the fish.

8.3.5 ***"...even if the decline is real it may only represent a portion of the population (i.e. only females) and thus not reflect the population as a whole."***

The population consists of males and females. A decline in the number of females must result in a decline in the population as a whole.

8.3.6 ***"The pooling of data to form regression points can affect trends and significance of outcomes, but to what degree it affects the conclusions drawn is not clear based on what was presented...."***

The pooling of data was an attempt to minimize the standard error about the regression line, while at the same time keep enough data points to estimate a reliable a regression line and use the most appropriate measure of effort and effect. This kind of pooling is done commonly. Regressions could have been conducted with the original raw data, but the original data was determined by definition. Fritz defined the unit of effort to be catch per hour. He could have chosen catch per haul, catch per day, or catch per week (all choices involve a decision by the analyst) and, in effect, these measures are similar in many respects to binning. However, using catch per haul would have added a great deal more variation to the data (i.e, hauls of 4 hours would, on average, be larger than hauls of 2 hours). Similarly, catch by day would add variation, as a day with 10 hauls would have more catch than a day with 5 hauls. The same kind of argument holds for catch per week. Fritz's method used the best measure of effort (catch per hour) and the best measure of effect (cumulative catch). His method was a reasonable attempt to tailor the analyses to the data available, and may have several positive effects on the analysis (i.e., may reduce heteroscedasticity and may reduce undue influence by outliers (a criticism of Hoenig and Kirkley). The regressions could be rerun with the raw data, but it is very unlikely that we would see significant changes in the results or conclusions.

The other pair of reviewers also raised this point, but also noted that "In general, but not always, aggregation of data over time typically provides more stable results and distinct temporal patterns." Those reviewers also stated that a very large set of aggregation schemes could be tested. In fact, Fritz tried a number of schemes in developing his method. But to argue that every combination should be tried is unrealistic, as the number of possible combinations is virtually endless. Again, the criteria used by Fritz (to minimize residual error about the regression while maintaining enough points to get a reliable regression) was reasonable.

8.3.7 ***The sea lion decline began before the fishery began to build. "If that is the case, then Atka mackerel may not be the limiting factor of the system."***

This proposed regulatory amendment is not founded on the assumption that the fishery was the cause of the decline. Nor is it founded on the assumption that the availability of Atka mackerel is the key limiting factor. Rather, it is founded on the fact that prey availability appears to be essential for recovery and conservation of the Steller sea lion, that Atka mackerel are known to be an important prey item for sea lions, that Atka mackerel occur predictably in waters proximal to sea lion rookeries and haulouts, and that fishery-induced localized depletion of Atka mackerel and removal of a significant portion of the catch from critical habitat may impede recovery.

8.4 Hoenig and Kirkley review

Executive Summary

This brief report provides a review of the analysis by Fritz (1998) "Do Trawl Fisheries off Alaska Create Localized Depletions of Atka Mackerel *(Pleurogrammus monopterygius)*?" We conclude there are numerous possible problems with the Fritz analysis. One of the more alarming problems, however, is the temporal aggregations considered. The temporal aggregation selected by Fritz may, in fact, be forcing the results. We simply cannot determine a reasonable basis for the different time periods considered in the study. We also find potential evidence of heteroscedasticity and serial correlation. Without a formal analysis of the data, however, we are unable to state whether or not heteroscedasticity and serial correlation are actually present. We also suggest that, although it is common practice to estimate the Leslie specification, used by Fritz, by ordinary least squares, the covariance between the error term and one of the right-hand side variables (one-half of current catch) does not equal zero; thus, the required conditions for obtaining best linear unbiased estimators are not satisfied. It is also highly advised that a full realm of regression diagnostics which include an analysis of influential data points be conducted. It appears that for some of the estimates, two observations are determining the statistical relationship. We also suggest that a Monte Carlo analysis, as recommended by Hilborn and Walters (1992, page 395), be conducted. Moreover, we recommend that additional analysis for an open population be conducted to better assess the possibility of depletion. There also is the problem that, for some areas, the confidence intervals for the estimated initial stocks are so large that it is erroneous to conclude localized depletion based on the results of Fritz. Last, we question the applicability of the analysis because of inconsistent results over different areas and different time periods. That is, the statistical results are significant for some areas and time periods but insignificant for other areas and time periods; it is particularly alarming when the estimates are significant for one area and time period but insignificant for the same area but a different time period. A remaining major issue is the appropriateness of using the fishery-dependent measure of resource abundance; Fritz provides no assessment of whether or not the CPUE is a realistic measure of abundance. Standardization of CPUE relative to area would provide a simple indicator of the appropriateness of the CPUE measure.

Introduction

The report "Do Trawl Fisheries off Alaska Create Localized Depletions of Atka Mackerel (*Pleurogrammus monopterygius*)?" by Fritz (1998) provides estimates of the initial standing stock of Atka mackerel for various Alaska resource/fishing areas. Based on the Leslie-Davis (1939) analysis presented in the report, Fritz concludes that in the Aleutian Islands, the fishery utilizes areas preferred by adult Atka mackerel and that these areas are replenished over time. Fritz also concludes, however, the estimates of the initial standing stock in one Gulf of Alaska area suggest that the local Atka mackerel population size decreased significantly from 1993 to 1994 and that the Gulf of Alaska population may be less resilient to exploitation than that in the Aleutian Islands. Last, Fritz concludes that the repopulation pattern of the Aleutian Islands could disadvantage Stellar sea lions and other Atka predators. In total, Fritz claims the Leslie regressions support the notion that local Atka mackerel biomass declined significantly over time in eight of the nine time-area mackerel fisheries analyzed.

Out of concern about the possible ramifications of Fritz's conclusions, the Groundfish Forum, Inc. requested Drs. Hoenig and Kirkley to review the report by Fritz. Initially, we provide an overview of the Leslie model. We next discuss the specification used by Fritz. We subsequently review the data and particularly the temporal aggregations used by Fritz. Regarding the statistical analysis, we consider the following potential problems: (1) implicit simultaneous equations bias caused by current catch appearing on both sides the Leslie equation; (2) the potential for heteroscedasticity because of dividing all variables by fishing effort or the large value of the independent variable (cumulative catch plus one-half of current catch) relative to the dependent variable (catch per unit effort); (3) the possibility of serial or autocorrelation; (4) the possibility of using a constrained nonlinear vs. unconstrained linear model; (5) the absence of a rigorous analysis of regression diagnostics (e.g., outliers, leverage values, and influential values); and (6) the apparently large confidence intervals for estimated standing stock of some areas. We also consider the possible need to modify the Leslie model to deal with recruitment and natural mortality; the paper provides no real evidence that the population is closed (no immigration and no emigration), which is a requirement for using a closed population depletion model.

Depletion Models

The peer-reviewed literature contains a wide array of possible depletion models as well as modifications of the DeLury and Leslie-Davis models (e.g., see Hilborn and Walters, 1992). The initial DeLury model is discussed in DeLury (1947 and 1951); the Leslie or Leslie-Davis model is discussed in detail in Leslie and Davis (1939). The two models are similar in that they both attempt to develop procedures for estimating the initial population and total standing stock of a resource. The Leslie-Davis model offered an approach for determining the absolute number of rats on a given area, and DeLury was specifically concerned with estimating the population of fish. The two procedures, however, are routinely applied to fish populations.

Hilborn and Walters (1992) describe the two approaches as depletion estimators. As per Hilborn and Walters (p. 391), "the concept behind depletion estimators is to examine how measured removals of fish influence the relative abundance of fish remaining in the total stock or in a designated depletion study area." The two approaches should provide similar estimates of the initial stock.

To use the Leslie model for closed populations (no new recruits or immigrants and no losses to natural mortality or emigration), Fritz, needed to assume:

$$N_t = N_0 - K_t$$

where K_t is the cumulative catch ($\sum_{i=1}^{T-1} catch_{t-i}$) taken prior to time t, T equals the total number of observations, and N_0 is the size of the population beginning of the period when $K_t = 0$. Now consider the conventional short-run model $Y_t = q\, N_t$, where $N_t = N_0 - K_t$. With the Leslie model, abundance, Y_t, may be measured in any way and completely independent of the fishing process that generates K (Hilborn and Walters 1992); Fritz measures resource abundance in terms of catch per unit effort (CPUE). The Leslie model does require the assumption that the value of q does not depend upon the level of effort. Thus, the Leslie model offers an extremely convenient framework, which does not require fishery-dependent estimates of resource abundance, for estimating initial stock abundance as well as determining whether or not resource depletion has occurred.

Fritz adopts the modified Leslie model to assess whether or not the resource has been locally depleted over time (Bratten 1969):

$$Y_t = qN_0 - qK_t$$

where Y_t equals catch per unit of effort, q is catchability, N_0 is the initial stock size when $K_t = 0$, and K_t equals lagged cumulative catch plus one-half of the catch at time t. Since the specification is linear, ordinary least squares is advocated by Fritz as the appropriate procedure to estimate the parameters and subsequently N_0.

Potential Caveats of the Conventional Leslie and DeLury Models

Hilborn and Walters (1992), Seber (1982), and Ricker (1975) indicate that both the Leslie and DeLury estimates of q and N_0 are approximately unbiased provided all fish are equally vulnerable to fishing, K and E are measured exactly, and the value of q does not depend upon the level of effort. Hilborn and Walters (p. 395) also indicate that "there is much practical and Monte Carlo simulation experience to indicate that the estimates must be treated with considerable care." More important Hilborn and Walters (p. 395) offer the following advisory note: "Warning: Be sure to estimate the reliability of depletion estimators by Monte Carlo methods for your specific problem." Fritz provides no Monte Carlo or sensitivity analysis of the estimates. Hilborn and Walters and Ricker (1975) all point out that errors in measurement of the independent variable (K or E) cause the estimate of q to be biased downward and N_0 to be over estimated. Depletion may thus appear to be more significant that it is actually. They also suggest that extreme bias in the estimates of q and N_0 may occur if catchability is not constant; alternatively, q should decline progressively as depletion proceeds. In this latter case, the estimate of q may be biased upward and the estimate of N_0 may be biased downward. Subsequently, the depletion estimate of N_0 may be too low. Fritz concludes that catchability is not believed to be changing. There is, thus, support for suggesting that the estimates indicate a greater depletion than might actually have occurred.

Data

Fritz uses catch and effort data obtained from the National Marine Fisheries Service Observer Program. Data collection procedures appear to conform to conventional sampling procedures. There appear to be some inconsistencies, however, in the manner in which catch and effort were aggregated over time. For some areas and years, catch and effort data are analyzed relative to a weekly period. In other cases, catch and effort data are specified relative to a wide variety of time periods (e.g., 1.75 days, 3.5 days, 0.5 days, etc.).

The time periods over which data were aggregated appears to be quite arbitrary. The only rational given for the aggregation was to ensure that there were at least ten hauls of data for each period and at least four periods of observations for each analysis. The notion of having ten observations appears to be related to Hilborn and Walter's recommendation that an experiment should be carried out for at least 10 time periods.

Ten observations according to Hilborn and Walters should be sufficient to permit examination of the depletion regression when catchability is not constant. Fritz does not, however, provide a rigorous analysis of the stability or possibility of changing regression estimates; a simple statistical test (F-test) over different time periods is all that is necessary to examine whether or not catchability is changing over time.

If one wanted to follow some statistical protocol, it might be argued that data should have been aggregated such that at least 30 hauls were included and 30 observations were available for analysis; a large sample, which is usually desired, is 30 or more observations. The number of observations only has to equal three; three observations allow the two parameters to be estimated and to have one degree of freedom upon which to base all statistical tests. Alternatively, it would make sense to use daily data in order to have a consistent set of observations.

Without reestimating the Leslie model for all areas and relative to all selected and possible time periods, the ramifications Fritz's selected time periods for the results are unknown. In general, but not always, aggregation of data over time typically provides more stable results and distinct temporal patterns. Alternatively, the influence of extreme data values may be masked by temporal aggregation.

Statistical Analysis

Potential Simultaneous Equation Bias: Although we suggest that the results suffer from implicit simultaneous equation bias, the actual problem is that an endogenous or dependent variable appears on both sides of the estimating equation. Bratten (1969) originally proposed adding one-half of the current catch, as done by Fritz, to compensate for the discontinuity in catch by treating the catch as if it was from the center rather than the end of the time interval. Alternatively, the Bratten approach was offered as one possible way to avoid losing an observation which might be serious when the number of observations are few.

Kelejian (1981, p. 242), however, shows that the covariance between the regressor, lagged cumulative catch plus 0.5 x $catch_t$ in the Fritz study, and the error term, u_t, does not equal zero. As a consequence, estimates of the slope (catchability coefficient, q, in Fritz) and the intercept--product of catchability and initial standing stock, q N_0 in Fritz--are not unbiased, minimum variance or efficient or even consistent. Results of statistical tests based on the normal distribution are, therefore, inappropriate (e.g., the significance of the regression, all t-tests, and all similar parametric tests requiring normal or asymptotic normal distribution). As shown by Kelejian, the estimate of the slope coefficient, q in Fritz, may be biased downward which leads to N_0 being overestimated. This is the same problem identified by Hilborn and Walters and Ricker (1975). It is, thus, possible that the empirically determined pattern of depletion, as obtained by Fritz, may be more severe than it appears. Hilborn and Walters and Ricker (1975), however, suggest that *nonconstant* catchability may cause a more severe bias in the estimate--they suggest that depletion estimates of N_0 may be too low.

Possible Heteroscedasticity: Although heteroscedasticity typically does not pose a problem when time-series data are used, it is possible that the estimates presented in Fritz suffer from heteroscedasticity or the case of nonconstant residual variance. While heteroscedasticity does not pose a problem for bias, its presence prevents the estimates from being minimum variance or efficient. A consequence of heteroscedasticity is erroneous conclusions regarding hypotheses (e.g., significant regression when results are actually not significant and inappropriate confidence intervals).

The issue of heteroscedasticity relates to the formulation of the Leslie model and the use of fishery-dependent data, $catch_t/effort_t$. The formulation used by Fritz specifies abundance to be a function of the initial standing stock, cumulative catch plus one-half of current catch, and catchability. Following DeLury (1951), catch may be specified as a function of catchability, initial standing stock, cumulative catch, and effort:

$$catch_t = q\, N_0\, effort_t - q\, K_t\, effort_t$$

Adding an appropriate error term and subsequently dividing by effort imposes heteroscedasticity. Regardless of the traditional catch formulation, heteroscedasticity might also be possible because the right-hand side regressor, lagged cumulative catch plus one-half of current catch, is quite large relative to catch per unit effort--a common problem which often results in heteroscedasticity.

In empirical work, it is quite common to provide results of tests for heteroscedasticity. Fritz provides no analysis of heteroscedasticity. A review of graphs for the various resource areas suggests that heteroscedasticity may be a problem relative to the following area estimates: (1) Kiska-1995; (2) Delarofs-1992; (3) Akutan-1991; (4) Seguam-1992--but inversely related to right-hand-side regressor; and (5) Buldir W-1996. Without *formal testing* for heteroscedasticity, it is problematic as to its presence and severity.

Serial or Autocorrelation: Autocorrelation is simply the case in which the value of the disturbance term in one period is related to the value of the disturbance term in one or more previous periods. If autocorrelation is present, parameter estimates obtained from ordinary least squares regression are not efficient, and inference based on the least squares estimates is adversely affected.

Fritz's paper provides no statistical results of an analysis for serial correlation. Instead, all results are available in separate analysis. The separate analysis, however, also contains no results of tests for first or nth order autocorrelation. A review of the residual plots available in Fritz's report suggests that serial correlation may be present for the following estimates: (1) Kiska-1995; (2) Petrel Bank - 1994; and (3) Seguam-1993. Examination of the residual plots in the separate analysis indicates that serial correlation may problems for the estimates of the following resource areas: (1) Kiska--1994 and 1995; (2) Kiska--1996 A and 1997; (3) Delarofs April 1994; (4) Delarofs 1997; (5) Akutan-1991; (6) Amchitka W-1996; (7) Amchitka E-1997; (8) Amchitka E-1995; (9) Seguam-1993 (all vessels); (10) Seguam-1994; (11) Seguam-1996 A; (12) Seguam-1996 B and 1997; (13) Buldir W-1997; and (14) Buldir E-1996 B. Unfortunately, we cannot determine whether or not autocorrelation poses a problem without an extensive analysis of all estimates.

At a minimum, all estimates should be examined for at least first-order autocorrelation. The author may use the Durbin-Watson statistic to test for first-order serial correlation; this statistic is typically available on ordinary-least-squares regression packages. Alternatively, other tests such as the Ljung-Box and Breusch (1978)-Godfrey (1978) tests may be used to examine serial correlation.

Linear vs. Nonlinear Model: While it is common practice to estimate the Leslie model via ordinary least squares and the assumption that all parameters are linear, it is possible that the specification may be nonlinear as well. An alternative specification and estimation is the nonlinear model in which q and N_0 are estimated separately, but q is constrained to be equal in the intercept term and the slope. With the limited number of observations in the study data set, it may not be possible, however, to obtain estimates via a nonlinear specification.

Regression Diagnostics: It is now common practice by statisticians and applied researchers to conduct regression diagnostics of estimates. Belsley et al. (1980) provide an extensive array of methods for identifying influential data points. The Fritz report and study provides no regression diagnostics; given the limited number of observations available to Fritz, it is highly likely that one or two data points may have significantly influenced the parameter estimates.

Two common measures for determining influential data points are studentized residuals and leverage values. These two measures are available in most statistical packages. The studentized residual is actually a standardized residual which permits determination of an influential data point; values in excess of 1.96 or 2.00 suggest observations deserving additional examination. The studentized residual permits the determination of the possibility of an influential y value. In contrast, leverage values, which also permit determination of influential data points, indicate influence relative to x variables.

A review of the plots contained in Fritz's report and separate analysis suggest that influential data points may be forcing several of the statistical results (e.g., last data point in Delarofs-1995 and 1997; first and last point in Amchitka W-1996; and first two data observations and last observation for Seguam-1992). Without conducting a comprehensive analysis of all resource areas and time periods, it cannot be stated, a priori, whether or not there are influential data points.

Using the 1992 data for Seguam, one outlier was determined to characterize the data. The outlier value corresponded to week number 7. Reestimating the same model of Fritz, the initial standing stock was estimated to equal 42,652 rather than 44,535 as obtained by Fritz. While the difference is only 1,883 metric tons, the level of significance of the regression is quite different. Moreover, the results without the outlier suggest that depletion was considerably lower than indicated by Fritz. Fritz's estimates are significant only at the 5% level of significance; they are not significant at the one percent level of significance. With the one observation deleted from-the estimation, the regression was determined to be significant at the one percent level of significance.

Another potential problem is that the estimated parameters may not be stable over time. Fritz provides no analysis of parameter stability (e.g., F or Chow tests or cusum and cusum-squared values). Although these are not "fool-proof" tests, they are usually reliable indicators as to whether or not parameters have changed over time; such tests would be particularly useful for testing the assumption of constant catchability over time which is a required assumption of the analysis.

Confidence Intervals for Initial Standing Stock: Perhaps the most alarming result of the Fritz study is the extremely large confidence intervals for the estimated initial standing stock. The large confidence intervals raise the issue of the usefulness of the estimates. The 95% confidence intervals are extremely large for the following resource area and time estimates: (1) Petrel Bank-week 32-37, 1993; (2) Petrel Bank-week 37-41, 1993; (3) Seguam Bank-week 3-15, 1992; (4) Seguam Bank-week 3-10, 1993; (5) Seguam Bank-week 3-9, 1993. Values corresponding to the 95% confidence intervals are extremely large and suggest, in many cases, the cumulative catch was very high relative to the standing stock, or alternatively, the total cumulative catch was minuscule compared to the initial standing stock (e.g., Seguam in 1992 has a cumulative catch of approximately 29,000 metric tons, but the initial standing stock might have been as high as 373,272 metric tons; the initial standing stock also may have been lower than the total cumulative catch, which suggests recruitment and/or growth).

Consistency of Results and Verification of Approach

Although the aggregation of observations over time presents a potentially serious problem for verifying the results and the applicability of the approach of Fritz, the fact that estimates are consistent for some areas and time periods and not consistent for other areas and time seriously calls into question the veracity of the results and the use of the approach. There is no basis for suggesting localized depletion in one area and time period, but not in the same area and another time period when the area was fished at similar levels of prosecution during both periods. Alternatively, such results may be possible, but Fritz fails to offer any explanation.

Examples of significance and nonsignificance for the same area over different time periods include the following: (1) Kiska 1994 (possibly significant) vs. Kiska 1995 (nonsignificant); (2) Kiska with some hauls (not significant) vs. Kiska with other hauls (significant); (3) Delarofs--not significant for most years and significant for 1996; (4) Amchitka W--1995 (not significant), 1996 (significant), 1997 (significant); (5) Amchitka E--1995 (not significant), 1996 (significant), and 1997 (significant); and-(6) Seguam--1994 (not significant), 1995 (significant), 1996 (not significant), and 1997 (not significant). We also find similar patterns of significance and nonsignificance for the other resource areas over time.

Closed and Open Population Model

Hilborn and Walters (1992), Chien and Condrey (1985), and Collie and Sissenwine (1983) all call into question the appropriateness of assuming a closed population. All suggest that immigration in the form of recruitment and emigration (e.g., natural mortality) likely occur for many fishery resources. The data plots contained in the report and the separate analysis, in fact, suggest that recruitment may be quite significant for some areas. The effect of recruitment is to lower the slope and lower the intercept; thus, N_0 may be overestimated and the decline in abundance may be underestimated. In addition, it is difficult to accept that natural mortality equals 0.0 for all areas.

Chien and Condrey (1985) offer one approach for estimating the initial stock when natural mortality is not negligible. They include variables to consider natural mortality or the case in which the ratio of natural mortality to fishing effort is relatively constant. Hilborn and Walters also offer several alternative approaches for estimating depletion in an open population. The various approaches should be further explored for examining the possible localized depletion of Atka mackerel.

Additional Concerns

Besides the statistical and closed vs. open population concerns previously discussed, there are some additional aspects of the analysis which raise concerns. There is the possible issue of standardizing q and abundance relative to area to determine if the data even make sense. If after standardizing abundance, catch per unit effort, for area, it appears that Atka mackerel are so dense they could be walked on, there would be considerable reason to doubt the usefulness of CPUE as a measure of abundance. Fritz provides no discussion about whether or not the fishery-dependent measure of abundance is appropriate.

Then there is the issue of variability in q over time and over different areas. Catchability, q should be independent of effort but, of course, may vary by area. However, if q were standardized for area, the value of q should be relatively homogeneous over different areas. Fritz provides no analysis of the values of q.

Conclusions

The analysis by Fritz appears to have numerous possible problems. First, there is the problem of data aggregation over time. Fritz provides only a tenuous reason for selecting periods of different lengths. Second, there is the possibility that estimates are biased, inconsistent, and inefficient; this is caused by the use of catch on both sides of the equation. Third, there is a possible problem of heteroscedasticity which causes the parameters to be inefficient and inconsistent, and may lead to erroneous conclusions based on conventional parametric tests. Fourth, there is the potential problem of serial correlation which also causes estimates to be inefficient and can lead to erroneous conclusions. Fifth, the analysis provides no regression diagnostics, particularly with respect to influential data points. Plots of the data for the various resource areas and time periods suggest that many estimates may be subject to influential data points (e.g., only one or two observations are giving the fit and mathematical relationship between abundance and cumulative catch). Sixth, the extremely large confidence intervals seriously undermine the usefulness of the models and the conclusions about depletion. Seventh, the results relative to resource areas and different time periods are inconsistent in that statistical results are significant at the five percent level of significance for some years or time periods and not other years or time periods. Last, the analysis by Fritz assumes a closed population, which simply may be incorrect; alternative models for dealing with an open population have been proposed Hilborn and Walters and should be further developed to more precisely examine whether or not there has been localized depletion. Last, we concur with Hilborn and Walters that analysis of depletion should include a rigorous Monte Carlo analysis.

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[End of Hoenig and Kirkley review]

8.5 Responses to Hoenig and Kirkley Review

8.5.1 *"One of the more alarming problems, however, is the temporal aggregations considered.... We simply cannot determine a reasonable basis for the different time periods considered."*

The time periods were determined by the dates and size of the fishery. Fritz did not have control over when these fisheries occurred. See response **8.3.6** under the Sullivan review.

8.5.2 *"... potential evidence of heteroscedasticity."*

Simply put, heteroscedasticity means that there is a greater spread of points around one part of the regression line than there is around another. There is some evidence of heteroscedasticity in the raw data, but as the reviewers themselves point out, " . . . heteroscedasticity typically does not pose a problem when time-series data are used . . . ." Furthermore, heteroscedasticity might be expected, in that CPUE (the Y variable in the regressions) is bounded by a lower limit (zero) and the lower limit is likely to be more of an influence the longer a fishery goes on. The linear regressions are based on binned data, and the process of binning indirectly reduces the amount of heteroscedasticity. The reviewers suggest that because of the potential for heteroscedasticity, the estimates may not be minimum variance or efficient. What does that mean? It simply means that the estimates may have a variance that is not the smallest possible under theoretical considerations, and that another method may give a smaller variance. The reviewers then go on to suggest that erroneous conclusions can be made regarding hypotheses, and they parenthetically give the example of assuming that regression results are significant when they actually are not, and giving inappropriate confidence limits. The reviewers fail to mention that heteroscedasticity can also result in the erroneous conclusion that a regression is not significant when, in fact, it is. But most importantly, the reviewers are essentially providing highly technical descriptions of all the potential defects of this analysis, but failing to give an indication of how severe they think these possible defects are. The fundamental question here is whether the results of the Leslie analyses provide a reliable indication of localized depletion, and the reviewers approach is to give all the theoretical reasons why this is not a perfect analysis. Clearly, it is not a perfect analysis - real data rarely meet all the requirements of statistical models perfectly.

8.5.3 *Serial or autocorrelation.*

The essence of this comment is that the catch at time t is likely to be related to the catch at time t+1 (or perhaps t+2, and so on). That is, consecutive (or near consecutive) catches may not be independent of each other. This specific problem has been examined by an outside consultant from UC Davis (see the review by Smith below), who tests for serial correlation, concludes that it is not a problem, and also finds strong evidence for significant reductions in CPUE. Here, too, the process of binning tends to reduce any effect of serial or autocorrelation.

8.5.4 *". . . the required conditions for obtaining best linear unbiased estimators are not satisfied."*

This is not an all or none concept. If, for example, a fishing vessel pulled in a haul which was 99.99% pollock and 0.01% cod, it would technically be incorrect to call this a "pure" haul of pollock. Nevertheless, the expression "pure haul of pollock" would provide a realistic and practical description of the haul. Here, the reviewers are making the same kind of technical distinction. That is, they are suggesting that the analysis conducted does not meet the assumptions of a parametric statistical model (based on a normal distribution), and therefore is inappropriate. Again, with any analyses, the data likely violate the assumptions of the statistical model to some degree. One can always point out defects in a statistical analysis simply because they represent simplistic models of a complex real world. The important question is whether these "violations" have a significant effect on the conclusions, and there is no indication that such is the case.

8.5.5 *Regression diagnostics should be run.*

Diagnostics are important and may indicate that, for example, the data in one time-area fishery could be better described by a nonlinear model (i.e., a straight line may not capture the pattern of the data as well as a curving line). However, that doesn't necessarily mean that the linear results are wrong. Unless diagnostics indicate serious defects with this application of the statistical model, the linear approach is still a valid method for describing significant declines in CPUE over the course of a fishery. The choice of a statistic model (e.g., linear versus nonlinear) may involve a trade-off. For some fisheries, a nonlinear model may provide a very good representation of the data, but the same model may be a poor representation in other cases. The linear model may not be the best model for every case, but it may provide a more general and consistent approach for a large set of time-area fisheries. Certainly other models should be investigated, but the potential utility of other models does not invalidate the use of the linear model or make it any less indicative of a localized depletion.

8.5.6 *The confidence limits for initial biomass are sometimes so large that it is erroneous to conclude localized depletion based on the results of Fritz.*

The confidence limits for estimates of initial biomass are not the best indicator of a significant decline. The question of significant decline in CPUE is addressed by standard statistical evaluation of the slope of the line, not confidence limits on the x-intercept. Normal regression techniques were applied and are valid. Where confidence limits for initial biomass are wide, then estimated initial biomasses should be used with caution. Such caution does not, however, invalidate the regression statistics pertaining to the slope of the line. Smith (below), addresses the issue of confidence limits using a Taylor series approach. Finally, it should be noted that while the confidence limits may appear large, they are small compared to the survey biomass estimates for each stratum, or for the entire Aleutian Islands region.

8.5.7 *Consistency of results - "... we question the applicability of the analysis because of inconsistent results over different areas and different time periods."*

Fish stocks exhibit variability. The environment in which fish stocks occur also exhibit variability. In fact, multiple sources of variability may influence the results in a given year at different sites, or at the same site in different years. The reviewers refer to this outcome as alarming, but it should not be. The outcome simply means that we have limited ability to predict when such depletions will occur due to variation in fish stocks and their environment. However, in spite of variability in the environment and in the fish stocks (see biomass estimates above) the results were consistent in one important respect: significant declines in CPUE were consistently associated with the largest removals from an area over the series of years analyzed. Lower catch levels apparently did not reduce the local population enough to result in CPUE declines.

8.5.8 *"If after standardizing abundance, catch per unit effort, for area, it appears that Atka mackerel are so dense they could be walked on, there would be considerable reason to doubt the usefulness of CPUE as a measure of abundance. Fritz provides no discussion of whether or not the CPUE is a realistic measure of abundance."*

Fritz does not provide a discussion of CPUE as a measure of abundance, but the whole point of his argument is that Atka mackerel are not so dense that they could be walked on. This conclusion is reinforced by the finding that CPUE declines significantly in certain areas as a result of the fishery. Measuring abundance has always been part of the fishery problem, but managers of marine fisheries can still use reason. Managers of marine fisheries rarely have cases where CPUE is such a good indicator of a local stock. These stocks are found in the same locations over time, the fishery occurs in the same areas and over short periods of time, and the fishery methods are probably relatively consistent from site to site and time to time. All these conditions indicate that CPUE is probably a relatively good indicator of relative abundance.

8.5.9 *CPUE should be standardized relative to area.*

The reviewers seem to be suggesting that the relationship of CPUE to area should be relatively constant. This is not necessarily true, and there are good arguments to the contrary. The apparent distribution of Atka mackerel indicates that they have specific habitat requirements. The extent to which different areas (i.e., Seguam versus Kiska) meet those habitat requirements may vary considerably, in which case fewer fish may be found in the habitat of lesser quality. Thus CPUE could vary considerably from site to site, and the relation between CPUE and area would not be constant.

8.5.10 ***Potential Simultaneous Equation Bias - "Implicit simultaneous equations bias caused by current catch appearing on both sides of the Leslie equation."***

This is a potential problem, but probably not serious as used in these analyses. Fritz needed some measure of the effect of fishing on an area. "Catch" from a given haul is used to estimate both CPUE (catch per hour - the dependent variable) and cumulative catch (sum of all catches to that point in the season - the independent variable). So catch appears on both sides of the regression (or on both axes of the graphs). Cumulative catch is, I think, the best measure of the ongoing effect of the fishery on an area. Fritz could have avoided this problem by using haul number, for example, for his x-axis variable. The same results would almost certainly be apparent. But haul number might not be quite as good an indicator of the previous effect of the fishery because of the observed variation in CPUE. This would be a more serious problem if catch appeared as a divisor on one side of the equation, but as it is used, should not be considered an important problem.

8.5.11 ***The reviewers raise questions about the assumptions of catchability being independent of effort, catch and effort being measured with minimal error, and all fish being equally vulnerable to fishing.***

Fritz discusses these assumptions. Catch and effort should be measured without significant error - this is the responsibility of the fishery participant. The question of equal vulnerability to fishing and constant catchability are reasonable assumptions that will be difficult to evaluate given the data available. The reviewers suggest a simple F test would be sufficient to look at equal catchability and this method will be investigated. The reviewers also point out that any failure of these assumptions could, in fact, also lead to an underestimation of depletion.

8.5.12 ***Fritz provides no Monte Carlo or sensitivity analysis of the estimates.***

Fritz has tested the sensitivity of the results to using different aggregation schemes, different numbers of boats to measure CPUE, and different amounts of data (i.e., cutting the season in half to see if the same results occur - they do). Monte Carlo simulations would be an interesting follow-up on this study, and Smith (see the review below) used such simulations to examine confidence limits and regression assumptions. These simulations are generally useful for estimating variances in regression parameters and examining regression assumptions.

8.5.13 ***"The time periods over which data were aggregated appears to be quite arbitrary."***

As stated in response to the Sullivan review (point **8.3.6**), the aggregation of points was an effort to limit residual variance while at the same time provide sufficient points to estimate a regression line. Note also that the reviewers themselves state "In general, but not always, aggregation of data over time typically provides more stable results and distinct temporal patterns." Also, the reviewers suggest another aggregation scheme might be to pool all the data so that only three points are available for estimating the regression line. But they also point out the potential problem of outliers or points with potential undue influence, and with three points, the regression is extremely sensitive to each point. That is, unless all three points lined up, any one of the points could be considered an outlier. Appendix provides results of different binning schemes

8.5.14 ***Closed versus open populations.***

The reviewers suggest that there is some question about the assumption of a closed population. Fritz has never suggested that these were closed populations, but only that their distribution and dynamics lead to a good approximation of closed populations. He discussed in detail the possibility of immigration and emigration, and provided evidence for limited immigration in one case. The reviewers suggest that the evidence indicates that recruitment may be quite significant in some case but, again, the only real evidence is the case where size structure of the catch changed. Whether the apparent depletions of mackerel are due to mortality or scattering as a result of fishing, they may still have a serious impact on sea lion foraging success.

8.6 Smith Review

Martin Smith of the Department of Agriculture and Resource Economics, University of California Davis, provided the following review.

I have been asked to investigate the statistical properties of Leslie regressions that are used to infer local populations of Atka mackerel in several Alaskan fishing areas. This paper first explores the use of catch per unit effort and cumulative catch to estimate catchability and the pre-fished population, as outlined in Fritz (1998, p. 5). Then it presents two alternative estimation techniques and describes results from twenty-six regressions for each alternative. A discussion of time series properties follows along with calculations of autocorrelation diagnostics and first-order autoregressive model estimations. The paper concludes with a discussion of potential improvements in the analysis from use of disaggregated data.

The Leslie Model

The basic Leslie model presumes a deterministic relationship and forwards a linear regression of the model:

$$\frac{C_t}{f_t} = qB_0 - qK_t$$

where C_t is current catch, f_t is effort, q is catchability, B_0 is underlying biomass, and K_t is cumulative catch (including one half of current catch). If the assumption of complete deterministic behavior is relaxed, catch per unit effort (CPUE) is a random variable. As such, an initial estimating equation would be:

$$\frac{C_t}{f_t} = qB_0 - qK_t + e_t$$

where e_t is a an error term with mean of 0 and variance σ^2. Ordinary least squares estimation of this equation leads to biased and inconsistent results due to the correlation of an explanatory variables with the error term. To see this, simply note the form of Kt:

$$K_t = C_t/2 + C_{t-1} + C_{t-2} + \ldots + C_0.$$

Now substitute for C_t on the right-hand side, and notice that K_t includes a function of the current error term e_t[1]. This problem is known generally in econometrics as endogeneity.

[1] The technical proof of inconsistency amounts to showing that plim **X'e** is not zero. **X** in this case is a two column matrix, the first column being a vector of ones and the second column being data on K.

By substituting the definition of K_t into the OLS slope coefficient formula, it is possible to sign the bias that results from the endogeneity problem. Making this substitution and taking the mathematical expectation, I find the following expression for bias:

$$bias = \frac{1}{2}\left(1-\frac{1}{n}\right)\sum_{t=1}^{n} f_t \sigma^2$$

where n is the number of observations. Since effort (f_t) is always positive, the bias is positive. Since we expect the slope to be negative, the bias will on average lead to a slope estimate that is less negative and hence smaller in magnitude. This, in turn, will lead to overestimates of initial biomass on average when OLS is used and cumulative catch includes one half of contemporaneous catch. An important caveat is that these comments involve the properties of estimators in repeated sampling; they neither imply that every estimate of the slope is higher than it should be nor that every biomass estimate is higher than it should be.
There are two possible remedies for the endogeneity of current catch. The standard approach to solving endogeneity problems in econometrics is to apply an instrumental variables procedure such as two-stage least squares. Another approach to treating endogeneity is to modify the definition of K_t so that it excludes contemporaneous catch[2]. This approach differs from Ricker (1975) and Gunderson (1993) but is consistent with Hilborn and Walters (1992). I will focus on this second method and will run instrumental variables regressions to see if results are greatly different.

Instrumental Variables

Instrumental variables techniques solve the problem of endogeneity by replacing the endogenous regressor K_t with an estimate of K_t based on an auxiliary regression of K_t on exogenous variables that are not correlated with the current error term. The difficulty with this approach is finding adequate instruments, i.e. finding other variables that are highly correlated with K_t but that are uncorrelated with e_t. One candidate instrument is lagged cumulative catch. If there is no autocorrelation in the error term, lagged cumulative catch will be uncorrelated with the error and instrumental variables estimates will be consistent. If there is autocorrelation, then the resulting estimates will still be inconsistent.

Two-stage least squares regressions for Seguam 1992 and Kiska 1994 show results that are similar to those of Fritz (1998). The inferred pre-fished populations of mackerel for these regions are 47,500 for Seguam and 28,687 for Kiska, compared to original estimates of 44,535 and 22,467. All two-stage least squares regression results are reported in Table 8.1[3]. In twenty-six total regressions, the slope coefficient is significant (at the 10% level or better) in seventeen regressions and has the expected sign of negative in all of the significant regressions but Amchitka West 1997. These findings provide strong evidence of a negative relationship between CPUE and cumulative catch. An interesting note is that the slope coefficient has the expected sign in seven of the nine regressions for which the slope coefficient is not significant. These results are also suggestive of a negative relationship between CPUE and cumulative catch.

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[2] From an econometric point of view, the justification for this could only be that the true model excludes current catch.

[3] For both the instrumental variables (in Table 8.1) and OLS regressions that are summarized in Table 8.2, a single regression appears for Seguam 1996, Kiska 1996, Buldir East 1996, and Delarof 1994. For each of these region/year pairs, the data were aggregated within the year. Fritz separates each of these region/year pairs into two separate intervals for analysis within the year.

One noteworthy caveat is the relationship between the instrument chosen and the assumption of no autocorrelation. Consider the regression of a dependent variable y_t on its own lag y_{t-1} and taking y_{t-2} as the instrument. If y_{t-2} and y_{t-1} are highly correlated, this is suggestive of autoregression. Thus, there will be autocorrelation in the error term unless the autoregressive process is AR(1), in which case the y_{t-1} regressor will purge this autocorrelation. In the Leslie model, the argument is less clear. If K_t and K_{t-1} are highly correlated, part of this may be due to autoregression of C_t. If the use of K_t as a regressor does not purge this autoregression, then there will be autocorrelation in the residual.

Ordinary Least Squares With Contemporaneous Catch Omitted From Cumulative Catch

By removing $C_t/2$ from K_t, OLS estimates are unbiased and consistent if there is no autocorrelation. I test for autocorrelation two sections later in this report. Table 8.2 reports the results from these twenty-six regressions. Results are similar to those of the two-stage least squares runs. The same seventeen slope coefficients are significant at the 10% level, although coefficient and standard error estimates vary somewhat. Again, there is a sign problem for Amchitka West 1997. Moreover, seven of the nine non-significant slope coefficients still have a negative sign. As in the case of two-stage least squares, the results are strongly indicative of a negative relationship between CPUE and cumulative catch.

Biomass Estimates and Confidence Intervals

Using the results from OLS regressions with omitted contemporaneous catch, I calculated biomass estimates. Following Ricker (1975), Gunderson (1993), Hilborn and Walters (1992), and Fritz (1998), biomass = -constant/slope. I also calculated confidence intervals based on the asymptotic normality of a nonlinear function of the OLS estimates[4]. The method uses a first-order Taylor approximation to calculate asymptotic variance:

$$v = \begin{bmatrix} \frac{\partial f(\alpha,\beta)}{\partial \alpha} & \frac{\partial f(\alpha,\beta)}{\partial \beta} \end{bmatrix} \Sigma \begin{bmatrix} \frac{\partial f(\alpha,\beta)}{\partial \alpha} \\ \frac{\partial f(\alpha,\beta)}{\partial \beta} \end{bmatrix}$$

$$= \begin{bmatrix} \frac{-1}{\beta} & \frac{\alpha}{\beta^2} \end{bmatrix} \Sigma \begin{bmatrix} \frac{-1}{\beta} \\ \frac{\alpha}{\beta^2} \end{bmatrix}$$

where v is the variance of biomass, α is the estimated constant, β is the estimated slope, and Σ is the covariance matrix of the OLS coefficient estimates. To construct a 95% confidence interval, I add and subtract ()from each point estimate of biomass. The results appear in Table 8.3.

This confidence interval methodology differs from that of Ricker (1975) who uses DeLury (1951) to construct an asymmetric interval. To evaluate this method, I ran Monte Carlo simulations for Seguam 1992 and Kiska 1994. Each Monte Carlo ran 20,000 simulations that fixed predicted CPUE, added normal errors

[4] See Greene (1993) for a discussion of these asymptotic properties.

to the predictions, and re-estimated the OLS coefficients. Not surprisingly, the results confirmed normality of OLS coefficients. However, results for the biomass estimates were inconclusive. Histograms for biomass showed extreme bunching in the center of the distribution with some very distant outliers. The symmetry or lack thereof of the distribution was ambiguous[5]. To obtain precise estimates of biomass and to further evaluate the existing estimates would require a deeper examination of the small-sample properties associated with the ratio of constant and slope OLS coefficients.

Tests for Autocorrelation

I ran two autocorrelation diagnostics on each region/year pair for which the time series of data was continuous, i.e. there were no gaps in the data. All of these diagnostics were based on the OLS regressions for which contemporaneous catch was eliminated from cumulative catch. The standard diagnostic for autocorrelation is the Durbin Watson (d) statistic. However, in the presence of a lagged dependent variable, Durbin's d does not apply and we must use a different test. I calculated both the Durbin's h statistic and the Ljung and Box Q statistic (based on a single lag only) for the fifteen region/year pairs that had a continuous time series. Durbin's h distributes asymptotically Standard Normal while the Q statistic distributes Chi-Square with one degree of freedom. In both cases, the null hypothesis is no autocorrelation. Results of these tests are reported in Table 8.4. The results show that we fail to reject the hypothesis of no autocorrelation in every region/year pair. That is, there are no significant findings of autocorrelation in the data[6]. There are two cautions in order. First, Durbin's h was constructed to apply to situation in which the lagged dependent variable appears on the right-hand side, not a function of the dependent variable lags. Second, while the Q statistic is reasonably powerful, it is sensitive to the choice of lags to consider in calculating autocorrelations. I chose one lag due to the limited data series, but in general, there is not a clear rule for choosing lag length.

I estimated first-order autoregressive models for the two regressions that were close to rejecting the no autocorrelation hypothesis. These were Seguam 1992 and Delarof 1995. The estimation technique used was nonlinear least squares. Results are reported in Table 8.5. As expected, the autoregressive parameter rho is not significant at the 10% level for Seguam 1992.

Use of Intensity of Effort and Fleet Composition Data

The use of disaggregated data may lead to more efficient estimates of catchability and underlying biomass. The fact that some periods have large fleets and/or a lot of fishing constitutes information that is not being used by ordinary least squares. There are two potential directions for the analysis that involve weighted least squares estimation[7]. First, consider weighting each period by the number of hauls. Periods for which there are many hauls should be weighted more heavily than periods for which there are few hauls. Second, weight each period by the fishing power of the fleet. This would require potentially subjective judgments about the fishing fleet. The maintained hypothesis would be that more powerful fleets provide more accurate information about the underlying mackerel population. As such, these observations on CPUE would have a lower variance and thus would be weighted more heavily in the estimation. Without weighted least

[5] In an earlier run of Seguam 1992 (10,000 simulations), the results appeared to support an asymmetric distribution with longer tail above the mean than below it. Upon closer examination, the number of observations to the right of the mean was still small relative to the extreme bunching of the mean.

[6] In a preliminary test, I found that the null hypothesis was rejected using the Q statistic in Seguam 1992, but this was due to a calculation error. With the correct calculation, the null hypothesis is not rejected.

[7] Weighed least squares is a form of generalized least squares in which observations are weighted by the inverse of their standard errors.

squares, periods were constructed to have large minimum numbers of hauls. With both of these weighted least squares approaches, the number of periods would increase by allowing shorter period lengths and simply assigning small weights to periods with very few hauls.

To undertake the weighted least squares analysis, a weighting scheme must be determined. If the weights for observations can be determined *a priori*, that is, on theoretical grounds, then one can apply generalized least squares immediately to obtain the results. If weights are an empirical question, the appropriate procedure is feasible generalized least squares.

Conclusions

The Leslie method leads to biased and inconsistent estimates when cumulative catch includes one half of current catch. Instrumental variables estimation is one way to correct this problem, but it leads to the problem of finding adequate instruments. Another approach is to drop contemporaneous catch from cumulative catch and return to ordinary least squares estimation. Both methods were used to estimate catchability for twenty-six region/year pairs. The statistical evidence strongly favors the hypothesis of a negative relationship between catch per unit effort and cumulative catch. The statistics also support the assumption that there is no autocorrelation in the data, an assumption that is necessary for OLS estimates to be unbiased and consistent. In contrast to these favorable results, estimates of biomass are not precise. These estimates would likely benefit from further analysis of disaggregated data.

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Smith Table 8.1. Two-stage Least Squares Regressions. Cumulative Catch Includes Half of Current Catch, Instrument is One Period Lag of Cumulative Catch.

Region/Year	Observations Used		Coefficient	Standard Error	t Ratio	P Value	Significance Level
Kiska 1994	15	Slope	-0.0014039	0.0002429	-5.78	0.001	1%
		Constant	40.273	2.7009	14.91	0.000	1%
Kiska 1995	13	Slope	-0.061053	0.092743	-0.66	0.524	Not Sig.
		Constant	2417.4	1814.4	1.33	0.210	Not Sig.
Kiska 1996	12	Slope	-0.0004114	0.0001516	-2.71	0.022	5%
		Constant	17.599	1.6292	10.80	0.000	1%
Kiska 1997	8	Slope	-0.0003034	0.0002142	-1.42	0.206	Not Sig.
		Constant	17.734	1.7954	9.88	0.000	1%
Seguam 1992	12	Slope	-0.000549	0.0002731	-2.01	0.072	10%
		Constant	26.075	4.2503	6.13	0.000	1%
Seguam 1993	8	Slope	-0.000703	0.0001568	-4.48	0.004	1%
		Constant	33.778	2.6212	12.89	0.000	1%
Seguam 1994	13	Slope	0.00047794	0.0008061	0.59	0.565	Not Sig.
		Constant	15.306	9.1915	1.67	0.124	Not Sig.
Seguam 1995	7	Slope	-0.0013755	0.0002691	-5.11	0.004	1%
		Constant	32.519	1.905	17.07	0.000	1%
Seguam 1996	12	Slope	-0.0004696	9.321E-05	-5.04	0.001	1%
		Constant	24.554	1.8391	13.35	0.000	1%
Seguam 1997	7	Slope	0.00034955	0.0004467	0.78	0.469	Not Sig.
		Constant	22.578	4.1459	5.45	0.003	1%
Amchitka East 1986	8	Slope	-0.0011561	0.0004871	-2.37	0.055	10%
		Constant	5.6912	1.0829	5.26	0.002	1%
Amchitka East 1995	9	Slope	-0.0014957	0.0026222	-0.57	0.586	Not Sig.
		Constant	23.118	6.8466	3.38	0.012	5%
Amchitka East 1996	9	Slope	-0.0022287	0.0009568	-2.33	0.053	10%
		Constant	25.847	4.2982	6.01	0.001	1%

Smith Table 8.1. (Cont.)

Region/Year	Observations Used		Coefficient	Standard Error	t Ratio	P Value	Significance Level
Amchitka East 1997	4	Slope	-0.0021525	0.0003213	-6.70	0.022	5%
		Constant	23.554	1.2395	19.00	0.003	1%
Amchitka West 1995	7	Slope	-0.0003811	0.0007002	-0.54	0.610	Not Sig.
		Constant	18.883	4.7261	4.00	0.010	5%
Amchitka West 1996	6	Slope	-0.0023752	0.0009394	-2.53	0.065	10%
		Constant	21.497	3.6233	5.93	0.004	1%
Amchitka West 1997	5	Slope	0.0024964	0.0009925	2.52	0.087	10%
		Constant	14.206	2.0034	7.09	0.006	1%
Delarof 1992	6	Slope	-0.0021263	0.001877	-1.13	0.321	Not Sig.
		Constant	23.07	5.3195	4.34	0.012	5%
Delarof 1994	8	Slope	-0.0039002	0.0023832	-1.64	0.153	Not Sig.
		Constant	23.161	5.9041	3.92	0.008	1%
Delarof 1995	4	Slope	-0.015388	0.0056714	-2.71	0.113	Not Sig.
		Constant	58.779	12.181	4.83	0.040	5%
Delarof 1996	7	Slope	-0.0024111	0.0002769	-8.71	0.000	1%
		Constant	26.056	1.4549	17.91	0.000	1%
Delarof 1997	4	Slope	-0.0074666	0.0020571	-3.63	0.068	10%
		Constant	29.143	4.5689	6.38	0.024	5%
Buldir East 1995	6	Slope	-0.0040786	0.0008399	-4.86	0.008	1%
		Constant	22.575	2.75385	8.20	0.001	1%
Buldir East 1996	7	Slope	-0.004014	0.001873	-2.14	0.085	10%
		Constant	32.145	6.8919	4.66	0.006	1%
Buldir East 1997	7	Slope	-0.0013048	0.0003669	-3.56	0.016	5%
		Constant	15.34	1.9116	8.02	0.001	1%
Buldir West 1995	6	Slope	-0.0029353	0.0010163	-2.89	0.045	5%
		Constant	31.13	4.3477	7.16	0.002	1%

Smith Table 8.2. Ordinary Least Squares Regressions. Cumulative Catch Does Not Include Contemporaneous Catch. With No Autocorrelation OLS estimates are Unbiased and Consistent.

Region/Year	Observations Used		Coefficient	Standard Error	t Ratio	P Value	Significance Level
Kiska 1994	16	Slope	-0.0013375	0.0002243	-5.96	0.000	1%
		Constant	38.316	2.2585	16.97	0.000	1%
Kiska 1995	13	Slope	-0.056521	0.084869	-0.67	0.519	Not Sig.
		Constant	2282	1607.4	1.42	0.183	Not Sig.
Kiska 1996	13	Slope	-0.0004284	0.0001309	-3.27	0.007	1%
		Constant	17.551	1.2856	13.65	0.000	1%
Kiska 1997	9	Slope	-0.0002708	0.0001738	-1.56	0.163	Not Sig.
		Constant	17.173	1.2442	13.80	0.000	1%
Seguam 1992	13	Slope	-0.0006649	0.0002635	-2.52	0.028	5%
		Constant	27.401	3.6496	7.51	0.000	1%
Seguam 1993	9	Slope	-0.000716	0.0001523	-4.70	0.002	1%
		Constant	32.436	2.1505	15.08	0.000	1%
Seguam 1994	14	Slope	0.0001719	0.0006065	0.28	0.782	Not Sig.
		Constant	19.145	6.4877	2.95	0.012	5%
Seguam 1995	8	Slope	-0.0013658	0.0001762	-7.75	0.000	1%
		Constant	31.345	1.0479	29.91	0.000	1%
Seguam 1996	13	Slope	-0.0003881	6.793E-05	-5.71	0.000	1%
		Constant	22.56	1.2436	18.14	0.000	1%
Seguam 1997	8	Slope	0.0002108	0.0003376	0.62	0.555	Not Sig.
		Constant	24.198	2.6615	9.09	0.000	1%
Amchitka East 1986	9	Slope	-0.0009945	0.0003137	-3.17	0.016	5%
		Constant	5.2047	0.62678	8.30	0.000	1%
Amchitka East 1995	10	Slope	-0.0016052	0.0017752	-0.90	0.392	Not Sig.
		Constant	23.221	4.1912	5.54	0.001	1%
Amchitka East 1996	10	Slope	-0.0021112	0.0008262	-2.56	0.034	5%
		Constant	24.481	3.3025	7.41	0.000	1%

Smith Table 8.2. (Cont.)

Region/Year	Observations Used		Coefficient	Standard Error	t Ratio	P Value	Significance Level
Amchitka East 1997	5	Slope	-0.0041154	0.0014525	-2.83	0.066	10%
		Constant	29.914	4.3967	6.80	0.007	1%
Amchitka West 1995	8	Slope	-0.0006519	0.0004481	-1.45	0.196	Not Sig.
		Constant	20.566	2.6482	7.77	0.000	1%
Amchitka West 1996	7	Slope	-0.0032887	0.0009725	-3.38	0.020	5%
		Constant	24.328	3.1802	7.65	0.001	1%
Amchitka West 1997	6	Slope	0.0020739	0.000737	2.81	0.048	5%
		Constant	15.748	1.1943	13.19	0.000	1%
Delarof 1992	7	Slope	-0.0017758	0.0012495	-1.42	0.215	Not Sig.
		Constant	21.435	2.9801	7.19	0.001	1%
Delarof 1994	9	Slope	-0.002767	0.0017733	-1.56	0.163	Not Sig.
		Constant	19.54	3.8232	5.11	0.001	1%
Delarof 1995	5	Slope	-0.0074413	0.0042119	-1.77	0.175	Not Sig.
		Constant	38.677	7.0755	5.47	0.012	5%
Delarof 1996	8	Slope	-0.002565	0.0002896	-8.86	0.000	1%
		Constant	25.356	1.2738	19.91	0.000	1%
Delarof 1997	5	Slope	-0.0048277	0.0011395	-4.24	0.024	5%
		Constant	21.585	2.0414	10.57	0.002	1%
Buldir East 1995	7	Slope	-0.0040308	0.0006927	-5.82	0.002	1%
		Constant	21.028	1.8883	11.14	0.000	1%
Buldir East 1996	8	Slope	-0.0035529	0.0014634	-2.43	0.051	10%
		Constant	28.935	4.5987	6.29	0.001	1%
Buldir East 1997	8	Slope	-0.0018017	0.0003219	-5.60	0.001	1%
		Constant	17.358	1.4481	11.99	0.000	1%
Buldir West 1995	7	Slope	-0.0035825	0.0008505	-4.21	0.008	1%
		Constant	32.073	2.9432	10.90	0.000	1%

Smith Table 8.3. Biomass Estimates and Asymptotic Confidence Intervals. Based on Table 8.2 Coefficients and 5% Critical Value of the Standard Normal Table.

Region/Year	Estimated Biomass	Lower Limit	Upper Limit	Slope and Constant Significant at 5% Level
Kiska 1994	28,647	21,813	35,481	Yes
Kiska 1995	40,374	-32,004	112,753	No
Kiska 1996	40,970	20,802	61,137	Yes
Kiska 1997	63,418	-9,215	136,053	No
Seguam 1992	41,211	16,339	66,084	Yes
Seguam 1993	45,304	30,002	60,608	Yes
Seguam 1994	-111,347	-947,454	724,755	No
Seguam 1995	22,950	18,318	27,581	Yes
Seguam 1996	58,131	43,556	72,708	Yes
Seguam 1997	-114,791	-496,233	266,653	No
Amchitka East 1986	5,233	3,025	7,441	Yes
Amchitka East 1995	14,466	-12,514	41,445	No
Amchitka East 1996	11,596	4,756	18,434	Yes
Amchitka East 1997	7,269	3,679	10,858	Yes
Amchitka West 1995	31,547	-4,294	67,387	No
Amchitka West 1996	7,397	4,437	10,358	Yes
Amchitka West 1997	-7,593	-13,820	-1,367	Yes
Delarof 1992	12,071	-2,043	26,184	No
Delarof 1994	7,062	400	13,720	No
Delarof 1995	5,198	895	9,500	No
Delarof 1996	9,885	8,341	11,429	Yes
Delarof 1997	4,471	2,983	5,959	Yes
Buldir East 1995	5,217	4,120	6,313	Yes
Buldir East 1996	8,144	3,415	12,873	No
Buldir East 1997	9,634	7,476	11,792	Yes
Buldir West 1995	8,953	5,982	11,924	Yes

Smith Table 8.4. Autocorrelation Diagnostics. Null Hypothesis is No Autocorrelation.

Region/Year	Durbin's h	Conclusion	Ljung and Box Q	Conclusion
Kiska 1994	-0.452	Fail to Reject	0.624	Fail to Reject
Kiska 1997	0.699	Fail to Reject	0.605	Fail to Reject
Seguam 1992	1.516	Fail to Reject	2.311	Fail to Reject
Seguam 1993	0.339	Fail to Reject	0.090	Fail to Reject
Seguam 1995	0.949	Fail to Reject	0.686	Fail to Reject
Seguam 1997	-0.205	Fail to Reject	0.096	Fail to Reject
Amchitka East 1997	0.318	Fail to Reject	0.110	Fail to Reject
Amchitka West 1995	0.779	Fail to Reject	0.408	Fail to Reject
Amchitka West 1997	-0.873	Fail to Reject	1.544	Fail to Reject
Delarof 1992	-0.328	Fail to Reject	0.255	Fail to Reject
Delarof 1995	-0.991	Fail to Reject	3.590	Fail to Reject
Delarof 1996	1.234	Fail to Reject	0.845	Fail to Reject
Delarof 1997	0.679	Fail to Reject	0.012	Fail to Reject
Buldir East 1995	0.358	Fail to Reject	0.067	Fail to Reject
Buldir East 1997	0.39	Fail to Reject	0.010	Fail to Reject

Notes:

Durbin's h statistic is distributed asymptotically Standard Normal. Thus, 1.96 is the 5% critical value.

The Q statistic distributes asymptotically chi-square (with 1 degree of freedom for an AR(1) process), so the critical value is 3.84.

The Q statistics calculated use one lag to diagnose autocorrelation.

Smith Table 8.5. Regressions with first-order autoregressive term; estimation used nonlinear least squares.

Region/year	Observations used	Coefficient	Standard error	t Ratio
Seguam 1992	Slope	-0.00049083	0.00036113	-1.36
	Constant	24.212	5.8944	4.11
	Rho	0.38539	0.25738	1.50
Delarof 1995	Slope	***Nonlinear least squares did not converge***		
	Constant			
	Rho			

[End of Smith Review.]

9.0 LIST OF PREPARERS

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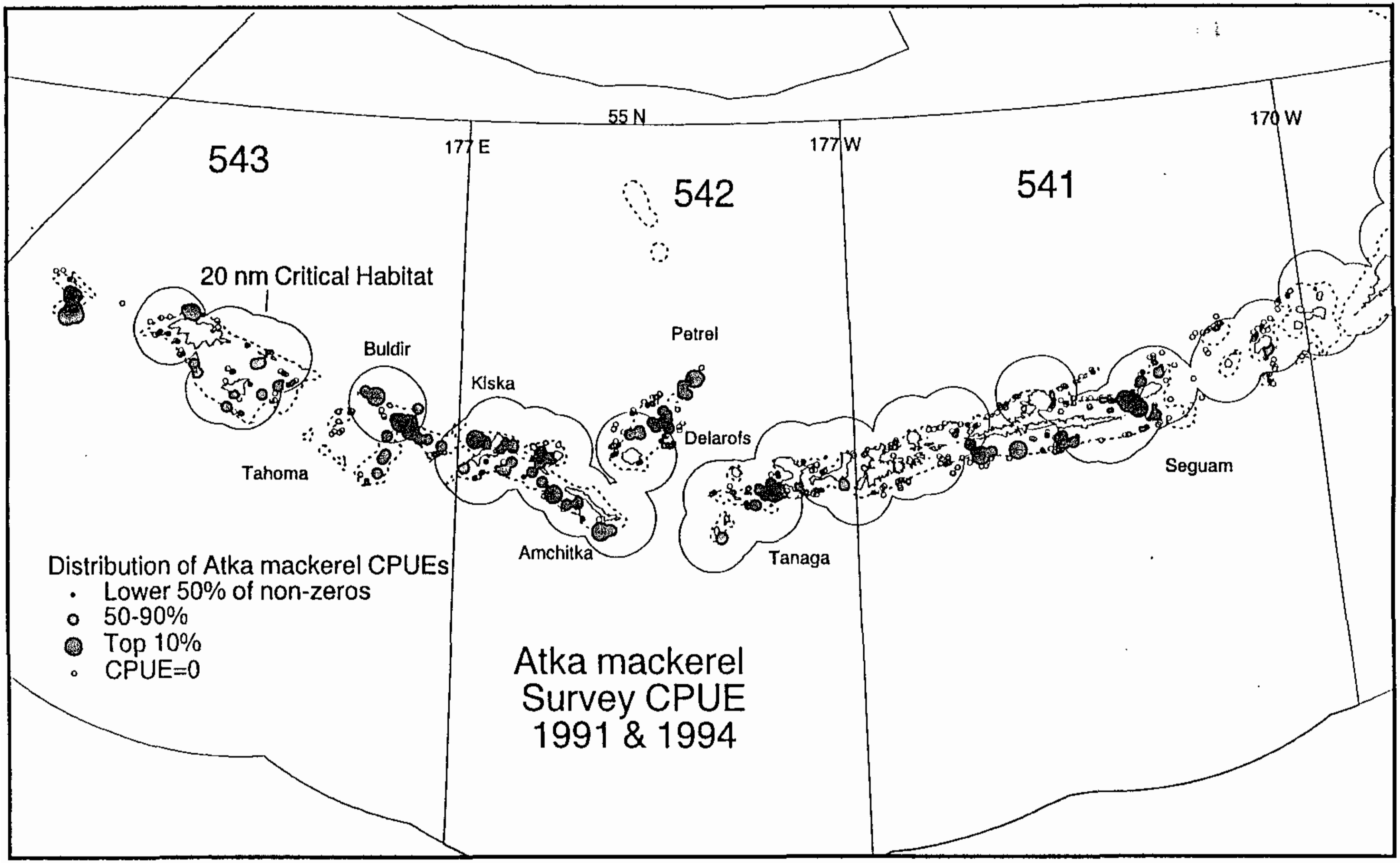


Figure 1. CPUE of Atka mackerel from the NMFS bottom trawl surveys of 1991 and 1994 in the Aleutian Islands region. Steller sea lion critical habitat zones around rookeries and haulouts, the 200 m isobath, management areas 541-543, and names of locations used by the fishery are shown.

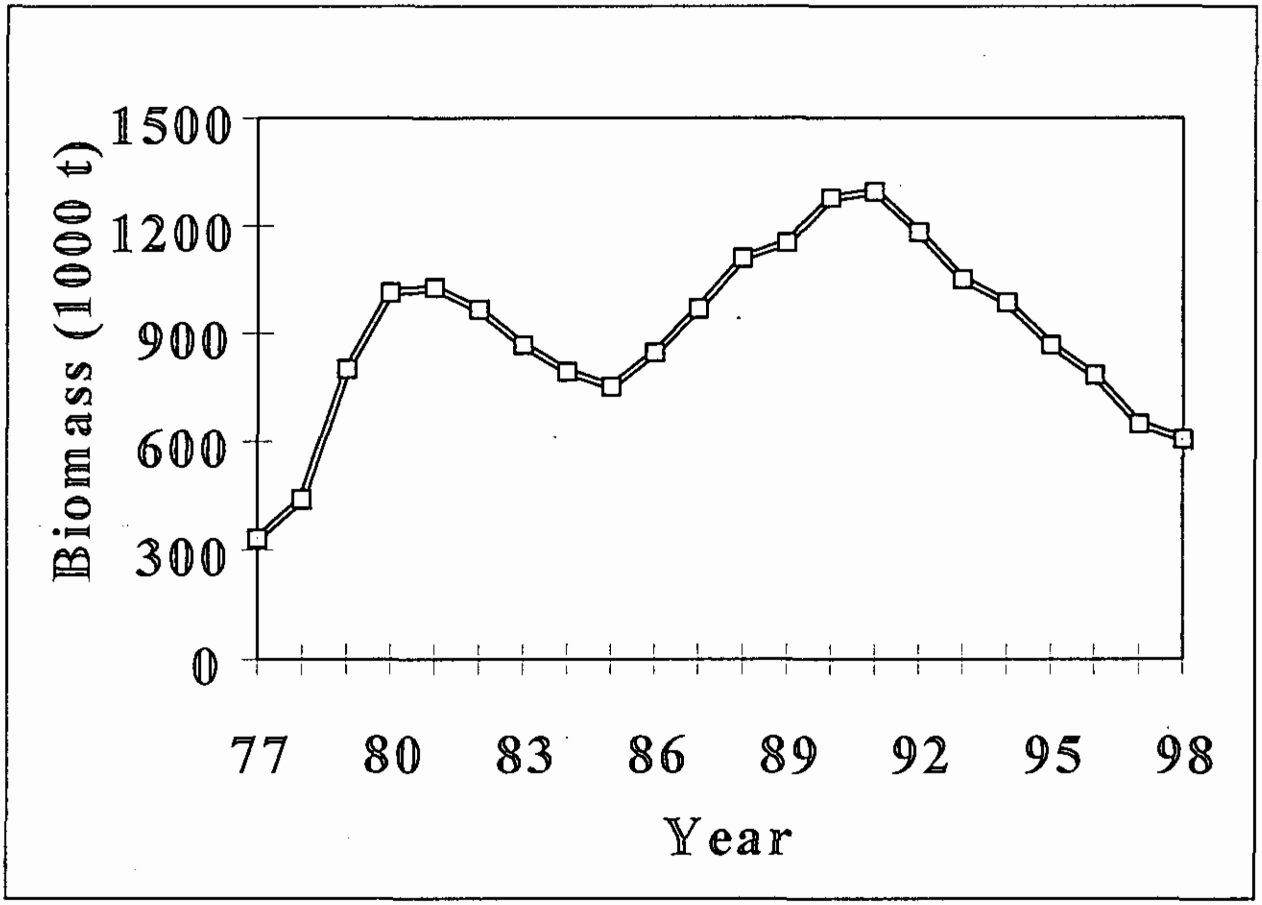


Figure 2. Estimated annual stock biomass for BSAI Atka mackerel, 1977-1998 (based on data from Lowe and Fritz 1997).

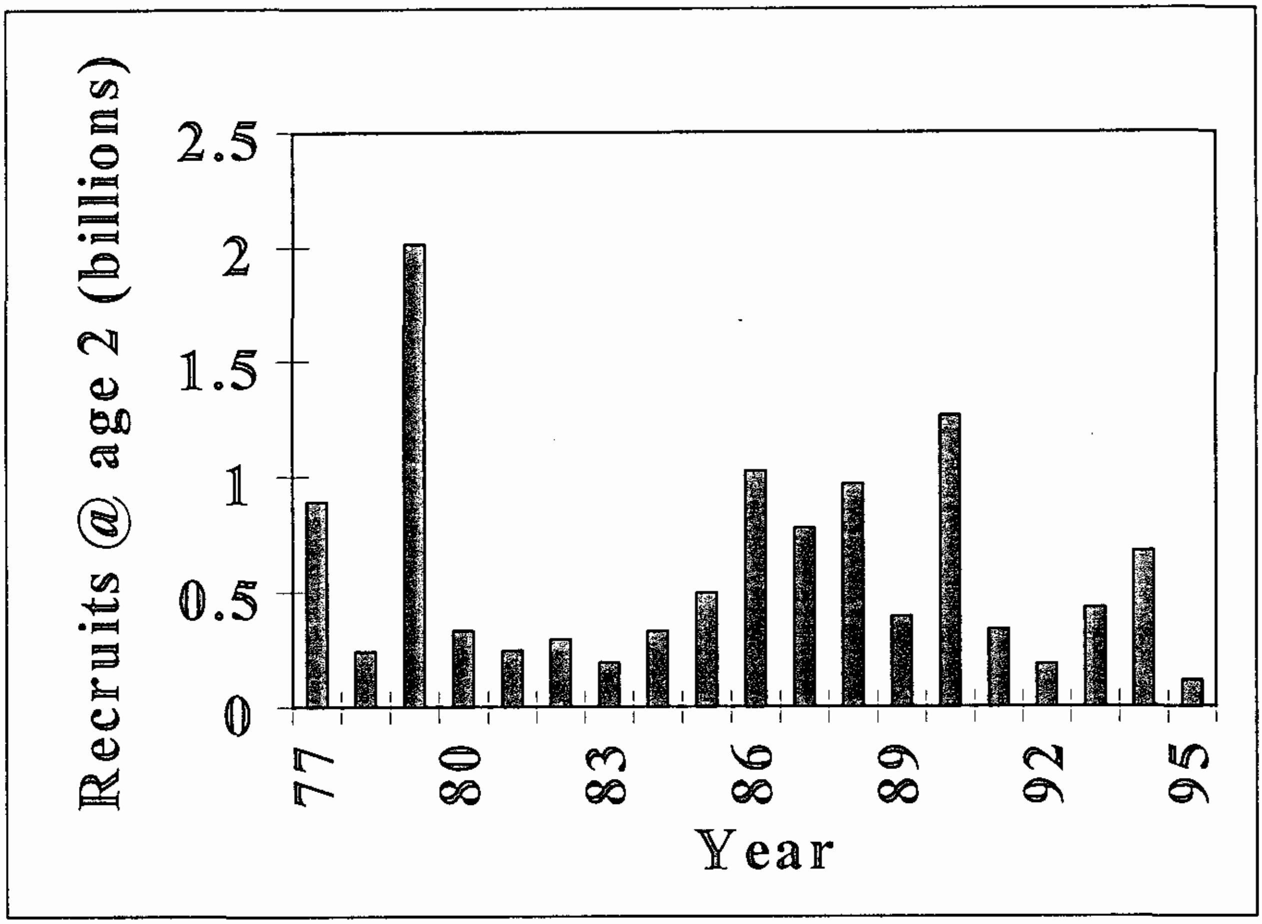


Figure 3. Estimated annual recruitment of 2-year-old Atka mackerel; e.g., the large recruitment in 1977 reflects a strong 1975 year class (from Lowe and Fritz 1997).

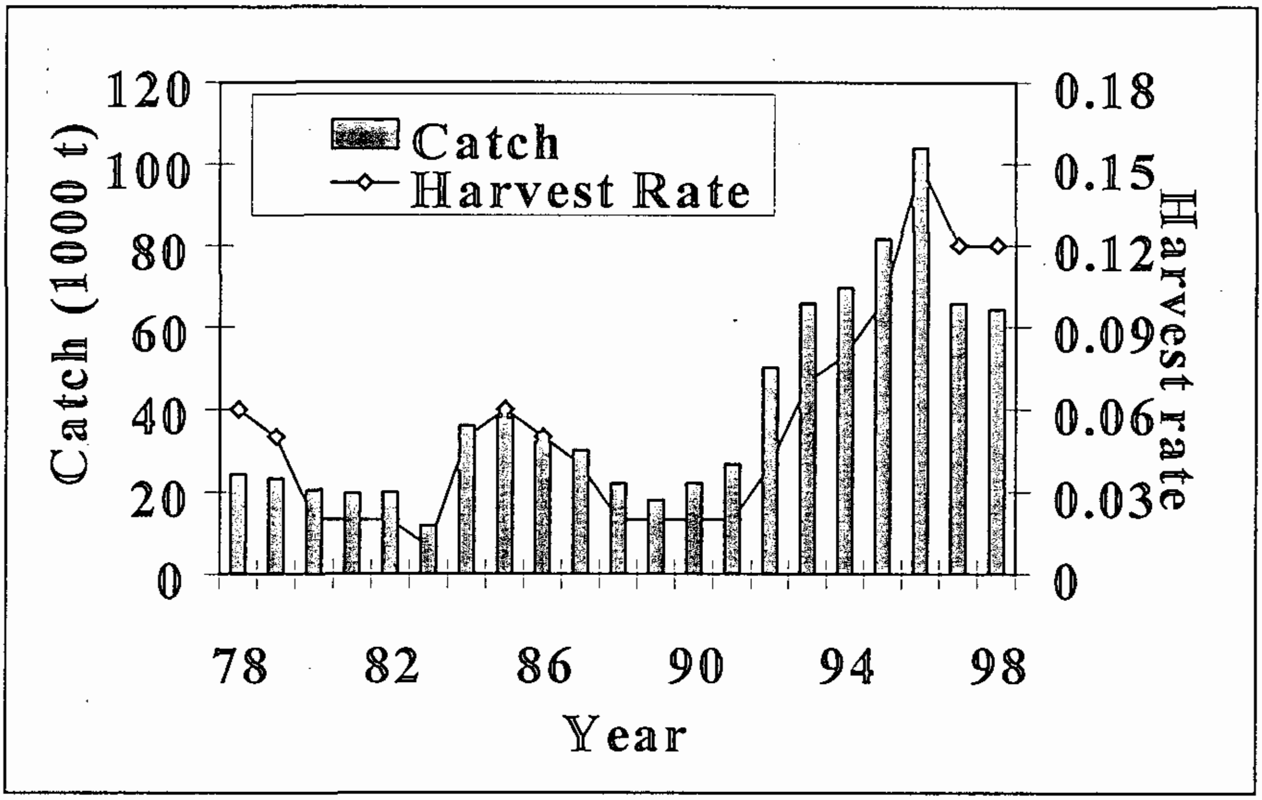


Figure 4. Estimated annual catch (1000 mt) and harvest rate (catch / estimated biomass) in the Atka mackerel fishery, 1978-1998 (from Lowe and Fritz 1997).

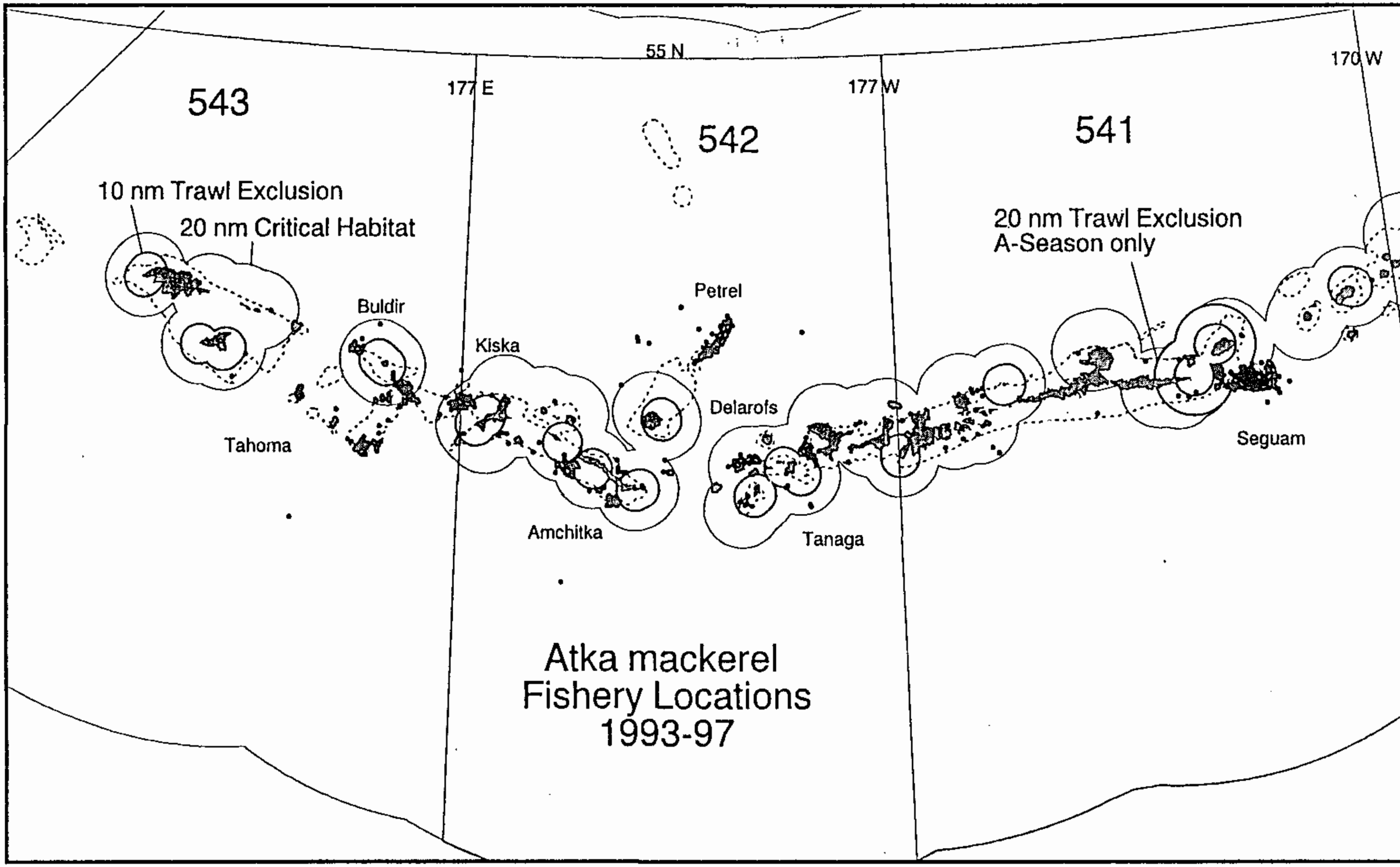
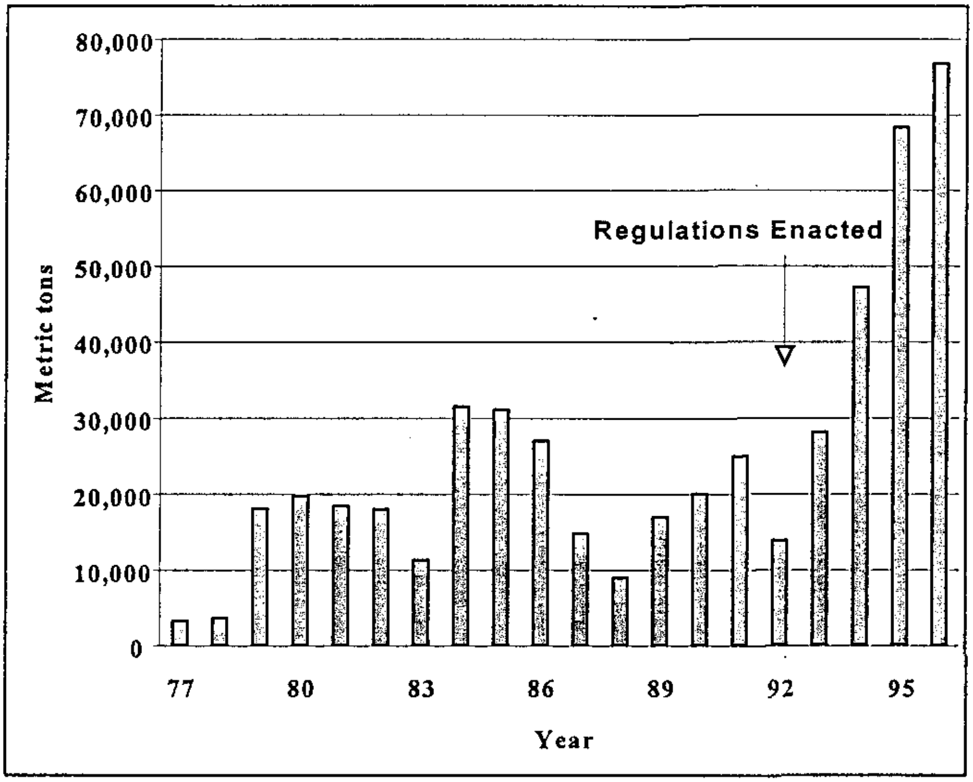


Figure 5. Atka mackerel fishery locations in the Aleutian Islands region in 1993-97. Trawl exclusion zones, Steller sea lion critical habitat zones around rookeries and haulouts, the 200 m isobath, management areas 541-543, and names of locations used by the fishery are shown.



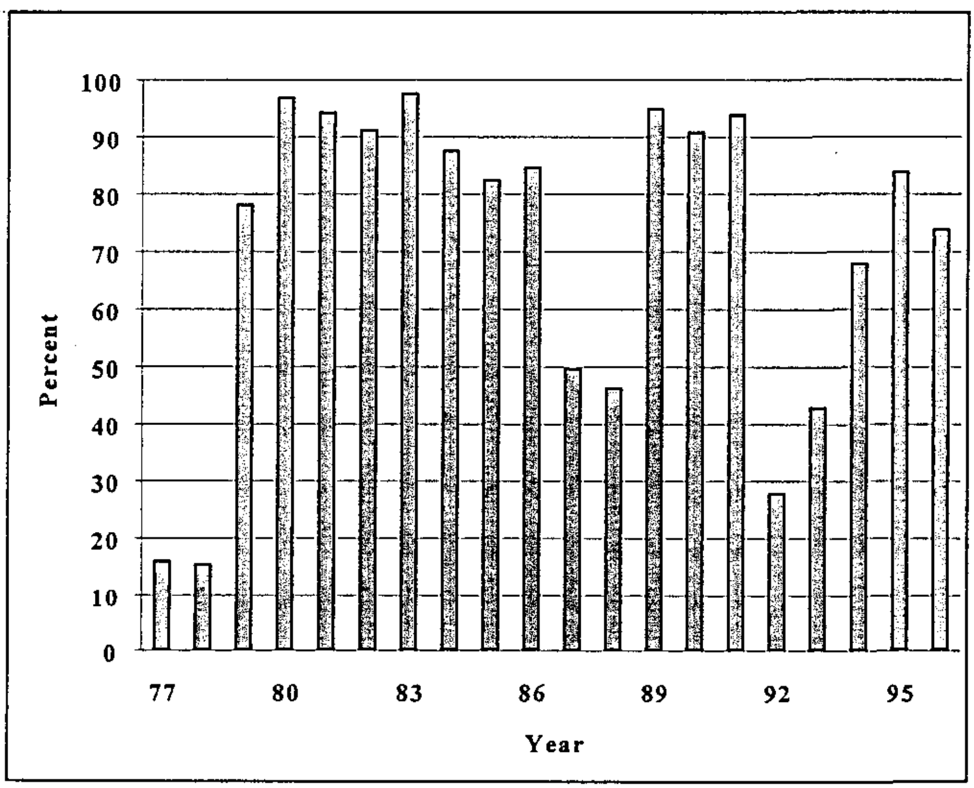


Figure 6. Annual amount (mt, top) of Atka mackerel caught within areas designated as Steller sea lion critical habitat, and percent (bottom) of total catch from within critical habitat, 1977-1996.

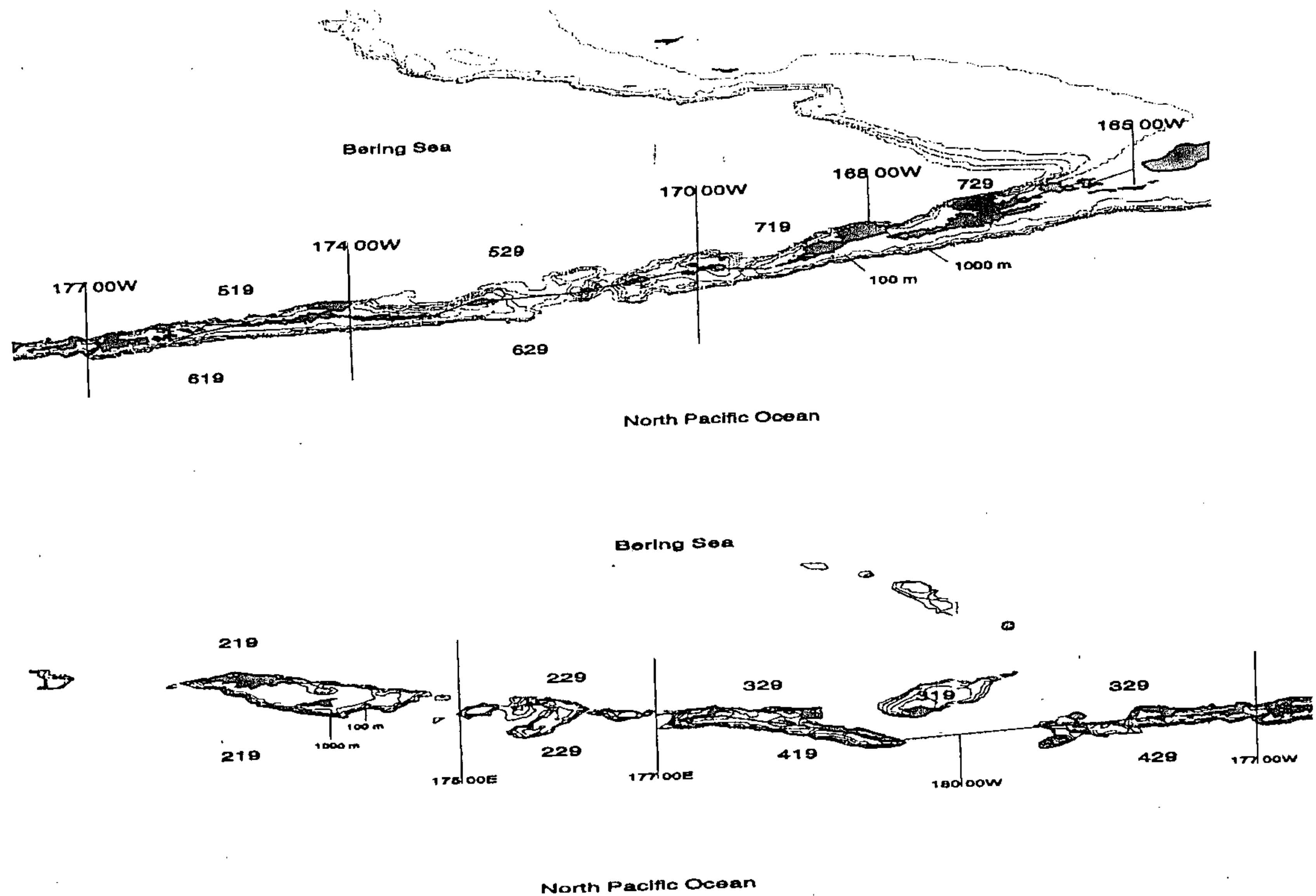


Figure 7. Survey strata used during the NMFS Triennial Aleutian Islands Bottom Trawl Surveys 1991-1997.

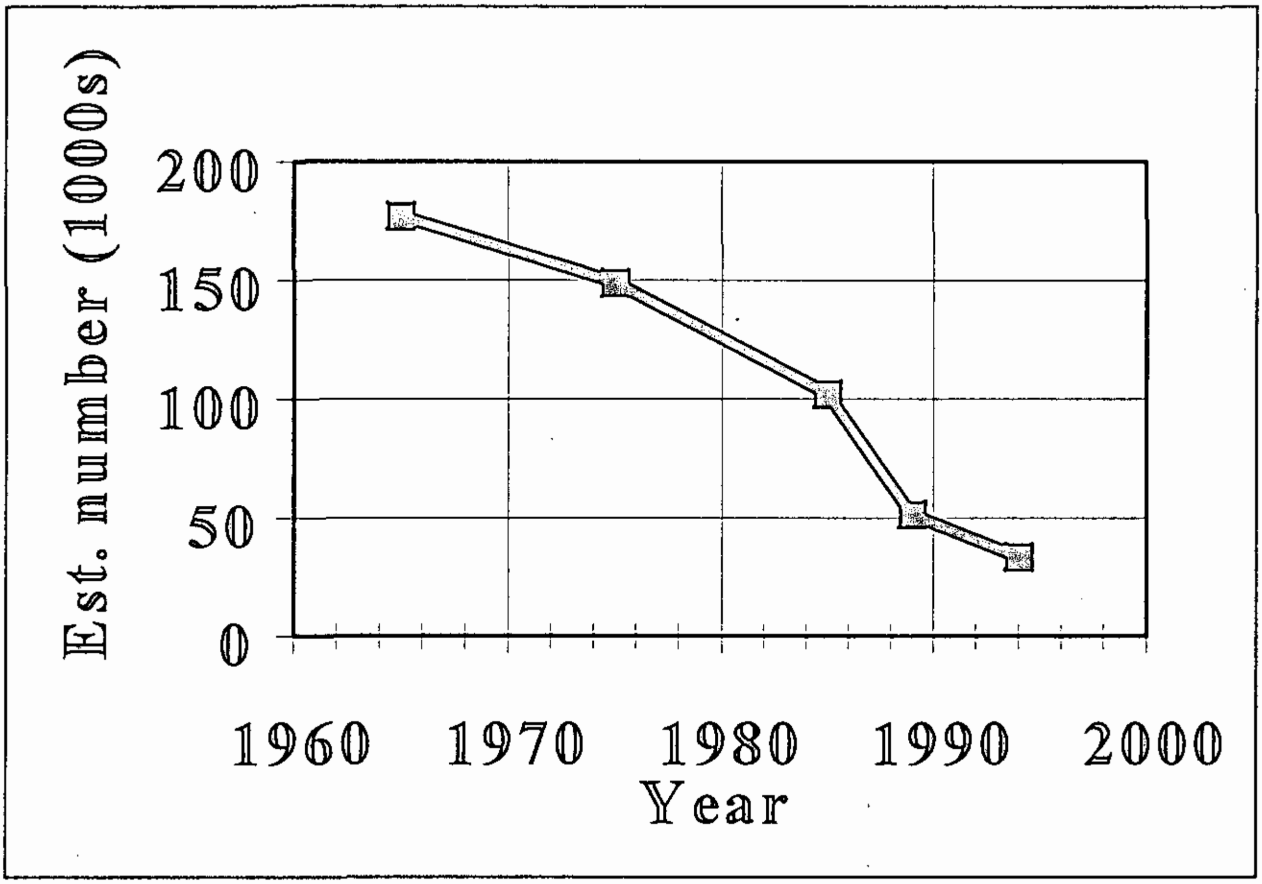


Figure 8. Estimated numbers of Steller sea lions in the western population from the mid 1960s to the mid 1990s (from NMFS 1995).

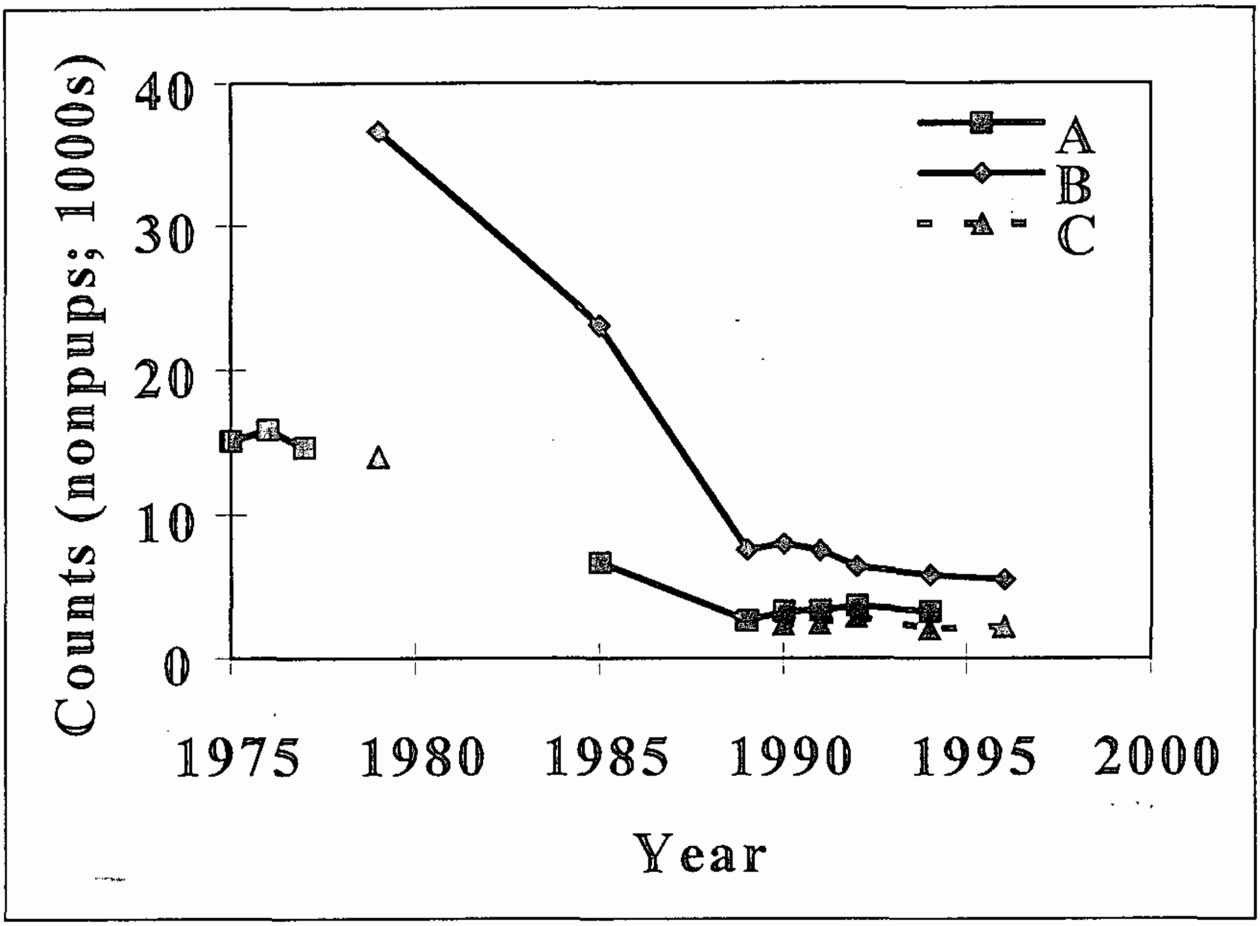


Figure 9. Declines in counts of Steller sea lions (nonpups) in the region from Amak Island to Samalga Pass (A), from Samalga Pass to Kiska Island (B), and west of Kiska Island (C) (from NMFS 1995).

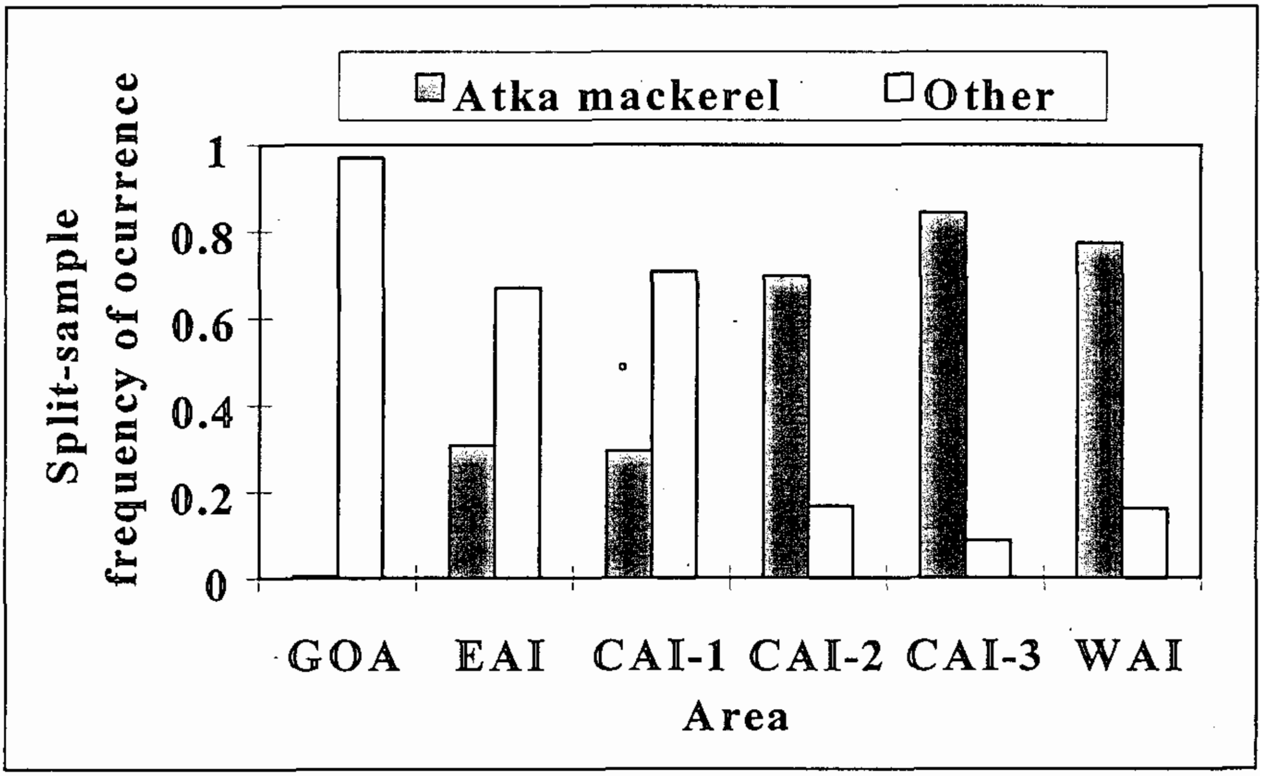


Figure 10. Split-sample frequency of occurrence of Atka mackerel in the diet of Steller sea lions from the Gulf of Alaska to the western Aleutian Islands in June-August, 1990-1993 (modified from Merrick et al. 1997).

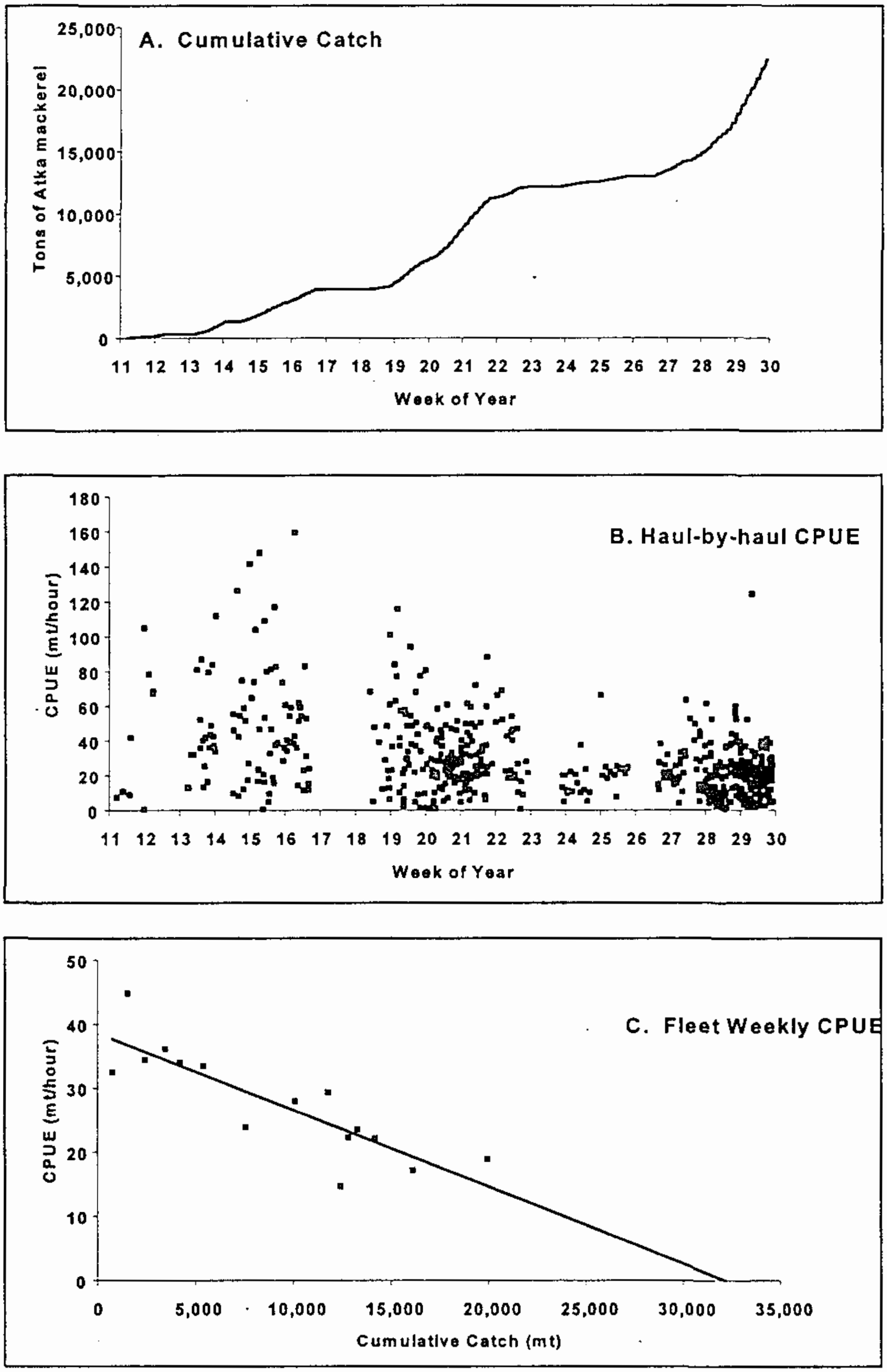


Figure 11. Atka mackerel fishery data from Kiska Island area, March-July, 1994. A. Cumulative catch. B. Haul-by-haul CPUE for all vessels (n = 11; # hauls = 592). C. Fleet weekly CPUE for all vessels (weeks 13-16, 18-22, and 24-29) with Leslie least squares linear regression line plotted. Estimate of initial biomass is 32,200 mt.

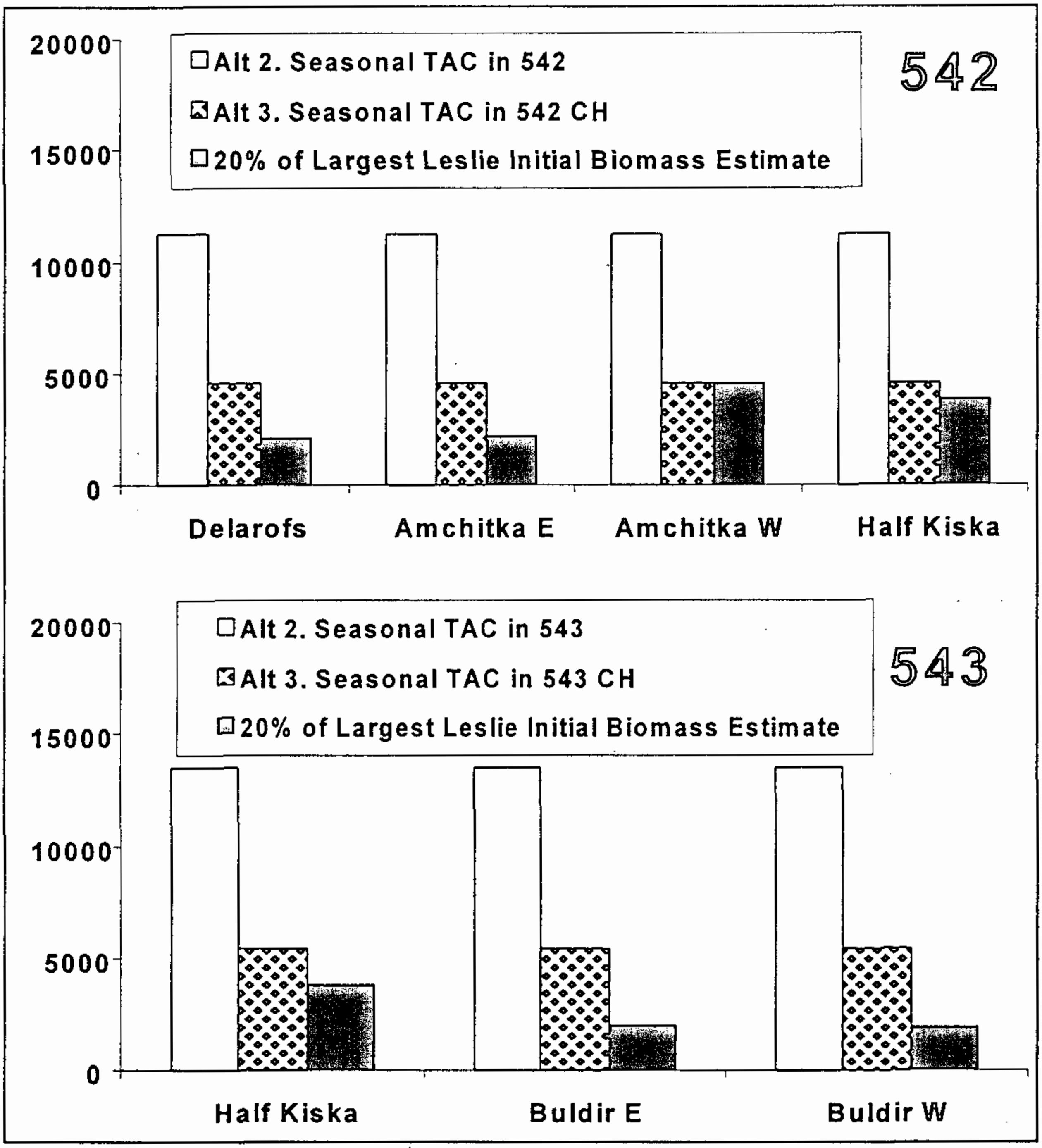


Figure 12. Comparison of potential seasonal releases of Atka mackerel in areas 542 and 543 under Alternatives 2 and 3 (inside critical habitat only) with 20% of the largest Leslie initial biomass estimate available for each fished site. The scenario envisioned to make this figure is that the fleet will attempt to take the entire areal TAC under each alternative at one site (e.g., Delarofs). BSAI Atka mackerel TAC was distributed 50% to each season for both Alternatives, to each management area as in 1998, and was set equal to 64,300 mt. Under Alternative 2, 100% of the catch would be from inside critical habitat, and under Alternative 3, 40% would be taken inside critical habitat. A seasonal TAC release in both area 542 and 543 is considerably greater than the 20% of the estimated biomass at any particular site, so alternative 2 is considerably more likely to result in localized depletion. Alternative 3 is much less likely to result in localized depletion, but may do so under this scenario of uneven fleet distribution.

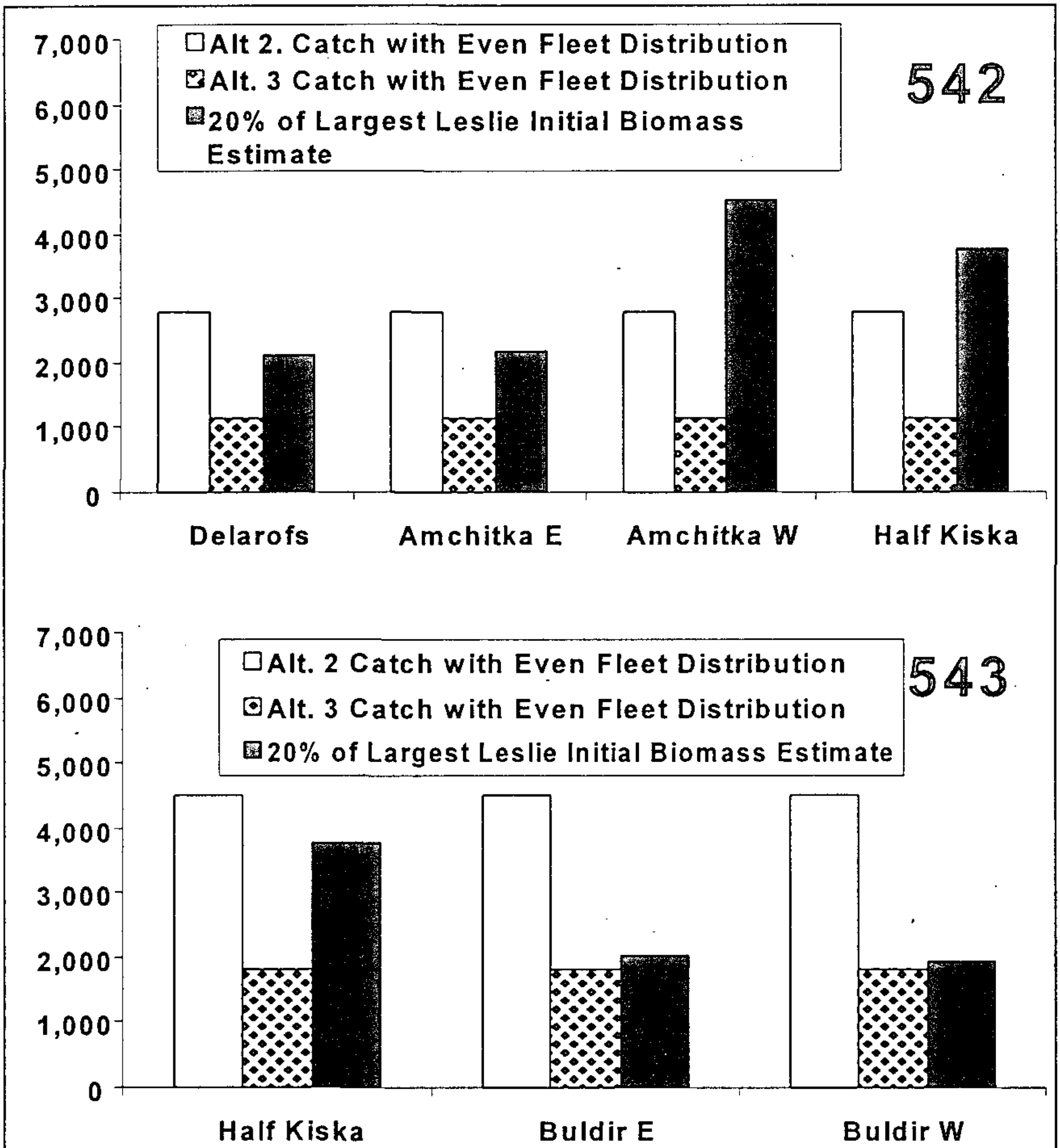


Figure 13. Comparison of potential seasonal releases of Atka mackerel in areas 542 and 543 under Alternatives 2 and 3 (inside critical habitat only) with 20% of the largest Leslie initial biomass estimate available for each fished site. The scenario envisioned to make this figure is that the fleet will distributes itself evenly among the fishing sites within each management area. BSAI Atka mackerel TAC was distributed 50% to each season for both alternatives, to each management area as in 1998, and was set equal to 64,300 mt. Under Alternative 2, 100% of the catch would be from inside critical habitat, and under Alternative 3, 40% would be taken inside critical habitat. Under Alternative 2, the catch would be less than 20% of the estimated biomass at some sites (e.g., Amchitka West and Kiska in 542), but greater than 20% of the biomass at others (e.g., Buldir East, Buldir West). Under alternative 3, catch would be less than 20% of the estimated biomass at all sites in both areas.

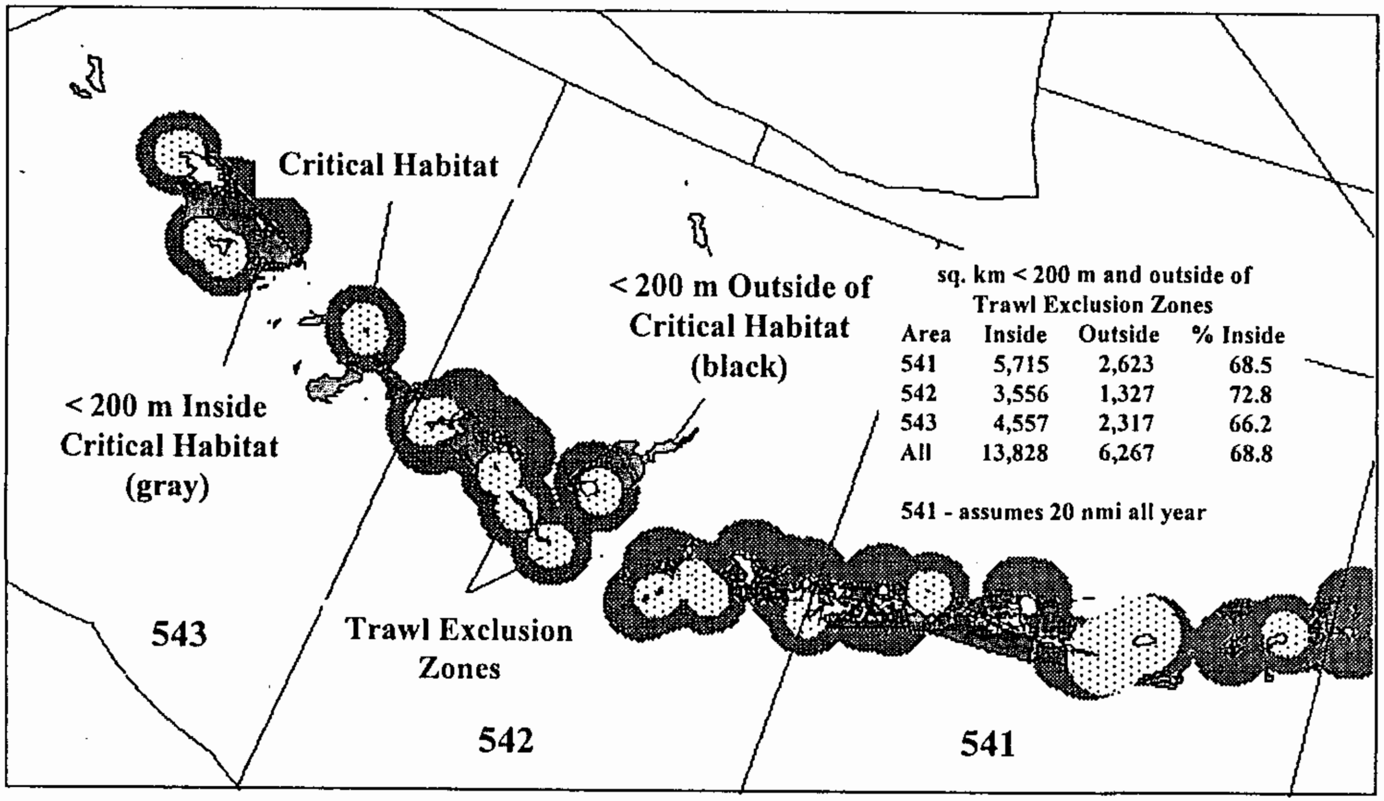


Figure 14. Areas < 200 m depth in the Aleutian Islands region inside and outside of Steller sea lion critical habitat and trawl exclusion zones.

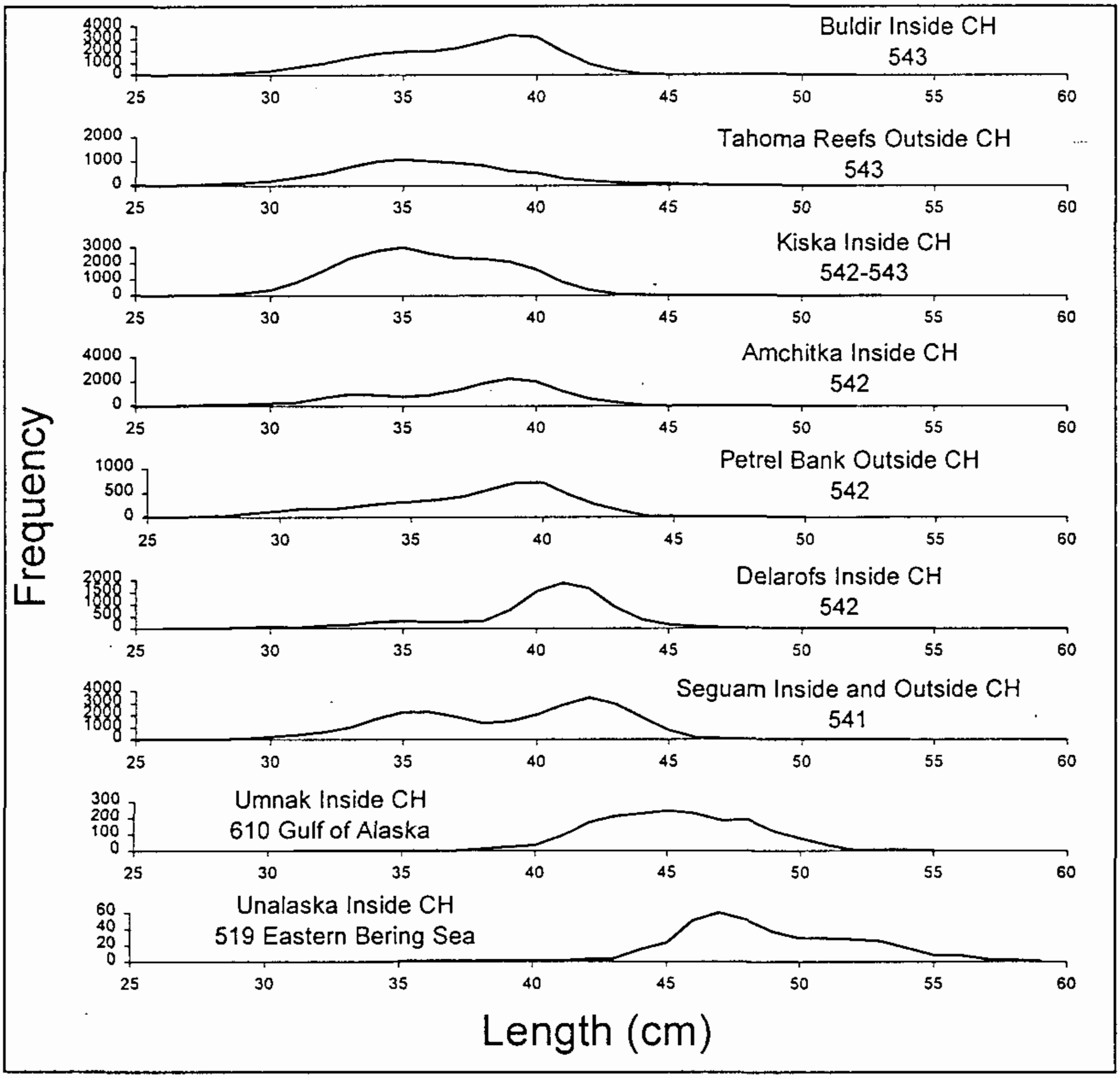


Figure 15. Atka mackerel length-frequency distributions caught by the fishery at various locations in 1996 from west (top) to east in the Aleutian Islands (top 7 panels), Gulf of Alaska (Umnak Island), and eastern Bering Sea management areas (Unalaska Island). CH=Steller sea lion critical habitat. Numbers 541-543, 519 and 610 are fishery management areas.

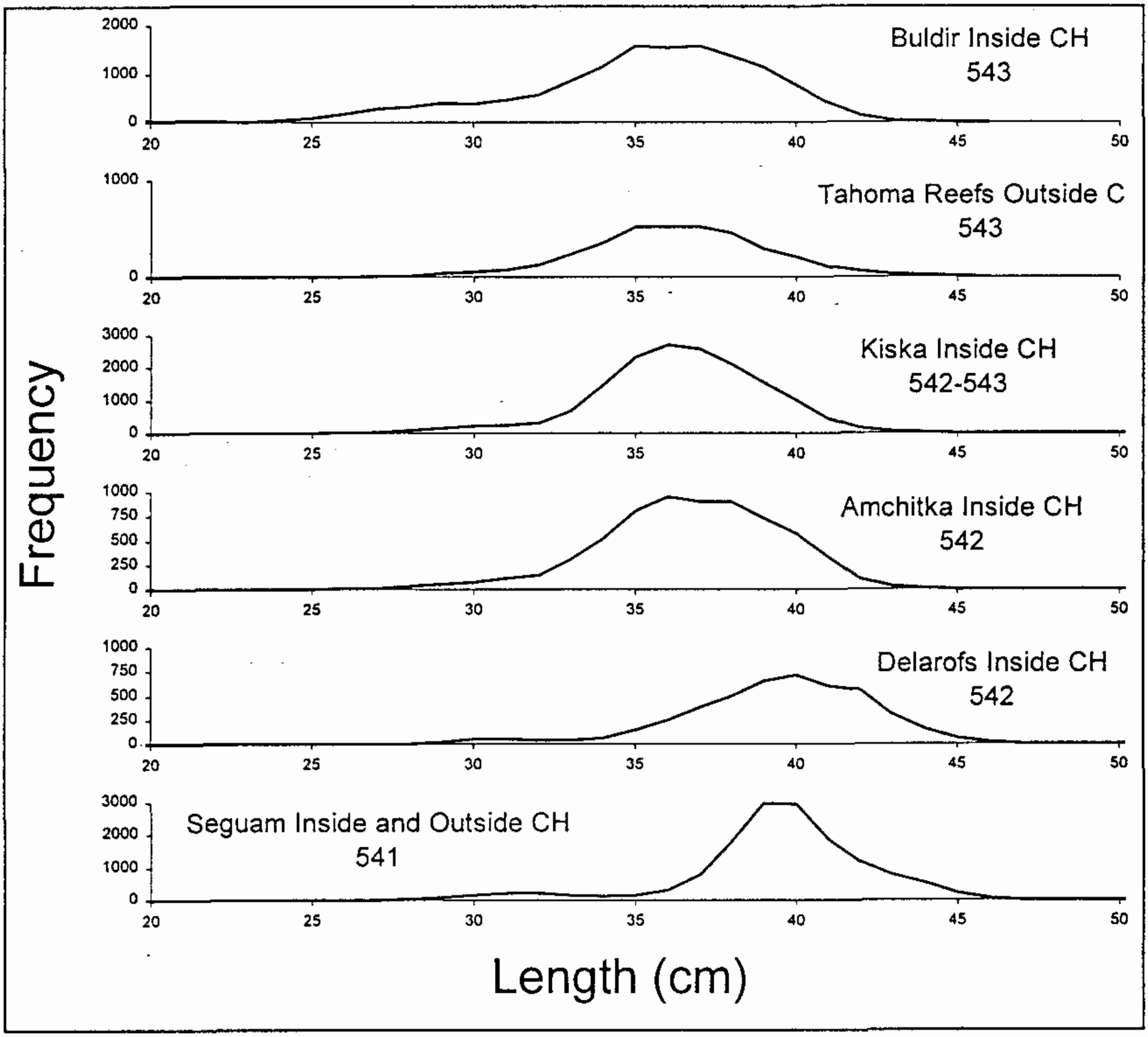


Figure 16. Atka mackerel length-frequency distributions caught by the fishery at various locations in 1997 from west (top) to east in the Aleutian Islands. CH=Steller sea lion critical habitat. Numbers 541-543 are fishery management areas.

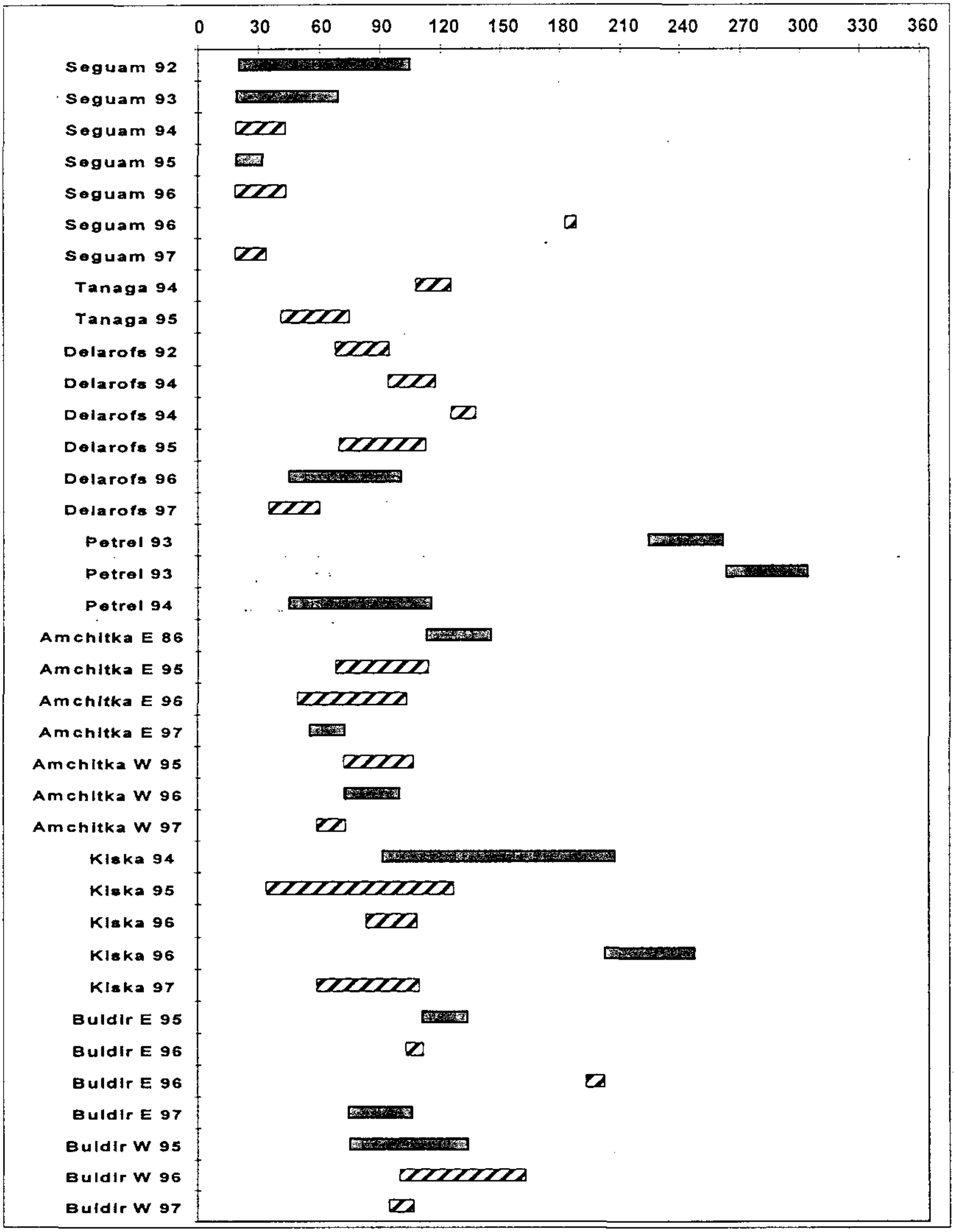


Figure 17. Time of year for studies of fishery-induced localized depletion of Atka mackerel. Solid bars indicate a statistically significant decline occurred in CPUE, hatched bars indicate statistical tests were not significant.

11.0 APPENDIX 1. FRITZ PAPER ON LOCALIZED DEPLETION

Appendix 1. Fritz paper on localized depletion.

Do Trawl Fisheries off Alaska Create Localized Depletions of Atka mackerel (*Pleurogrammus monopterygius*)?

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Keywords: Atka mackerel, *Pleurogrammus monopterygius,* Aleutian Islands, Gulf of Alaska, localized depletion, fishery

Abstract--Leslie regression analyses of Atka mackerel (*Pleurogrammus monopterygius*) fishery catch per unit effort (CPUE) data collected in the Aleutian Islands and Gulf of Alaska in 1992-95 revealed significant reductions during the course of 8 local fisheries lasting between 3 days and 17 weeks. Estimates of harvest rate (catch divided by the initial population size estimate, B_0) ranged between 55% and 91% while estimates of catchability (q=proportion of the initial population size caught with one unit of effort, which in this study was one hour trawled) ranged between 0.0006 and 0.0119. Length-frequency distributions and the time-series of catches and effort suggest that the exploited populations were not closed (e.g., immigration was evident) yet the rates of removal (or emigration) apparently far exceeded rates of immigration. Estimates of B_0 from the second year studied in three Aleutian Islands areas (with periods of fishing separated by at least 15 weeks) were nearly identical to those from the first year. This suggests that in the Aleutian Islands, the fishery utilizes areas preferred by adult Atka mackerel and that these areas are replenished over time. In contrast, B_0 estimates in one Gulf of Alaska area suggest that the local Atka mackerel population size decreased significantly from 1993 to 1994 and that the Gulf of Alaska population may be less resilient to exploitation than the population in the Aleutian Islands. Temporary reductions in the sizes of local Atka mackerel populations could affect other Atka mackerel predators, such as the Steller sea lion (*Eumetopias jubatus*).

Introduction

In marine systems, the use of the Leslie model (as described by Ricker (1975) and Gunderson (1993)) to estimate stock abundance has been primarily restricted to intensive fishing experiments of relatively sedentary species, such as invertebrates (Ralston 1986; Joll and Penn 1990; Iribarne et al. 1991; Miller and Mohn 1993) or tropical reef fish (Polovina 1986), using standardized gear in well-defined areas. With a time-series of catch and effort data from such experiments, Leslie's model permits estimation of the species' initial abundance and its catchability (proportion of the stock caught with one unit of effort) within the context of certain assumptions, which include that: 1) the population being fished is closed, or alternatively that immigration and growth are equal to emigration from the area plus natural mortality, 2) catchability over the course of the experiment remains constant, and 3) changes in catch per unit effort are directly related to changes in fish density. These assumptions may be met if the area fished is well-defined (e.g., is surrounded by habitat that is unsuitable for the species), and the fishery duration is relatively short. Accurate measurements of the size of the area originally occupied by the fished stock and of the area actually fished by the gear are only necessary when estimates of gear efficiency are desired.

In this study, catch and effort data collected by observers aboard commercial vessels fishing for Atka mackerel (*Pleurogrammus monopterygius*) off Alaska were analyzed using Leslie's model *a posteriori* to estimate initial stock sizes, catchability, and local harvest rates. This species and the fishery for it have several characteristics that may make Leslie's method appropriate. The fishery, which uses bottom trawls, occurs in several isolated areas where the species congregates in island passes or over submerged reefs, usually in waters less than 200 m deep. In any one area, fishery durations generally ranged between several days to several months. Since 1990, only large (> 125 feet in length) domestic catcher-processor vessels subject to 100% observer coverage have participated in the fishery, which eases their identification in the database, minimizes between-vessel differences in catch per unit effort (CPUE), and reduces the likelihood of unobserved removals. Because of its preference for areas with high current and rocky bottom, Atka mackerel are not commonly caught as bycatch in fisheries targeting other species, nor does the Atka mackerel fishery itself have a high bycatch of other species (Lowe and

Fritz 1996a;b)

This study is similar to that of Iribarne et al. (1991), who conducted a 31-day depletion experiment by collecting CPUE data aboard 11 different commercial vessels each using their own gear. Their experiment provided data to address questions of initial scallop abundance and catchability without any adjustment of the data for between-vessel differences in fishing power (e.g. vessel or gear performance). The one major difference between this study and that of Iribarne et al. (1991) is their use of a buoy-marked area within which vessels were required to fish. In this study, the fishery chose the areas to fish based on the distributions of the species and suitable bottom as well as management regulations.

The North Pacific Fishery Management Council (NPFMC) sets separate catch quotas for the Aleutian Islands and Gulf of Alaska management areas, which are separated by the 170°W meridian (Fig. 1) (Lowe and Fritz 1996a;b). In 1993, the NPFMC also began allocating the Atka mackerel catch quota within each management area to 3 subareas in the Aleutian Islands and 2 subareas in the Gulf of Alaska. Catch quotas are spatially allocated within each management area to reduce the likelihood of localized depletions as a conservation measure for Atka mackerel since little is known about its movement patterns, and to ensure that fishery data are collected throughout the species' Alaska range. However, the issue of fishery-induced localized depletions also is important in the recovery efforts for the Steller sea lion (*Eumetopias jubatus*), which was listed as threatened under the Endangered Species Act in 1990. Atka mackerel is an important prey of Steller sea lions in the Aleutian Islands, and the fishery for it has historically been conducted within close proximity to sea lion rookeries and haulouts. To reduce the potential for competitive interactions between all trawl fisheries and sea lions, the NPFMC in 1992 created annual 18 km and seasonal 37 km trawl exclusion zones around Alaskan Steller sea lion rookeries west of 150°W longitude (Fritz et al., 1995).

Materials and Methods

Intra- and interannual changes in the CPUE of Atka mackerel fisheries were investigated in three Aleutian Islands areas and one within the Gulf of Alaska management district: west of Kiska Island, Petrel Bank, Seguam Bank, and southeast of the Shumagin Islands (Figure 1). Fishery data collected in two consecutive years during 1992-95 were analyzed at each site (Table 1).

Fishery observers record a wide variety of information about each haul taken by a fishing vessel, including its retrieval location, depth, date, and total catch weight (all referred to hereafter as haul data). In addition, the catch of a randomly chosen subset of hauls is sampled to determine the species composition of the haul and the length distribution of the target species (see Nelson et al. (1981) and NMFS (1996) for observer sampling methodologies). To obtain a complete record of Atka mackerel removals from an area, hauls during which the species was targeted were defined as those where the species comprised at least 20% of the haul catch weight (Fritz 1997). Using this list of hauls, individual vessels that targeted Atka mackerel in each of the four areas were identified, and the haul data for every haul conducted by these vessels in the area and year were obtained. To estimate each vessel's haul-by-haul removals of Atka mackerel, the average proportion of Atka mackerel in the sampled hauls during each month was used to estimate the amount of the species caught in the unsampled hauls; only hauls (both sampled and unsampled) taken in the same contiguous area and depth range were used in the analysis.

Catch and effort data for all hauls from the fleet were pooled over various periods to obtain the time-series used in the Leslie analyses, with no fishing-power correction applied between vessels. Period length was one week in the three Aleutian Islands areas (Kiska, Petrel Bank and Seguam Bank), and ranged from half-days to half-weeks in the Gulf of Alaska area (Shumagin) to ensure that at least 10 hauls were pooled in each period and that there were at least 4 periods for the Leslie regression analysis. Average CPUEs of the fleet were obtained for each period by summing the Atka mackerel catch and dividing by the total hours trawled in the area. Periods with fewer than 10 hauls were excluded from regression analyses, but the catches were included in the cumulative catch.

Leslie's method of CPUE analysis provides a mechanism for estimating catchability (q) and the biomass of the original, pre-fished population (B_0) from a time series of catch and effort data through the following linear equation (Ricker 1975):

$$\frac{C_t}{f_t} = qB_0 - qK_t$$

where C_t and f_t are catch taken (metric tons (t) of Atka mackerel) and effort expended (hours trawled), respectively, during period t, and K_t is the cumulative catch to the start of period t plus half that taken during the period. Catchability is defined as the proportion of B_0 that is captured with one unit of effort (one hour trawled). Confidence limits for the estimate of B_0 were calculated according to DeLury (1951) as cited by Ricker (1975). Regression parameters were calculated using the data analysis tool pack provided with Microsoft Excel 5.0[1].

Results

On average, observers sampled about two-thirds of the hauls for catch composition (Table 1). Actual percentages ranged from 53% for the 1994 Shumagin fishery to 79% for the 1994 Kiska fishery. Consequently, the percentage of hauls for which estimates of the amounts of Atka mackerel caught were calculated ranged from a high of 47% for the 1994 Shumagin fishery to a low of 21% for the 1994 Kiska fishery. Sampled hauls contributed, on average, about 70% of the total Atka mackerel tonnage caught in each area and year, with catch estimates from the unsampled hauls providing the remainder (Table 1).

Aleutian Islands Areas

Kiska

The area west of Kiska Island utilized by the fishery in 1994 and 1995 was the smallest of the four considered in this study. It was approximately 20 km x 10 km, and centered about 25 km west of the island (Figure 2). Approximately 22,500 t and 27,100 t of Atka mackerel were caught in this area in 1994 and 1995, respectively (Table 1).

1994

In 1994, landings of Atka mackerel from Kiska occurred sporadically from April through July (Figure 3A). During weeks 11-16, 2 vessels caught approximately 4,000 t and had weekly

[1] Mention of a product name does not imply an endorsement by the National Marine Fisheries Service, NOAA.

average CPUEs between 33 and 45 $t \cdot hr^{-1}$ (Figure 3B). This was followed in turn by about 2 weeks with no landings and 4 weeks (18-22) when 6 vessels caught an additional 9,000 t and had weekly average CPUEs ranging from 24 and 34 $t \cdot hr^{-1}$. Only about 1,000 t of Atka mackerel were landed during the next 4 weeks (23-26). The fishery closed after 10 vessels caught approximately 10,000 t in the following 3 weeks (27-29), and had weekly average CPUEs ranging from 17 to 22 $t \cdot hr^{-1}$. The Leslie regression using fleet data from weeks 13-22 and 24-29 (weeks 11, 12 and 23 were excluded because the sample sizes were too small) was significant ($p<0.001$), and yielded estimates of q (0.0012), B_0 (32,161 t), and harvest rate (70%; Table 2). No subset of individual vessels had landings throughout the 1994 Atka mackerel fishing season at Kiska.

The same size-class of Atka mackerel, with modal lengths ranging from 38 to 40 cm, was caught each week during the 4-month fishery (Figure 4A). Only during weeks 22 and 26-29 were significant numbers of smaller Atka mackerel (between 30 and 35 cm) caught.

1995

The 1995 fishery at Kiska began in early February and in the first 6 weeks (weeks 5-10), almost 21,000 t were caught by 9 vessels (Figure 3C). During the next 9 weeks (11-19), only about 2,000 t was landed by as many as 7 catcher-processors. No fishing for Atka mackerel occurred west of Kiska Island from May 16 until July 3, a period of 7 weeks. The fishery closed on July 18 after an additional 4,000 t of Atka mackerel was caught.

For the first 10 weeks of the 1995 fishery (weeks 5-14), weekly average CPUEs ranged between 25 and 40 $t \cdot hr^{-1}$, similar to the range at the beginning of the 1994 fishery (Figure 3D). There was no evidence of a decline in CPUE during this period when most of the fishery landings occurred. From week 15 through 19, however, weekly average CPUEs declined to 9 $t \cdot hr^{-1}$. The Leslie regression was computed only for the data through week 18, with data from weeks 11, 13, and 19 excluded because the sample sizes were too small, and data from weeks 26-28 excluded because of the 7-week gap in fishing that preceded them. The regression coefficient was not significantly different from 0 at $p=0.153$ (Table 2). When the fishery resumed in weeks 26-28 (after a 7-week gap in fishing), weekly average CPUEs were approximately one-half those of weeks 5-7 (12-16 $t \cdot hr^{-1}$ and 24-36 $t \cdot hr^{-1}$, respectively).

In the fishery's first 3 weeks, the length-frequency distributions were unimodal (with modes of 38-39 cm), and were skewed to the left (smaller sizes; Figure 4B). Beginning in week 8 and continuing through week 18, the distributions were bimodal with the addition of 25-30 cm Atka mackerel. Following the 7-week period of no fishing, length-frequency distributions were unimodal in weeks 26-28.

Petrel Bank

The area fished on Petrel Bank was centered about 70 km northeast of Semisopochnoi Island and was roughly 50 km x 15 km (Figure 2). In 1993 and 1994, 21,200 t and 14,500 t of Atka mackerel were caught in this area, respectively (Table 1).

1993

Catches of Atka mackerel at Petrel Bank in 1993 accumulated steadily from mid-August through mid-October (weeks 32-41), when more than 19,000 t were caught by 6 vessels (Figure 5A). This was followed by 1 week of no fishing and approximately 2 weeks when 2,200 t were caught by 3 vessels. The weekly average fleet CPUE declined from 17-19 $t \cdot hr^{-1}$ in weeks 32-35 to less than 8 $t \cdot hr^{-1}$ in the first part of week 37. However, there was a sharp increase in CPUE, to a fleet average of 26 $t \cdot hr^{-1}$, in the second part of week 37. The same four vessels fished in both the first and second parts of week 37, and each had a similar increase during the week. From the second part of week 37 through week 41, average CPUEs for the fleet declined to between 11 and 14 $t \cdot hr^{-1}$. Average fleet CPUE remained at that level in weeks 42 and 43 even after a week-long gap in landings.

Leslie regressions were computed separately for the two intervals of CPUE decline observed in the 1993 Petrel Bank fishery: weeks 32-37 and weeks 37-41 (Table 2 and Figures 5B,C). In the first interval, a total of 5 vessels fished, and 3 had landings in each of the 6 weeks. Two regressions, which yielded similar results, were calculated on first interval data; one using the CPUE data of all 5 vessels ($p=0.032$), and the other using CPUE data from only the 3 vessels that fished the entire first interval regressed against the fleet's cumulative catch ($p=0.007$; Table

2). The latter regression analysis was conducted to see if the CPUE data from a subset of vessels that fished the entire interval yielded similar results to those utilizing aggregate data from the entire fleet, some of whom fished during only part of the interval. In the second interval, the Leslie regression was significant (p=0.034), yielding an estimate of q that was slightly higher than that from the first interval, while N_0 and harvest rate were slightly lower (Table 2).

In the first 5 weeks (32-36), length-frequency distributions were similar and unimodal at 37-38 cm; few fish smaller than 33 cm were caught (Figure 6A). Beginning in week 37, fish < 33 cm in length were increasingly caught by the fishery. The principal modal length in the catches (37-38 cm), however, remained the same each week.

1994

Approximately 3,300 t of Atka mackerel was caught by 3 boats during the first 1.5 weeks (weeks 6-7 beginning in mid-February) of the 1994 Petrel Bank fishery (Figure 5D). This initial fishing effort was followed by 1.5 weeks (weeks 7-8) with little or no catch and 8 weeks (9-16 ending in late April) when the remaining 11,200 t was caught by a total of 9 different vessels. Fleet average weekly CPUE declined from 28 $t \cdot hr^{-1}$ in week 7 (which was similar to the beginning of the second interval in 1993) to 7 $t \cdot hr^{-1}$ in weeks 15 and 16, and the Leslie regression was highly significant (p<0.001; Table 2 and Figure 5E). Regression parameters from the 1994 fishery were similar to those computed using data from the first interval of the 1993 fishery.

The fishery caught principally Atka mackerel between 35 and 42 cm in length in weeks 6-8 (Figure 6B). Beginning in weeks 9-11, smaller fish between 25 and 35 cm were caught in greater numbers, particularly in week 13. For most weeks, the principal length mode of the fishery catches was 37-39 cm, which was identical to 1993.

Seguam Bank

In both 1992 and 1993, the fishery utilized an area approximately 40 km x 30 km southeast of Seguam Island (Figure 2). About 30,000 t of Atka mackerel were caught in this area each year (Table 1).

1992

Atka mackerel catches accumulated slowly in weeks 3-10 (late January through mid-March), when 4 vessels caught a total of about 8,000 t (Figure 7A). During the last 5 weeks of the fishery, approximately 22,000 t was caught by as many as 16 vessels working in any single week. Fleet average CPUE declined from 31-36 $t \cdot hr^{-1}$ in weeks 3-6 to 9-17 $t \cdot hr^{-1}$ in weeks 7-11, increased in week 12 to 27 $t \cdot hr^{-1}$, and then declined to 11-12 $t \cdot hr^{-1}$ in weeks 13-15. The slope of the Leslie regression was significantly different from 0 ($p=0.034$), and the equation yielded estimates of q (0.0006), B_0 (44,535 t), and harvest rate (67%; Table 2 and Figure 7B).

During the first 5 weeks (3-7), each weekly length-frequency distribution had one mode at 34 cm and was skewed to the right (Figure 8A). In weeks 8 and 9, the size distribution was much broader and larger fish were caught. However, in the final 6 weeks, weekly length-frequency distributions were similar to those of weeks 3-7.

1993

In 1993, approximately the same amount of Atka mackerel was caught at Seguam Bank as in 1992, but the fishery was 5 weeks shorter, occurring only from late January through mid-March (weeks 3-10; Figure 7C). Only 4 vessels fished during the first 5 weeks and caught almost 10,000 t, while the remaining 21,000 t was caught by as many as 21 vessels each week during the last 3 weeks. Weekly average CPUEs ranged between 22 and 39 $t \cdot hr^{-1}$ during the first 5 weeks, and declined steadily to 13 $t \cdot hr^{-1}$ by week 10. The Leslie regression using data from the entire 1993 fleet was highly significant ($p=0.004$), and yielded estimates of q, B_0, and harvest rate that were similar to those calculated from the 1992 Seguam fishery (Table 2 and Figure 7D).

Four vessels fished continuously from weeks 3 through 9 and had similar mean CPUEs (ranging from 21 to 31 $t \cdot hr^{-1}$) during the 1993 Seguam fishery. Their weekly aggregate CPUE was regressed against the cumulative catch of all vessels to see what effect the 17 vessels (which had weekly average CPUEs ranging from 2.3 to 60.4 $t \cdot hr^{-1}$) entering the fishery in weeks 7-9 had on the Leslie regression estimates of q and B_0; the Leslie regression parameters were almost identical to those calculated using all the data (Table 2 and Figure 7D). The size distribution of the exploited population did not change during the 1993 Seguam Bank fishery (Figure 8B).

Gulf of Alaska Area

Shumagin Islands

Near the Shumagin Islands, Atka mackerel were targeted by the fishery in a 45 km x 25 km area east of Simeonof Island (Figure 2) in both 1993 and 1994. In 1993, over 1,800 t was caught, while catches dropped to just over 800 t in 1994 (Table 1).

1993

The 1993 Shumagin fishery began on 4 October and ended on 1 November after 6 vessels caught 1,858 t of Atka mackerel (Table 2 and Figure 9A). Initial fleet CPUEs were only about 8 $t \cdot hr^{-1}$, but declined significantly to less than 2 $t \cdot hr^{-1}$ over the course of the 29-day fishery ($p<0.001$; Table 2 and Figure 9B), and yielded Leslie regression estimates of B_0 (2,199 t) and harvest rate (84%). The estimate of q (0.0039) was over twice as high as any estimate from an Aleutian Islands area. Modal lengths ranged from 45 to 47 cm during the 1993 Shumagin fishery (Figure 10A).

1994

The 1994 Shumagin fishery lasted 13 days (from 30 September to 12 October), and 834 t of Atka mackerel was caught by 4 vessels (Table 2 and Figure 9C). Initial fleet CPUEs were about 10 $t \cdot hr^{-1}$ and declined rapidly to about 2 $t \cdot hr^{-1}$ (Figure 9D). Initial fleet CPUEs at the Shumagin area in both years were the smallest observed in any time/area fishery analyzed. The Leslie regression for the 1994 Shumagin fishery was significant ($p=0.001$), yielding an estimate of B_0 (920 t) that was less than one-half that estimated for 1993, while the estimate of q increased three-fold (to 0.0119; Table 2). The harvest rate estimate for the 1994 Shumagin fishery (91%) was the highest calculated in this study. Atka mackerel caught in 1994 in the Shumagin area were slightly longer than those caught in 1993, with modal lengths ranging from 47 to 49 cm (Figure 10B).

Discussion

An assumption of Leslie's method is that q remains constant over the course of a single fishery.

For fisheries with relatively short durations (days to several weeks), this assumption is probably not violated unless significant gear modifications were made (which in this study, while unknown, were unlikely). However, catchability may not be constant in longer Atka mackerel fisheries, particularly those that include portions of the summer spawning season when Atka mackerel congregate in shallow nearshore waters (Zolotov 1993; McDermott and Lowe, in press; Fritz and Lowe, in prep). The lack of information concerning gear design or deployment between years restricts inter-annual comparisons to be qualitative in nature (e.g., are estimates of N_0 and q of the same magnitude for the same area in different years?).

In all but one of the nine time-area Atka mackerel fisheries analyzed (two periods were analyzed in 1993 at Petrel Bank), Leslie regressions revealed that fleet CPUE and, by analogy, local Atka mackerel biomass, declined significantly over time. Analyses of changes in CPUE for the Kiska Island fishery in 1995 did not show a significant decrease over the course of the entire fishery, but fleet CPUE declined steeply in the last 3 weeks of the first period fished, and remained lower when the fishery resumed 7 weeks later. The remaining 8 time-area fisheries that had significant decreases in fleet CPUE with time lasted between 3 days and 17 weeks. Harvest rates in these fisheries ranged between 55% and 91%, indicating that these were periods of rapid and intensive fish removal.

There is little if any search time included in the haul duration denominator of the CPUE metric used in these analyses. The fishery operates primarily by towing back and forth along a number of specified tows in each area which requires much local knowledge of tides and bathymetry. The tows were originally developed by the foreign groundfish fisheries in the Aleutian Islands in the early 1970s and are of considerable importance to the fishery since Atka mackerel are found at these locations year after year and the fishery has developed methods and gear to effectively fish them with minimal loss of gear (S. McDermott, School of Fisheries, University of Washington, Seattle, WA 98195. Personal communication). Since the fishery does not spend much time searching for Atka mackerel (they have no swim bladder, and hence, make poor acoustic targets), the haul duration reflects the time it took to achieve the desired net fullness. Consequently, the time series of fleet CPUE also reflects the changes in size and density of Atka mackerel schools in the fished area, an assumption necessary for the use of

Leslie's method to calculate q, B_0 and harvest rate.

While results indicate that local fish population densities were reduced significantly, length-frequency data suggest that the exploited populations of Atka mackerel may not have been closed during the course of the fisheries. Immigration into the area utilized by the fishery would decrease q and increase B_0. This apparently occurred at both Petrel Bank in 1993 and Kiska Island in 1995: at the former, CPUE increased significantly during the course of the fishery, while at the latter, data suggest that immigration of small fish contributed to the maintenance of high CPUE during weeks 5-14. During the other time-area fisheries, Atka mackerel length-frequency distributions did not change significantly with time. However, the lack of significant change in length distributions does not necessarily mean that immigration was not occurring, but perhaps only that fish with similar length distributions were immigrating. Similarly, the increase in catch rates of small fish at Petrel Bank in 1993 and Kiska Island in 1995 could be due to emigration or fishery removals of the larger fish, not necessarily immigration of small fish. Emigration of large Atka mackerel, particularly males, may occur in late spring and summer as the reproductive portion of the population leaves pelagic feeding areas (where the fishery occurs) to spawn in shallow waters near shore (Fritz and Lowe, in prep.; Zolotov 1993). Emigration of fish would exaggerate the effects of the fishery on CPUE reductions, and result in a higher q and lower B_0.

Assuming that some level of immigration and emigration may have been occurring, the fishery removed Atka mackerel from exploited areas faster than they could repopulate it. Only in one instance was there strong evidence that large numbers of Atka mackerel immigrated during the course of the fishery. This occurred in week 37 of the 1993 Petrel Bank fishery, when an additional 14,000 t of Atka mackerel appeared and CPUEs increased over three-fold. In the case of the 1995 Kiska Island fishery, there was not a dramatic overnight increase in CPUE, but a maintenance of high CPUEs by the apparent continuous immigration of fish, many of which were smaller (and probably younger) than those originally exploited, for at least the first 10 weeks. By week 18, however, average CPUE declined to about one-quarter of the rates observed in weeks 5-14, suggesting that immigration rates had also declined. Indeed, even after a 7-week gap in fishing, weekly average CPUEs were only one-half of those observed at the beginning of the fishery, indicating that Atka mackerel had yet to fully repopulate the fished area. These patterns of CPUE decline and immigration suggest that the fishery utilizes areas prefered by adult Atka mackerel, and that the area from which the fishery actually removes fish is larger than that shown by the trawl locations in Figure 2.

At all three Aleutian Islands areas, Leslie analyses indicated that the Atka mackerel population had rebounded by the time the second year's fishery began. At Kiska Island, there was a 27-week gap between the 1994 and 1995 fisheries. There was no B_0 estimated in 1995, but weekly average CPUEs for the first 10 weeks were similar to those initially observed in 1994, when almost 22,500 t were caught. Initial B_0 estimates at Petrel Bank were about 18,500 t in both 1993 and 1994, even with 1993 removals totalling over 21,000 t; the two fisheries were separated by over 15 weeks. Similarly, the estimate of B_0 for Seguam Bank in 1993 (47,300 t) was almost identical to that of 1992 (44,500 t), despite 1992 removals of almost 30,000 t; these two fisheries were separated by 39 weeks.

At the Shumagin Islands area analyzed in the Gulf of Alaska, the 1994 B_0 estimate was significantly smaller than that estimated in 1993. The Atka mackerel population in the Gulf of Alaska has experienced considerable fluctuations in the recent past. In the mid-1970s, annual catches as high as 27,000 t were realized by Russian factory-trawlers, but the population all but disappeared by the mid-1980s (Lowe and Fritz 1996b; O. Zolotov, Laboratory of Pelagic Fish, Pacific Research Institute of Fisheries and Oceanography, Kamchatka Branch, 18, Naberezhnaya, Petropavlovsk-Kamchatsky, 683602, Russia. Personal communication). The Atka mackerel population in the Gulf of Alaska is apparently dependent on recruitment (probably as juveniles or adults) from large year-classes in the Aleutian Islands (Lowe et al., in press). While spawning has been observed in the Gulf of Alaska (McDermott and Lowe, in press), Atka mackerel < 25 cm in length have been very rarely caught by either survey or fishery trawls (Lowe and Fritz 1996b). Five of the six cohorts spawned from 1984 to 1989 in the Aleutian Islands were above average in numbers (Lowe and Fritz 1996a), and beginning in 1990, these same year-classes of Atka mackerel were targeted by the fishery in the Gulf of Alaska (Lowe and Fritz 1996b). However, the 1990-93 year-classes (with the possible exception of 1991) do not appear to be large in the Aleutian Islands. Leslie regression analyses presented here suggest that the size of the Atka mackerel population near the Shumagin Islands in the Gulf of Alaska declined from 1993 to 1994, perhaps reflecting the passage of the large, late 1980s year classes through the population. Because evidence suggests that the Atka mackerel population in the Gulf of Alaska is not self-sustaining, a fishery targeting it may cause more rapid fluctuations in its population size than in the Aleutian Islands.

From 1992 to 1994, annual harvest rates for the entire Aleutian Islands Atka mackerel population were each less than 10% based on age-structured population modeling (Lowe and Fritz 1996a). In the Gulf of Alaska, Atka mackerel was not given its own catch quota in 1993 but was included in the "Other Species" category; catch quotas of "Other Species" were higher than the Atka mackerel catches in 1993 (Lowe and Fritz 1996b). In 1994, however, an annual quota for Atka mackerel was established based on a target harvest rate of 15% of the 1993 bottom trawl survey biomass estimate of 21,600 t (Lowe and Fritz 1996b). Thus, even though target, system-wide harvest rates were low in both the Aleutian Islands and Gulf of Alaska, the fishery in each region was actually conducted as a series of intense fish removals from small areas where local harvest rates greatly exceeded the intended target rate of removals from the entire managed system. Furthermore, allocation of proportions of the system's quota to subareas in the both the Aleutian Islands and Gulf of Alaska management areas, which began in 1993, did not prevent high local harvest rates from occurring.

Whether the documented reductions in CPUE constituted localized depletions of Atka mackerel remains a matter of definition of the phrase "localized depletion". In these cases, local harvest rates were as high as 91% and population densities in one area apparently remained low for as long as 7 weeks after the fishery ended. In the Aleutian Islands, Atka mackerel repopulated each area prior to the beginning of the subsequent year's fishery. While the timing of this repopulation apparently does not affect the fishery, it could disadvantage Steller sea lions and other Atka mackerel predators. The Atka mackerel fishery significantly reduced local population densities of an important sea lion forage fish that, in one instance, remained low long after fishing vessels left the area. Furthermore, since evidence suggests that Atka mackerel immigrated into the fished area, the area occupied by the original population and from which Atka mackerel were removed may have been larger than that actually fished and may have included areas inside trawl-exclusion zones. While this study revealed the magnitude and provided indications of the areal extent of fishery-induced reductions in local Atka mackerel populations, more research on how these reductions affect foraging success is required before the competitive interactions between fisheries and sea lions are understood.

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Figure Legends

Figure 1. The Aleutian Islands and western Gulf of Alaska. Box in inset A shows the location enlarged in B. The four labelled boxes in B show the locations of the Atka mackerel fisheries detailed in Figure 2. EEZ=U.S. Exclusive Economic Zone.

Figure 2. Trawl retrieval locations of Atka mackerel fisheries west of Kiska Island in 1994 and 1995 (A), on Petrel Bank in 1993 and 1994 (B), on Seguam Bank in 1992 and 1993 (C), and near the Shumagin Islands in 1993 and 1994 (D). Depth contours and the locations of annual 10 nautical mile (nmi) and seasonal (January-April) 20 nmi trawl exclusion zones (TEZ) are also shown.

Figure 3. The Atka mackerel fisheries west of Kiska Island in 1994 (A and B) and 1995 (C and D). Cumulative catch in 1994 (A) and 1995 (C). Weekly average Atka mackerel CPUE ($\sum t \cdot \sum h^{-1}$) of the fleet plotted against Leslie cumulative catch (K_t; defined in text), and the Leslie regression line (see Table 2) for the 1994 (B) and 1995 (D) fisheries.

Figure 4. Weekly aggregate percent length-frequency distributions of Atka mackerel from the 1994 (A) and 1995 (B) fisheries west of Kiska Island.

Figure 5. The Atka mackerel fisheries on Petrel Bank in 1993 (A, B and C) and 1994 (D and E). Cumulative catch in 1993 (A) and 1994 (D). Weekly average Atka mackerel CPUE ($\sum t \cdot \sum h^{-1}$) of the fleet plotted against Leslie cumulative catch (K_t; defined in text), and the Leslie regression line (see Table 2) for the 1993 (B. Weeks 32-37; data from all vessels and from three that fished the entire time, and C. Weeks 37-41) and 1994 (E) fisheries.

Figure 6. Weekly aggregate percent length-frequency distributions of Atka mackerel from the 1993 (A) and 1994 (B) fisheries on Petrel Bank.

Figure 7. The Atka mackerel fisheries on Seguam Bank in 1992 (A and B) and 1993 (C and D). Cumulative catch in 1992 (A) and 1993 (C). Weekly average Atka mackerel CPUE ($\sum t \cdot \sum h^{-1}$) of the fleet plotted against Leslie cumulative catch (K_t; defined in text), and the Leslie regression line (see Table 2) for the 1992 (B) and 1993 (D. Weeks 3-10 for all vessels and Weeks 3-9 for four vessels that fished the entire time) fisheries.

Figure 8. Weekly aggregate percent length-frequency distributions of Atka mackerel from the 1992 (A) and 1993 (B) fisheries on Seguam Bank.

Figure 9. The Atka mackerel fisheries southeast of the Shumagin Islands in 1993 (A and B) and 1994 (C and D). Cumulative catch in 1993 (A) and 1994 (C). Average Atka mackerel CPUE ($\sum t \cdot \sum h^{-1}$) of the fleet for each period plotted against Leslie cumulative catch (K_t; defined in text), and the Leslie regression line (see Table 2) for the 1993 (B; period=half-week) and 1994 (D; period=quarter-week) fisheries.

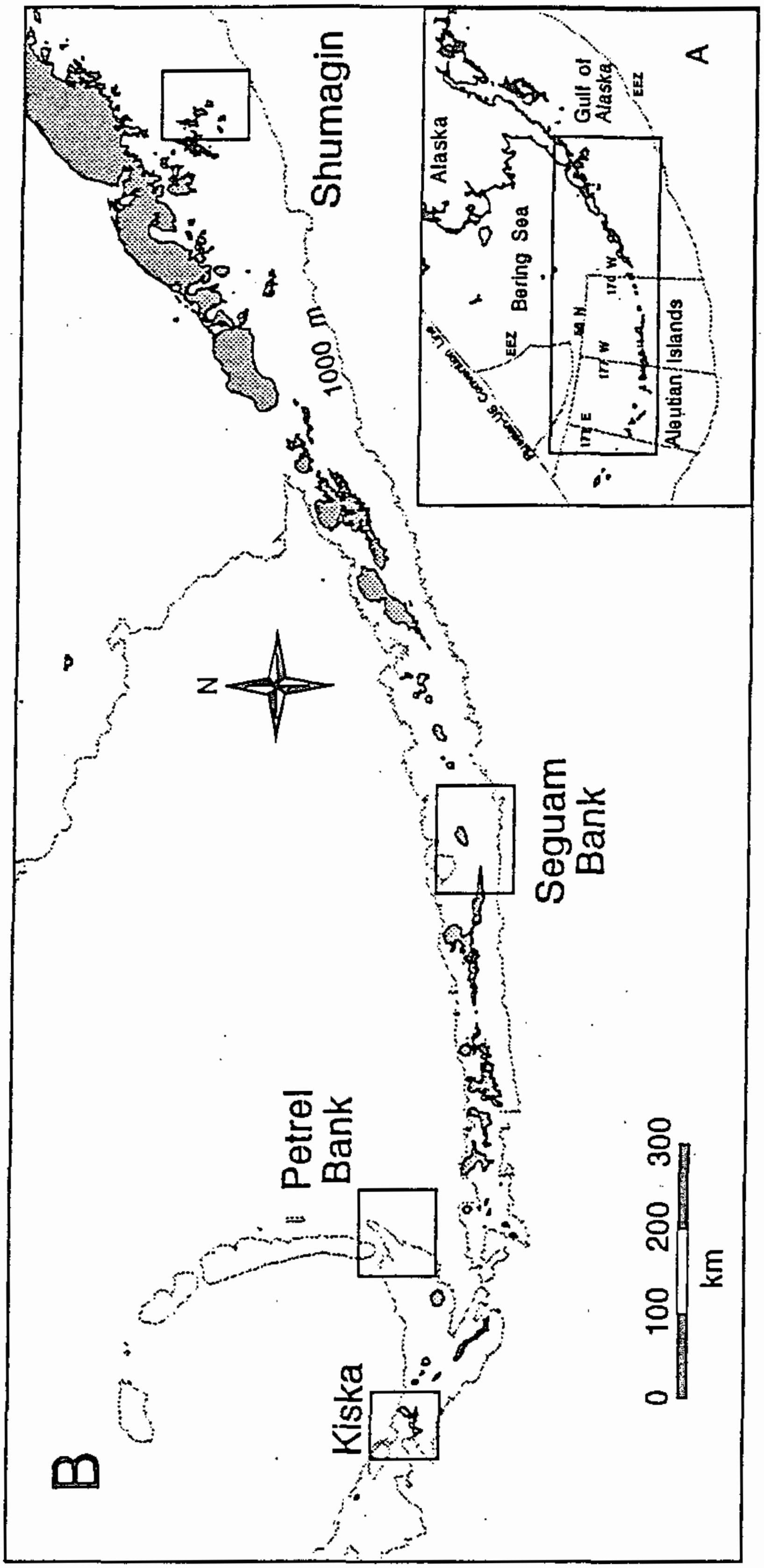
Figure 10. Aggregate percent length-frequency distributions of Atka mackerel from the 1993 (A; period=half-week) and 1994 (B; period=quarter-week) fisheries southeast of the Shumagin Islands.

Table 1. Description of data used in analyses of fishery catch per unit effort of Atka mackerel at four areas in the Aleutian Islands and Gulf of Alaska, 1992-95.

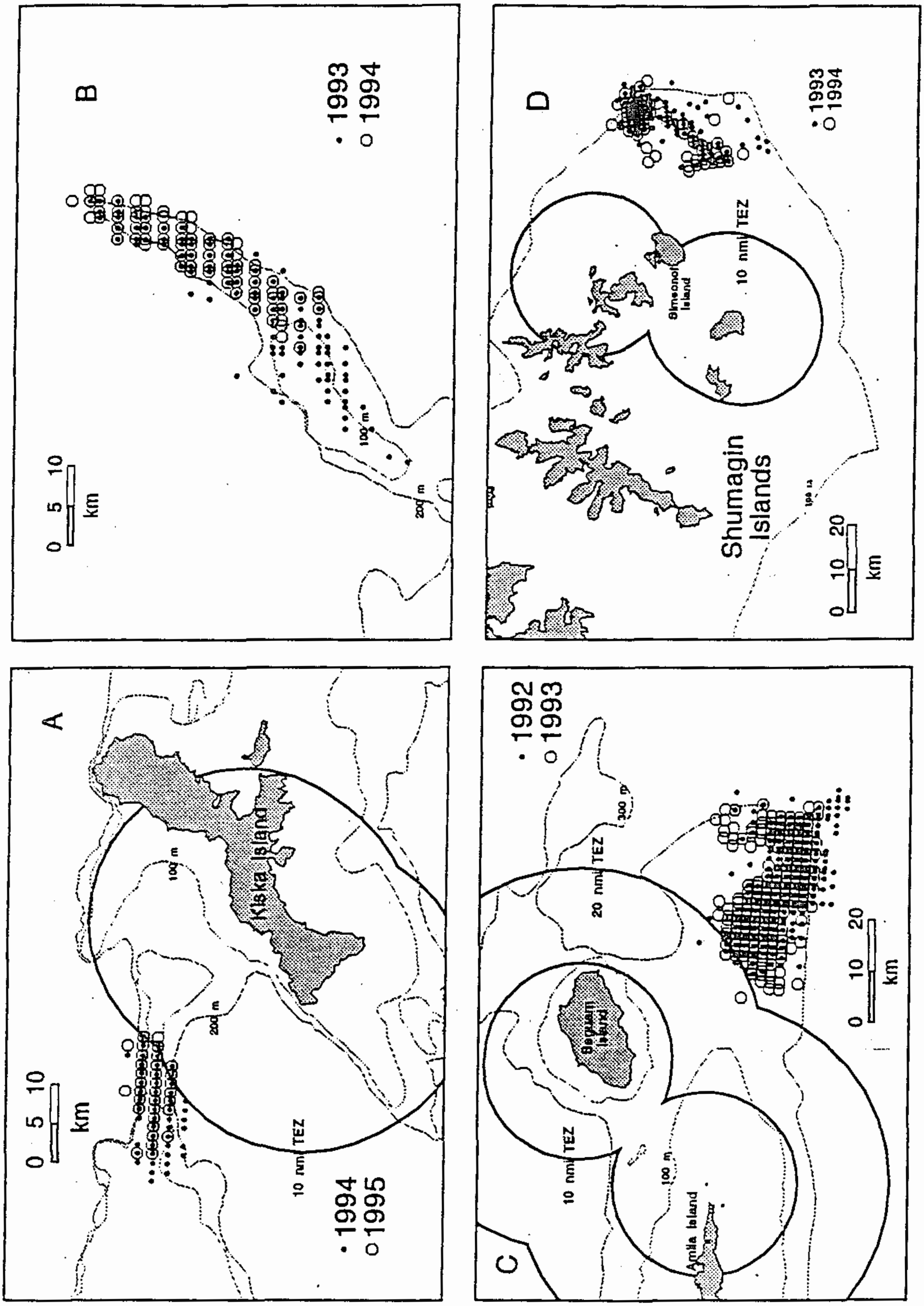
Area	Year	Number of: Vessels	Number of: Sampled Hauls	Number of: Total Hauls	Number of: Lengths	Percent Hauls Sampled	Atka mackerel t in: Sampled Hauls	Atka mackerel t in: Total Hauls	Percent Atka mackerel in Sampled Hauls
Kiska Island	94	11	467	592	35,775	79%	18,168	22,467	81%
	95	11	390	597	29,552	65%	18,632	27,069	69%
Petrel Bank	93	7	378	564	20,702	67%	15,066	21,206	71%
	94	9	297	496	13,339	60%	9,158	14,530	63%
Seguam Bank	92	25	738	1,326	50,777	56%	19,081	29,909	64%
	93	21	676	1,030	42,969	66%	22,875	31,704	72%
Shumagin Islands	93	6	159	279	4,031	57%	971	1,858	52%
	94	4	71	135	2,047	53%	505	834	61%

Table 2. Results of Leslie regression analyses for Atka mackerel fisheries in four areas and years. Period refers to the length of time over which catch and effort data were accumulated. Periods used refers to the period used (by number during the year) in the analysis. f = total hours trawled; q = catchability; C = total catch of Atka mackerel in tons; B_0 = computed original, unfished population size in tons; $C \cdot B_0^{-1}$ = harvest rate; CI = confidence interval in tons; p = significance of regression coefficient (all except Kiska Island 1995 were significant at $p<0.05$).

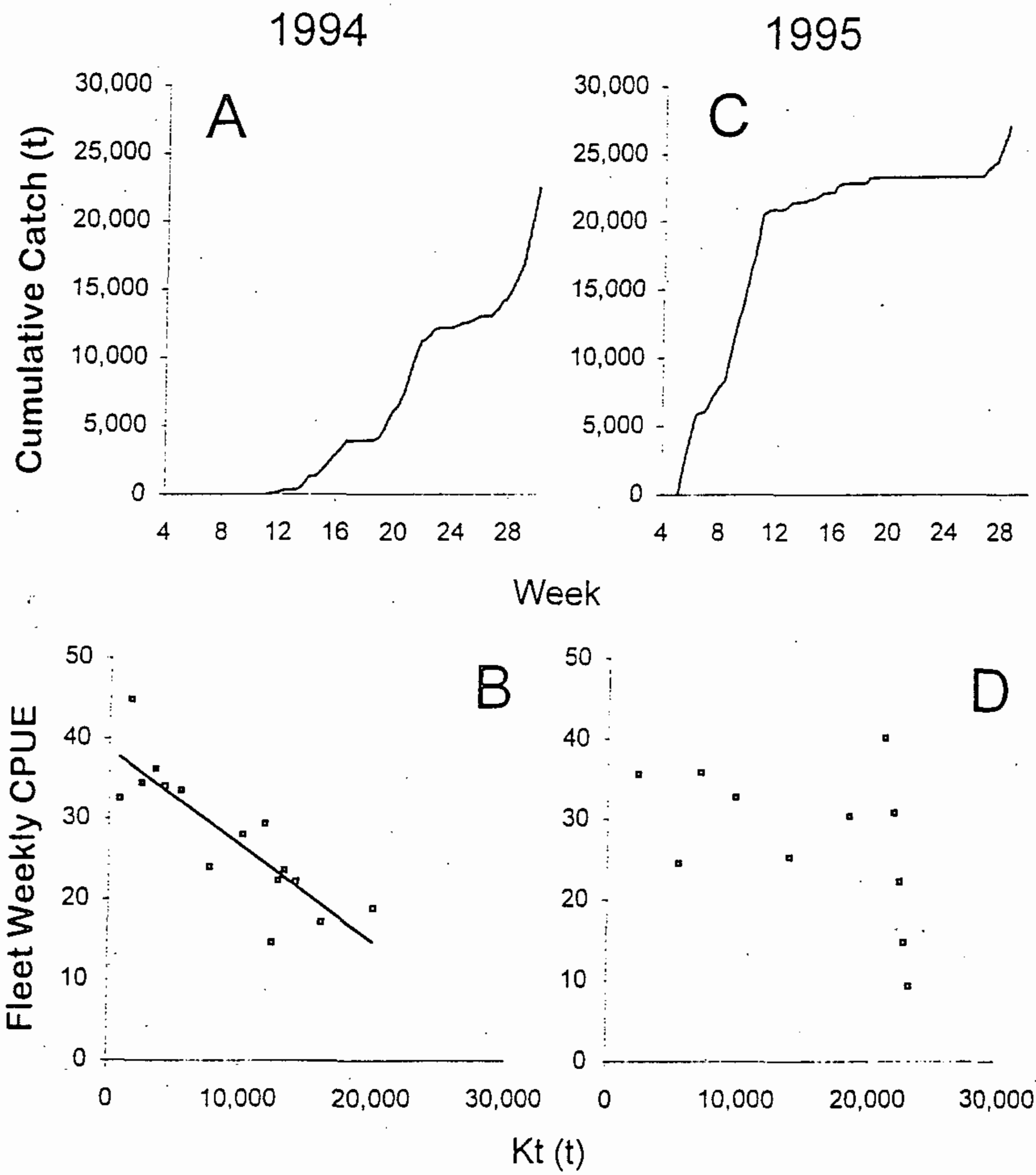
Area	Year	Period	Periods Used	No. of Vessels	f	q	C	B_0	$C \cdot B_0^{-1}$	95% CI on B_0	p
Kiska	94	Week	13-22, 24-29	11	952.4	0.0012	22,467	32,161	69.9%	25,711 - 45,768	<0.001
	95	Week	5-10, 12,14-18	11	801.1		23,232				0.153
Petrel	93	Week	32-37	5	851.4	0.0012	11,268	18,395	61.3%	12,145 - 97,625	0.032
Bank	93	Week	32-37	3	583.1	0.0014	11,268	16,028	70.3%	12,068 - 28,965	0.007
	93	Week	37-41	7	476.4	0.0018	7,784	14,045	55.4%	9,281 - 72,010	0.034
	94	Week	7,9-16	9	1,146.4	0.0013	14,530	18,585	78.2%	15,468 - 25,354	<0.001
Seguam	92	Week	3-15	25	1,812.3	0.0006	29,909	44,535	67.2%	27,676 - 372,271	0.034
Bank	93	Week	3-10	21	1,573.1	0.0007	31,705	47,493	66.8%	34,819 - 86,875	0.004
	93	Week	3-9	4	701.5	0.0007	30,836	47,256	65.3%	31,634 - 130,298	0.014
Shumagin	93	Week/2	79-86	6	521.3	0.0039	1,858	2,199	84.5%	1,924 - 2,677	<0.001
	94	Week/4	157-162	4	185.5	0.0119	834	920	90.6%	763 - 1,227	0.001



B
Shumagin
1000 m
N
Seguam
Bank
Petrel
Bank
Kiska
0 100 200 300
km
A
Alaska
Gulf of
Alaska
Bering Sea
Aleutian Islands
EEZ


A
Kiska Island
10 nmi TEZ
100 m
200 m
0 5 10
km
• 1994
○ 1995
B
0 5 10
km
100 m
200 m
• 1993
○ 1994
C
Seguam Island
Amlia Island
10 nmi TEZ
20 nmi TEZ
100 m
300 m
0 10 20
km
• 1992
○ 1993
D
Simeonof Island
10 nmi TEZ
Shumagin Islands
0 10 20
km
• 1993
○ 1994

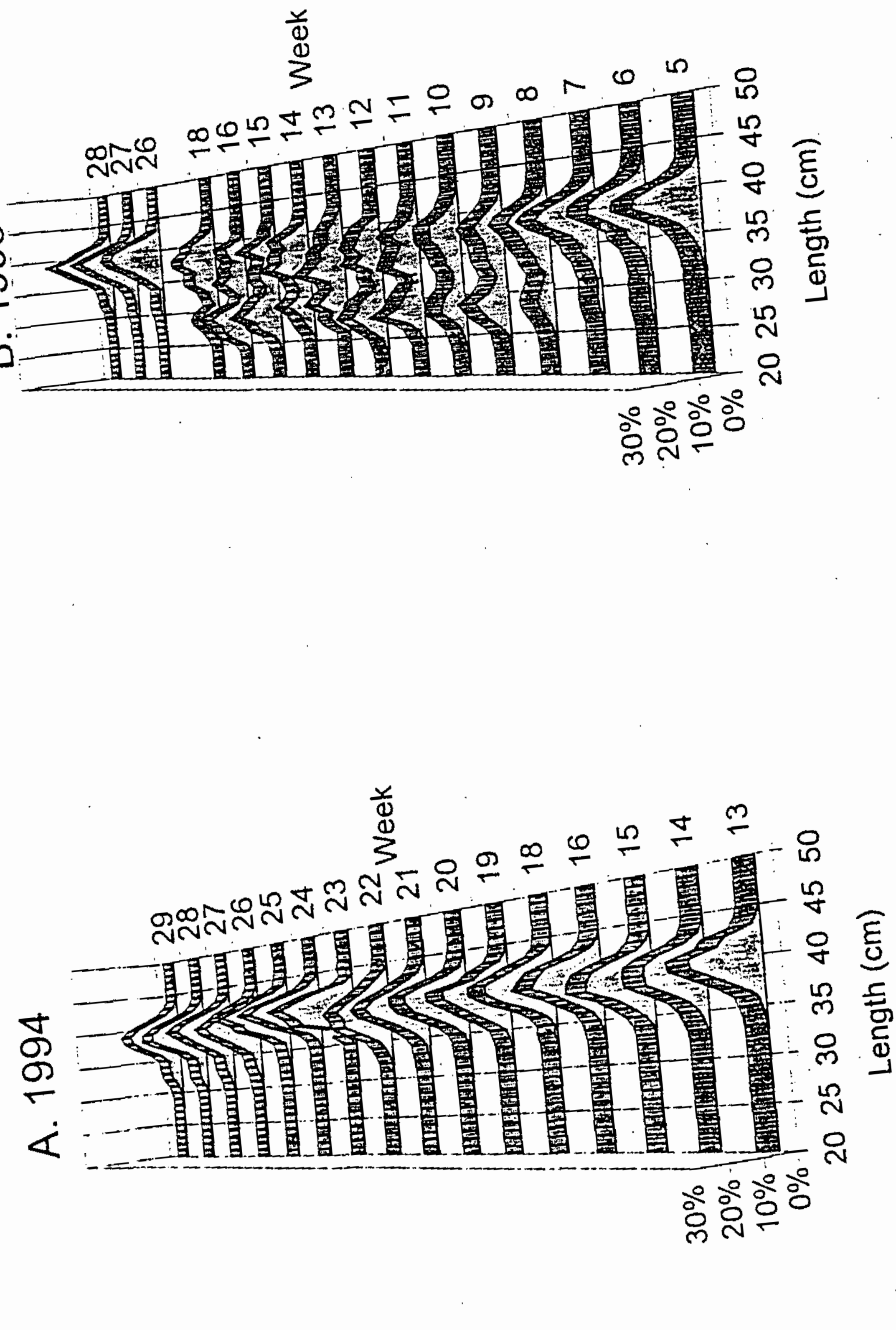
(3)



1994
1995
A
B
C
D
Cumulative Catch (t)
30,000
25,000
20,000
15,000
10,000
5,000
0
4
8
12
16
20
24
28
Week
Fleet Weekly CPUE
50
40
30
20
10
0
10,000
20,000
30,000
Kt (t)

Fig 3

(4)



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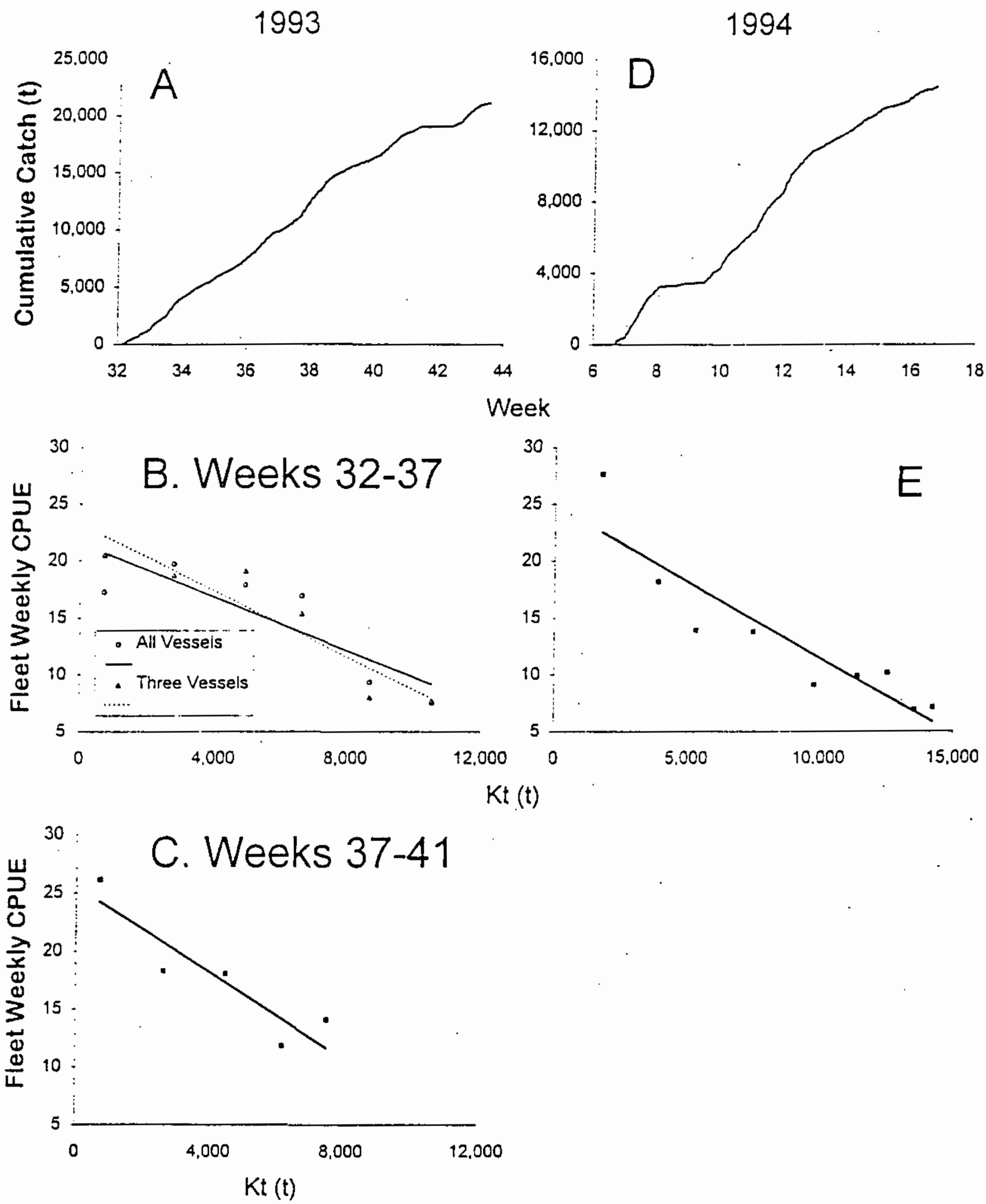
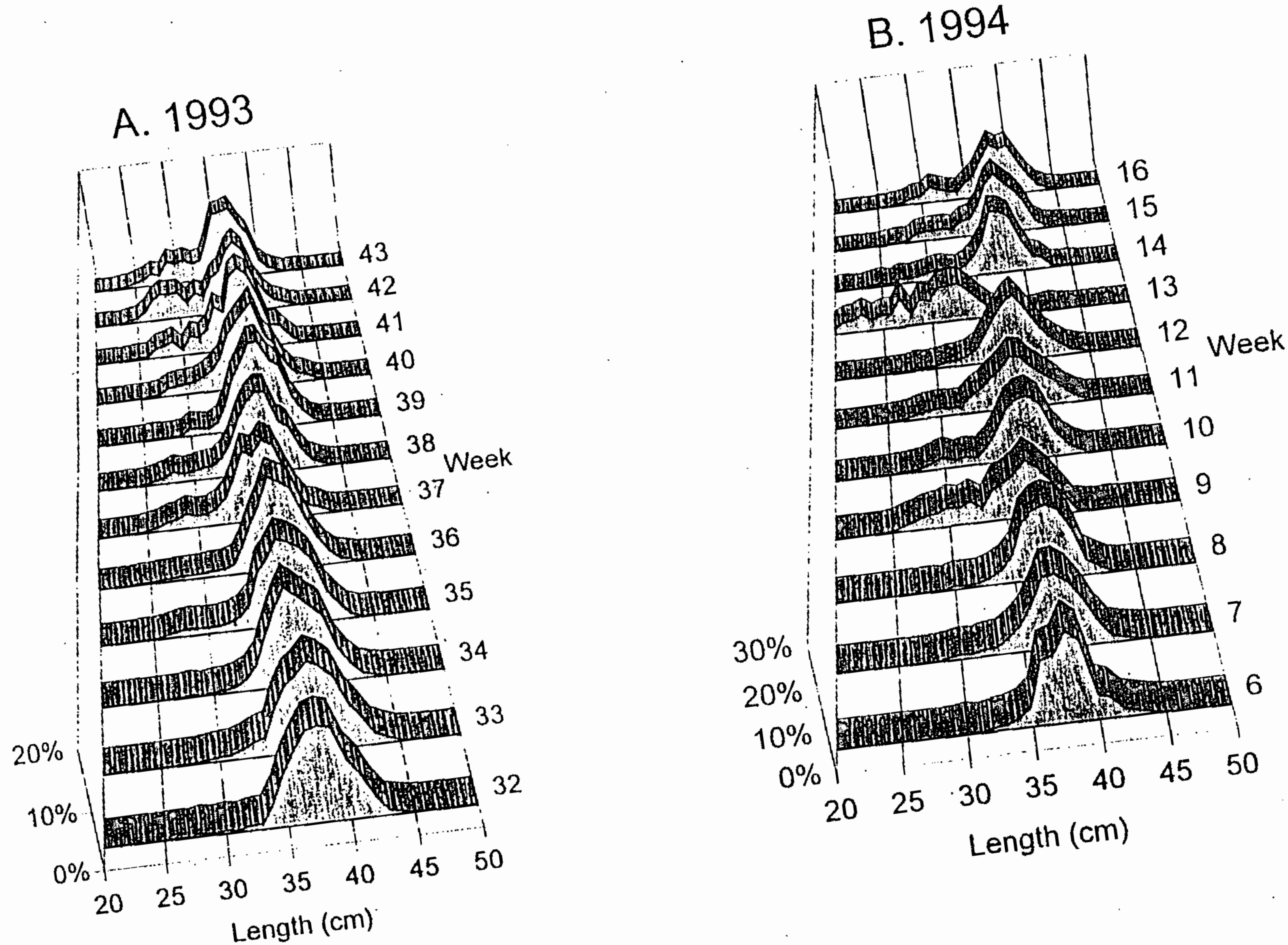
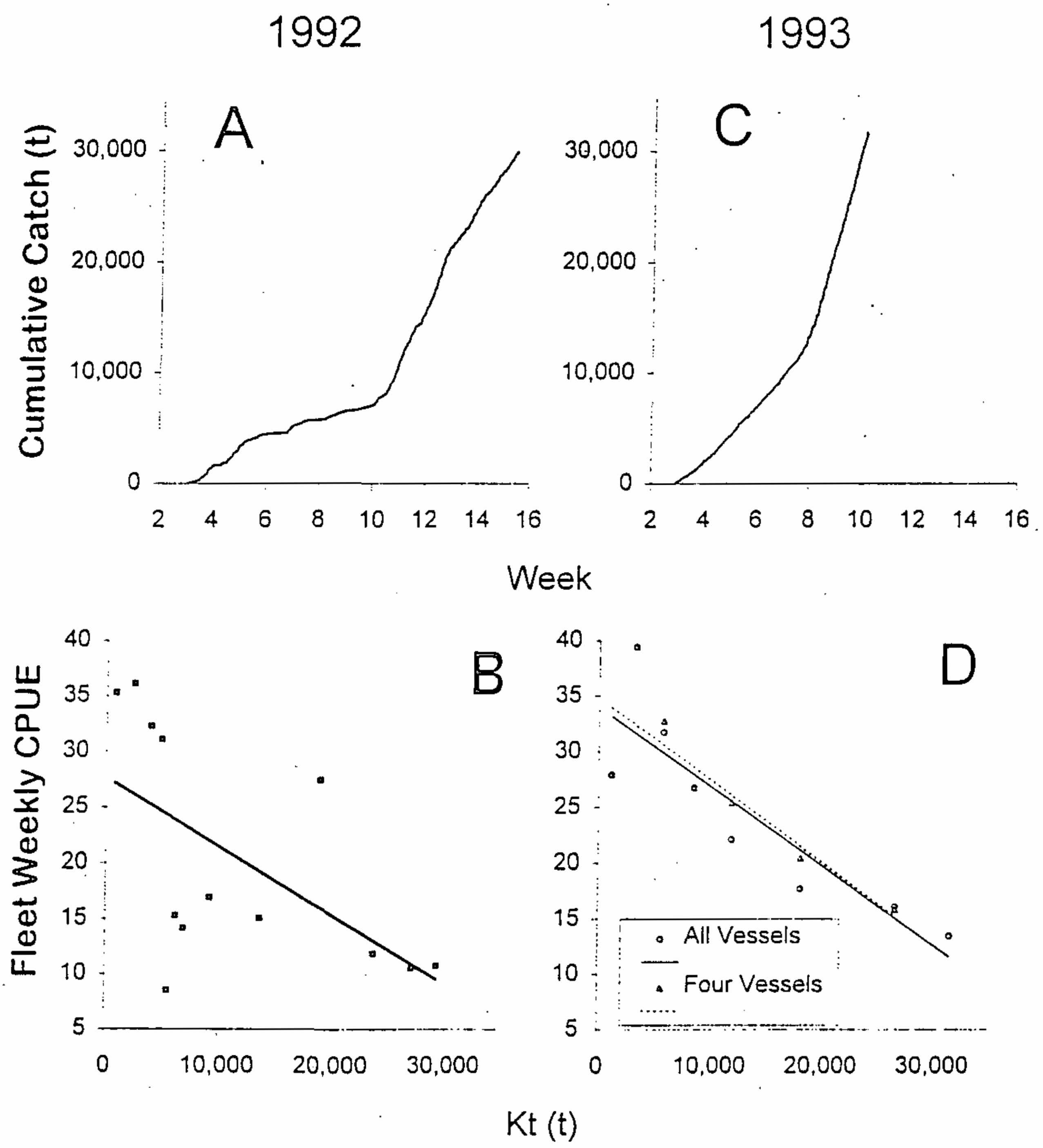
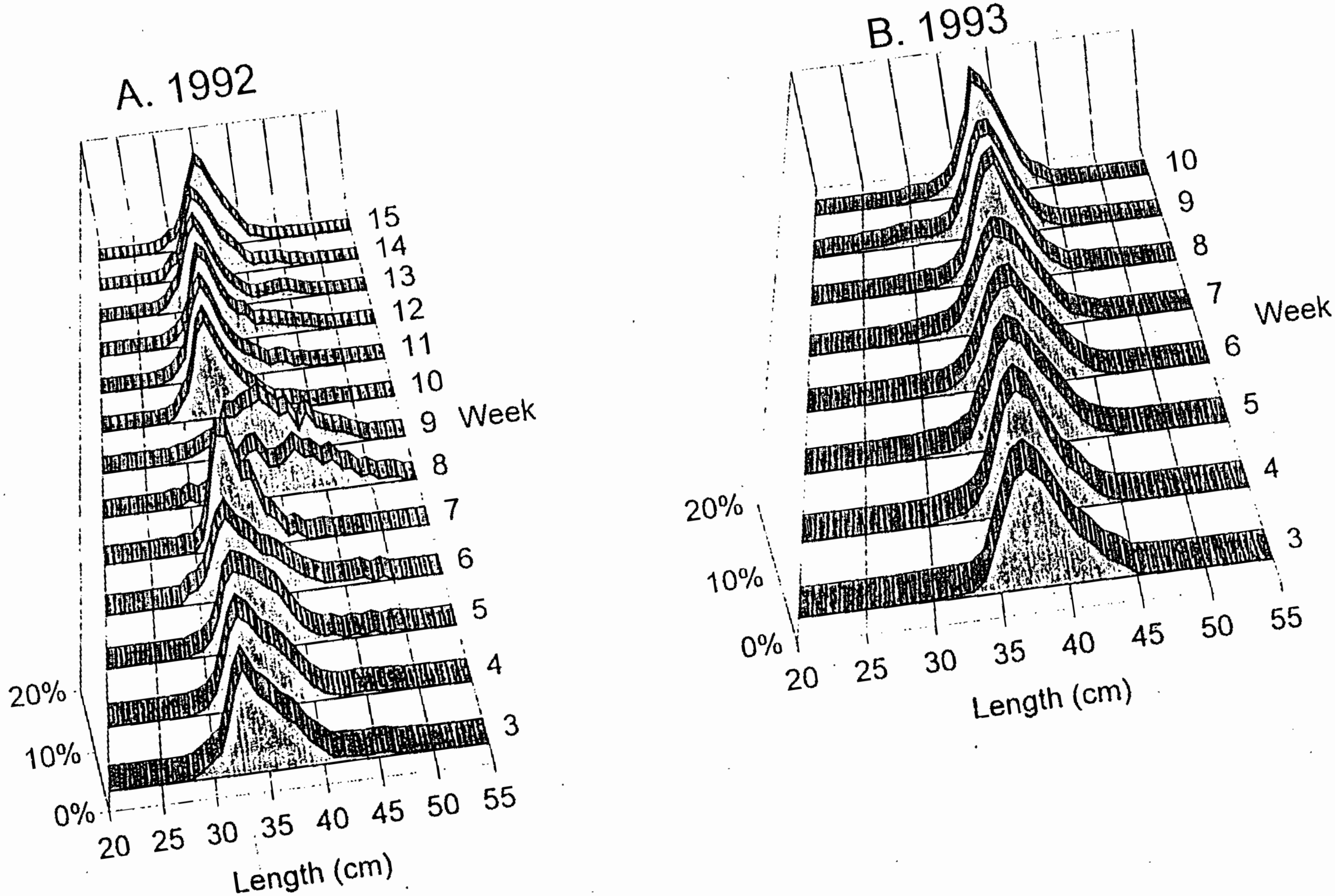
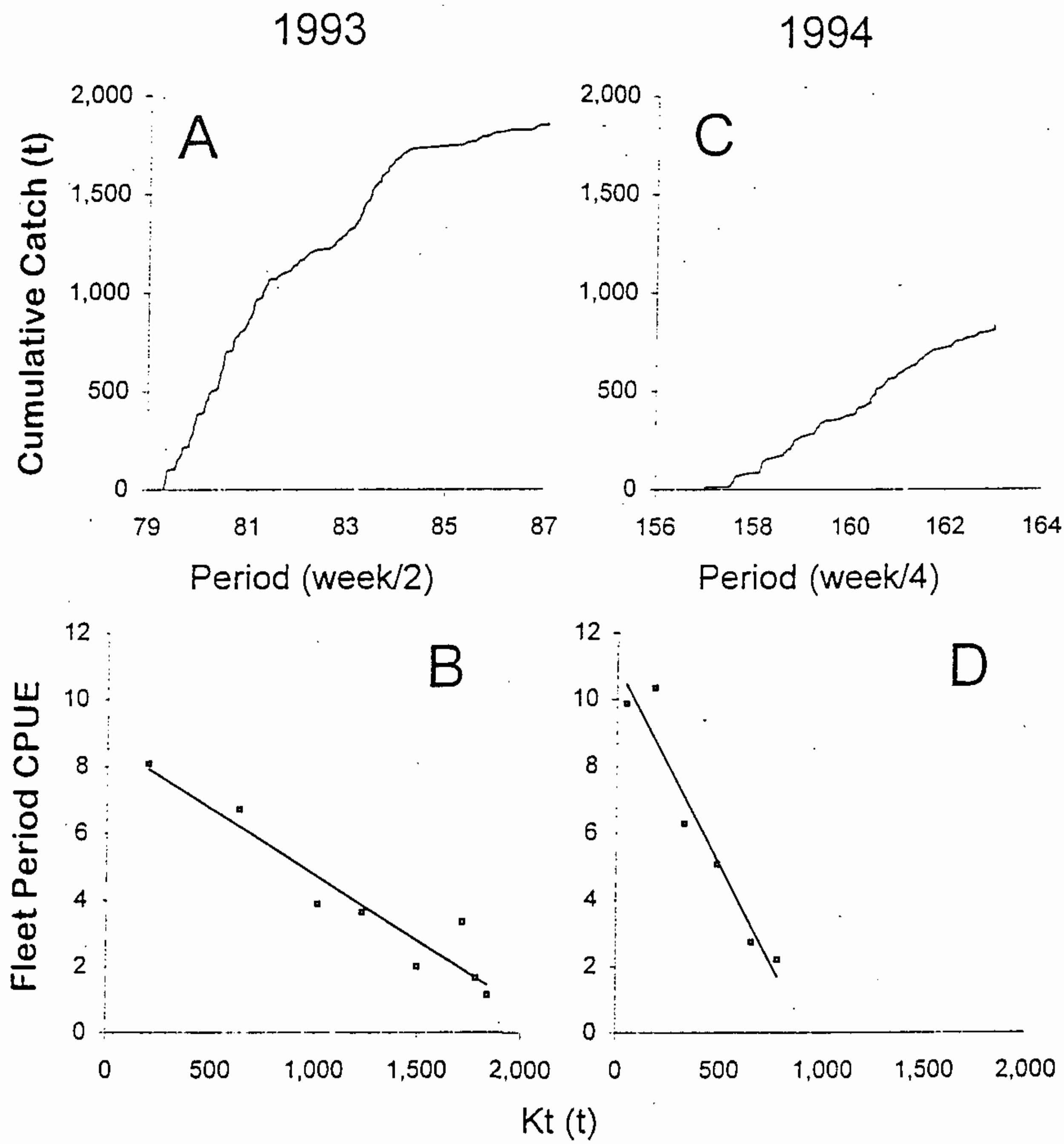

1993
1994
A
D
Cumulative Catch (t)
25,000
20,000
15,000
10,000
5,000
0
16,000
12,000
8,000
4,000
32
34
36
38
40
42
44
6
8
10
12
14
16
18
Week
B. Weeks 32-37
E
Fleet Weekly CPUE
30
25
20
15
10
5
All Vessels
Three Vessels
0
4,000
8,000
12,000
5,000
10,000
15,000
Kt (t)
C. Weeks 37-41
Fleet Weekly CPUE
Kt (t)

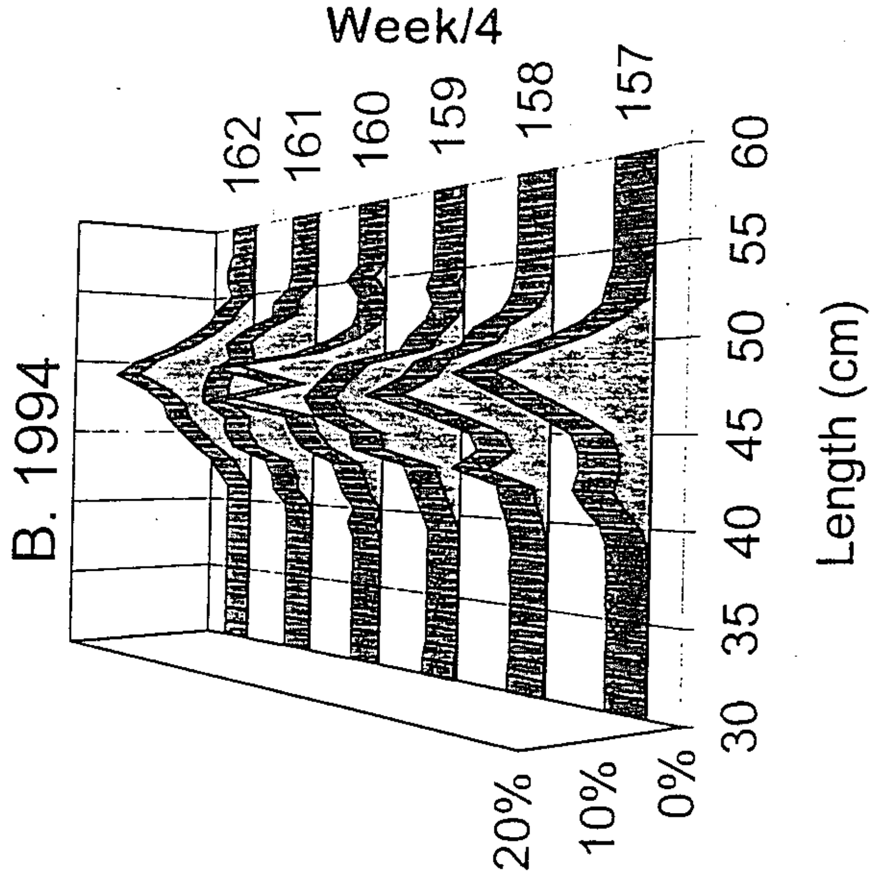

A. 1993
B. 1994
Week
43
42
41
40
39
38
37
36
35
34
33
32
16
15
14
13
12
11
10
9
8
7
6
0%
10%
20%
30%
20
25
30
35
40
45
50
Length (cm)

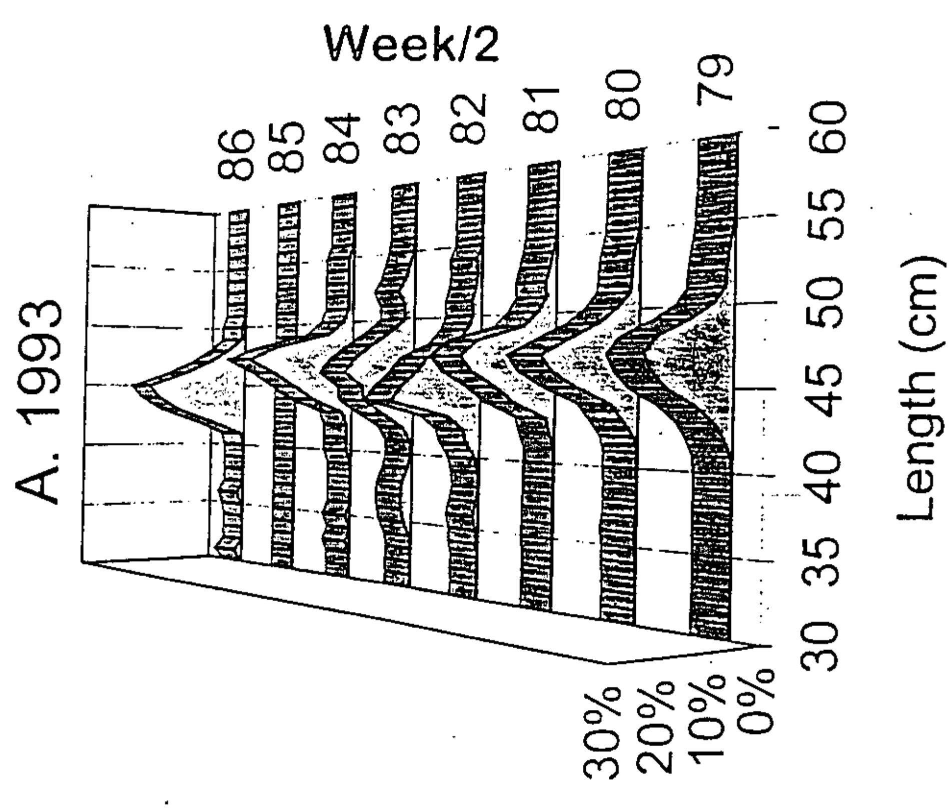


1992
1993
A
C
B
D
Cumulative Catch (t)
30,000
20,000
10,000
0
2
4
6
8
10
12
14
16
Week
Fleet Weekly CPUE
40
35
30
25
20
15
10
5
0
10,000
20,000
30,000
All Vessels
Four Vessels
Kt (t)


A. 1992
15
14
13
12
11
10
9
8
7
6
5
4
3
Week
20%
10%
0%
20
25
30
35
40
45
50
55
Length (cm)
B. 1993
10
9
8
7
6
5
4
3
Week
20%
10%
0%
20
25
30
35
40
45
50
55
Length (cm)


1993
1994
A
C
B
D
Cumulative Catch (t)
2,000
1,500
1,000
500
0
79
81
83
85
87
156
158
160
162
164
Period (week/2)
Period (week/4)
Fleet Period CPUE
12
10
8
6
4
2
0
500
1,000
1,500
2,000
Kt (t)


B. 1994
Week/4
162
161
160
159
158
157
20%
10%
0%
30
35
40
45
50
55
60
Length (cm)


A. 1993
Week/2
86
85
84
83
82
81
80
79
30%
20%
10%
0%
30
35
40
45
50
55
60
Length (cm)

12.0 APPENDIX 2. SUMMARY OF LESLIE DEPLETION ANALYSES

Appendix 2. Summary of Leslie depletion analyses on Atka mackerel fishery data, 1986-97.

The following tables and figures summarize the results of the Leslie depletion analyses of in-season changes in catch-per-unit-effort (CPUE=mt Atka mackerel/hour trawled) at 9 areas in the Aleutian Islands (Figure 6). Eight of these fished areas are entirely or mostly (Seguam) within the 20 nm critical habitat zone around Steller sea lion rookeries and major haulouts, and are:

- Amchitka, south of the east and west ends of the island (n=2) in area 542
- Buldir, east and west of the island (n=2) in area 543
- Delarofs, north of the Delarof Islands in area 542
- Tanaga, east side of Tanaga Pass in area 542
- Seguam, south of Seguam Island on the 200 m bank in area 541
- Kiska, west of Kiska Island, split between 542 and 543

The ninth area, Petrel Bank, is outside of critical habitat in area 542.

The tables provide summaries of catches of Atka mackerel, the number of vessels, the day the fishery began and ended, and the total number of hauls for all time/area fisheries analyzed. The period length column in the tables denotes the length of time over which catch and effort data were summed for the Leslie analyses. If the relationship between CPUE and cumulative catch for a single time/area fishery was significant (slope of the line significantly different from 0 at $p<0.05$)), then the Leslie estimates of initial biomass and catchability (q=slope) are provided, and harvest rate is calculated as the ratio of catch to initial biomass. The column labelled "Smith Biomass" is that calculated by Martin D. Smith, a graduate student at U. California, Davis, who reviewed the statistical properties of the Leslie model particularly with respect to auto-correlation. For those time-area periods that he found significant relationships between CPUE and cumulative catch (with contemporaneous catch removed), the initial biomass he calculated is provided for comparison with the one computed by NMFS.

The figures provide visual representations of the cumulative Atka mackerel catch over the course of each fishery as well as the CPUE of each haul. The aggregate fleet CPUE is also plotted against cumulative catch, and for those relationships that were significant, the Leslie regression line is plotted.

At Kiska (1994) and Seguam (1993), two other methods of aggregating data besides equal time interval were examined. These included (1) equal number of hauls, and (2) equal Atka mackerel catch amounts. For both types of binning, greater number of data points for the Leslie regression were obtained than when equal time intervals were used. The results of the Leslie regression from all three types of binning were very similar.

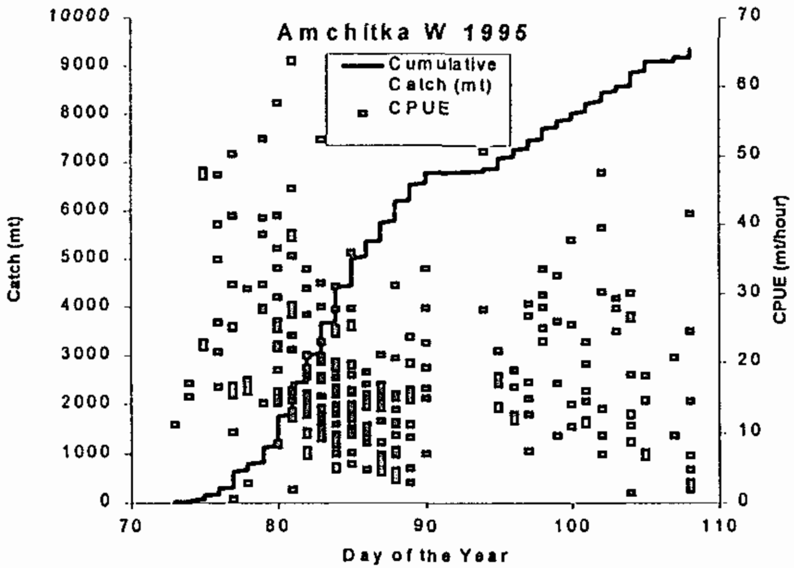
Included for some areas and years that yielded significant relationships between cumulative catch and CPUE are Leslie analyses using only the first half of the data (in terms of tonnage caught). This was performed to see if splitting the year into two seasons alone would have prevented a significant CPUE decline. For these analyses, equal time periods were not used to aggregate data. Instead, either the equal number of hauls method or the equal tonnage method (at Seguam and Kiska only) of binning was used. The number of hauls pooled at each location varied, but was between 8 and 14. The results of these analyses are in bold face type in the tables below, and in all cases except 1 (8 of 9 examined) also yielded a significant relationship between CPUE and cumulative catch.

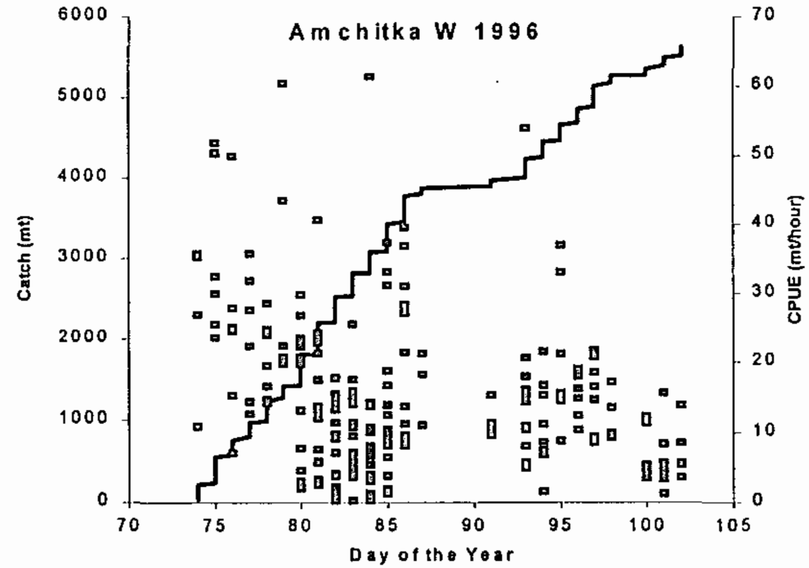
Amchitka West

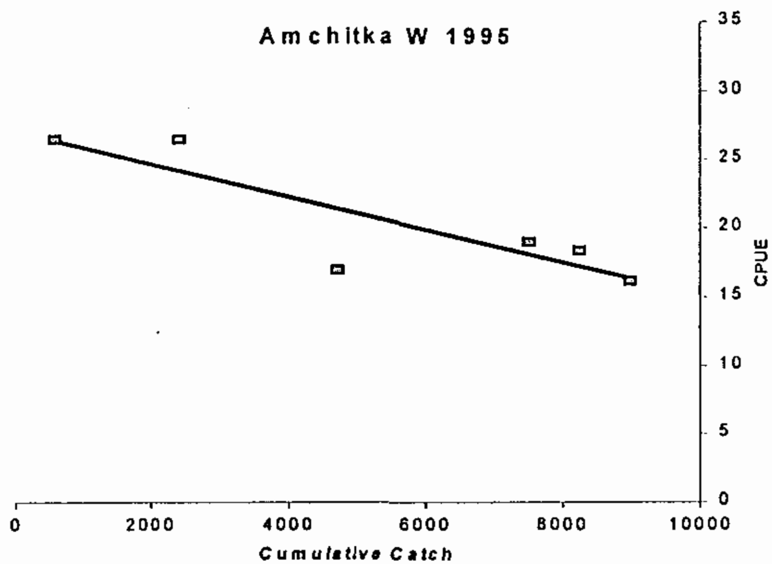
Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Catchability	Harvest Rate	Smith Biomass
1995	14-Mar	18-Apr	32	4	9	289	9,344				
					using CPUE of 1 vessel			22,630	0.0012	41%	
	14-Mar	**26-Mar**	**12**	**hauls=14**	**7**	**138**	**4,683**	**11,198**	**0.0022**		
1996	14-Mar	11-Apr	24	4	7	214	5,633	7,476	0.0035	75%	7,397
					using CPUE of 1 vessel			8,587	0.0033	66%	
1997	1-Mar	15-Mar	15	2.5	3	97	3,219				

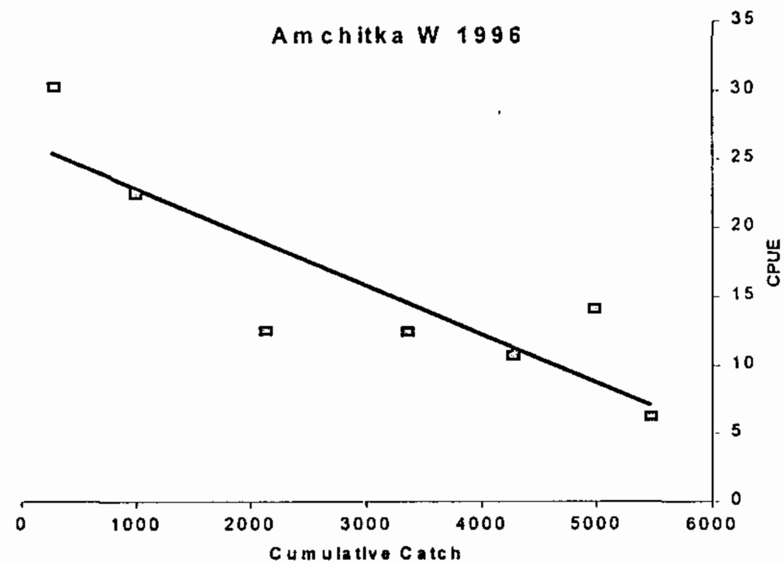
Amchitka East

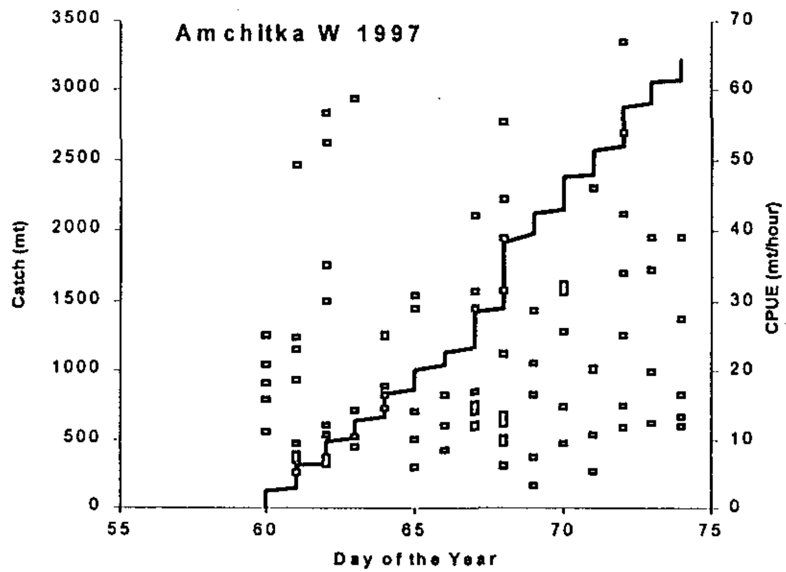
Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Catchability	Harvest Rate	Smith Biomass
1986	24-Apr	27-May	24	4	3	204	2,841	4,757	0.0012	60%	5,233
1995	10-Mar	25-Apr	31	6	1	84	3,331				
1996	19-Feb	14-Apr	46	7	9	198	6,973				11,596
					using CPUE of 1 vessel			10,941	0.0027	64%	
	19 Feb	**28-Mar**	**39**	**hauls=9**	**7**	**95**	**3,561**				
1997	25-Feb	15-Mar	18	3	7	110	5,610	7,461	0.0044	75%	7,269

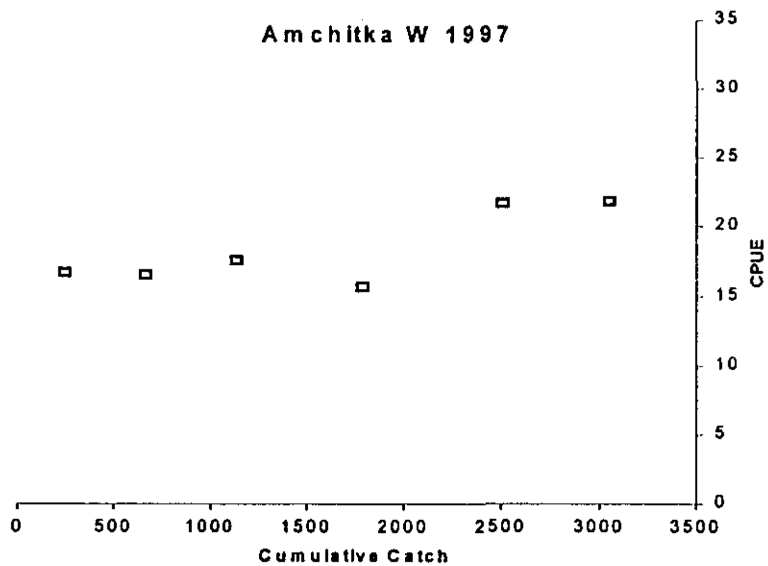

Amchitka W 1995
Cumulative Catch (mt)
CPUE
Catch (mt)
CPUE (mt/hour)
Day of the Year

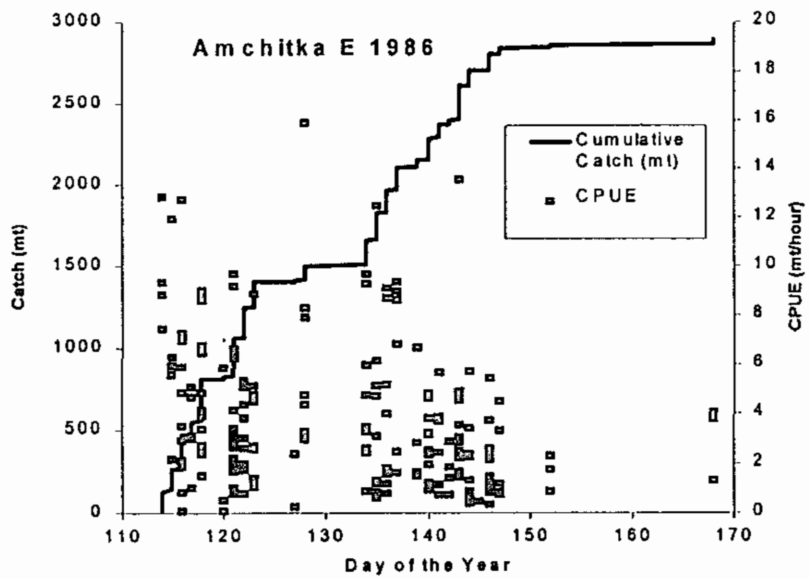

Amchitka W 1996
Catch (mt)
CPUE (mt/hour)
Day of the Year


Amchitka W 1995
CPUE
Cumulative Catch

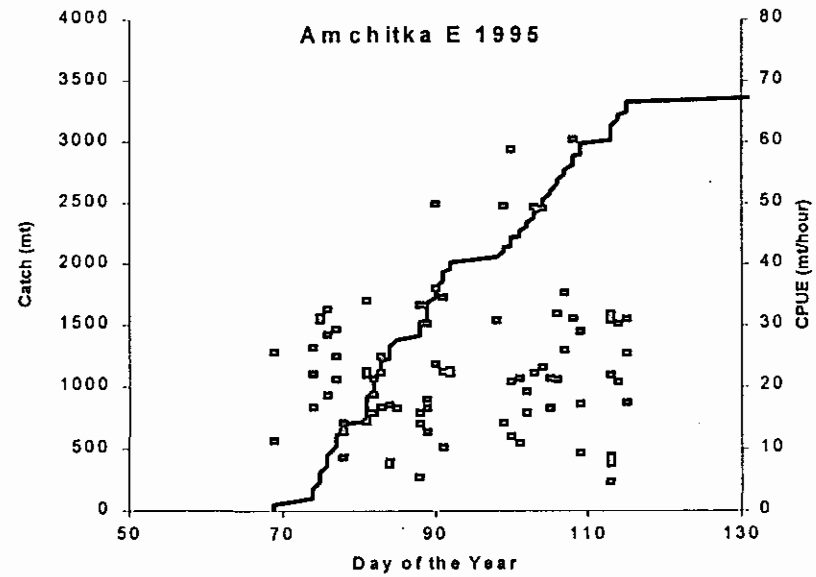

Amchitka W 1996
CPUE
Cumulative Catch


Amchitka W 1997
Catch (mt)
CPUE (mt/hour)
Day of the Year
3500
3000
2500
2000
1500
1000
500
0
55
60
65
70
75
70
60
50
40
30
20
10

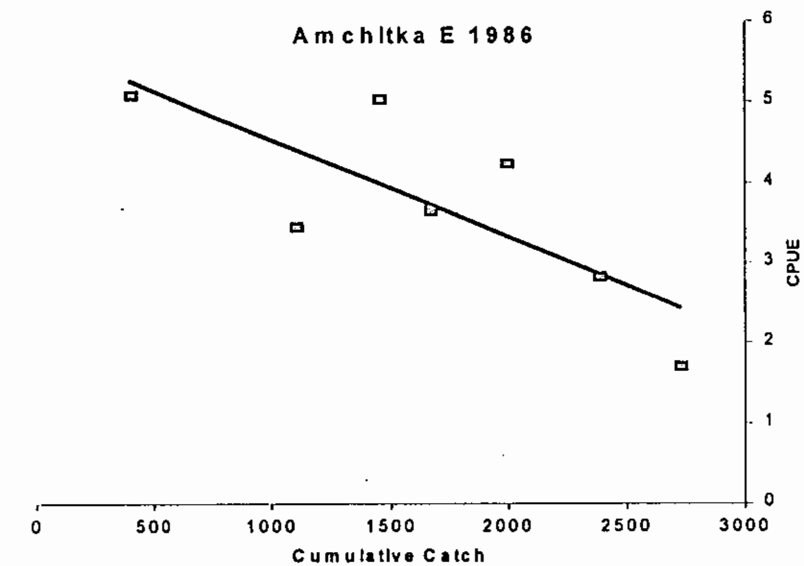

Amchitka W 1997
CPUE
Cumulative Catch
35
30
25
20
15
10
5
0
500
1000
1500
2000
2500
3000
3500



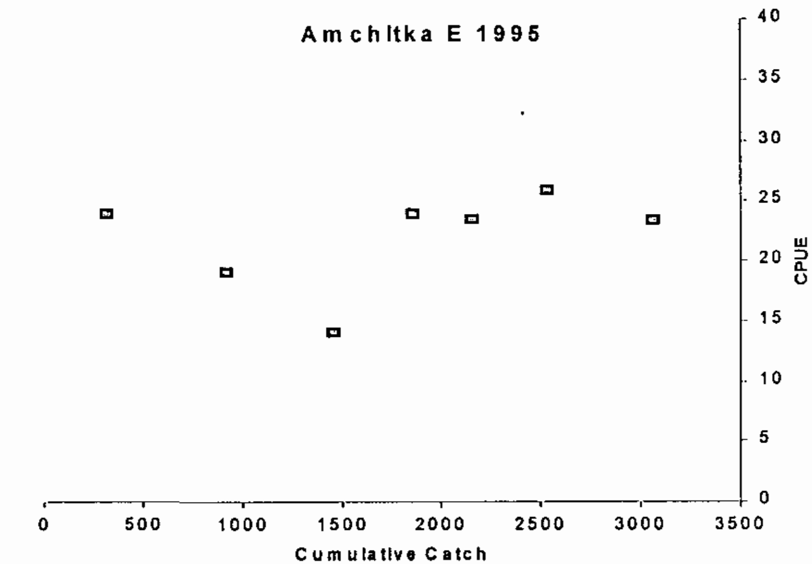
Amchitka E 1986
Cumulative Catch (mt)
CPUE
Catch (mt)
CPUE (mt/hour)
Day of the Year



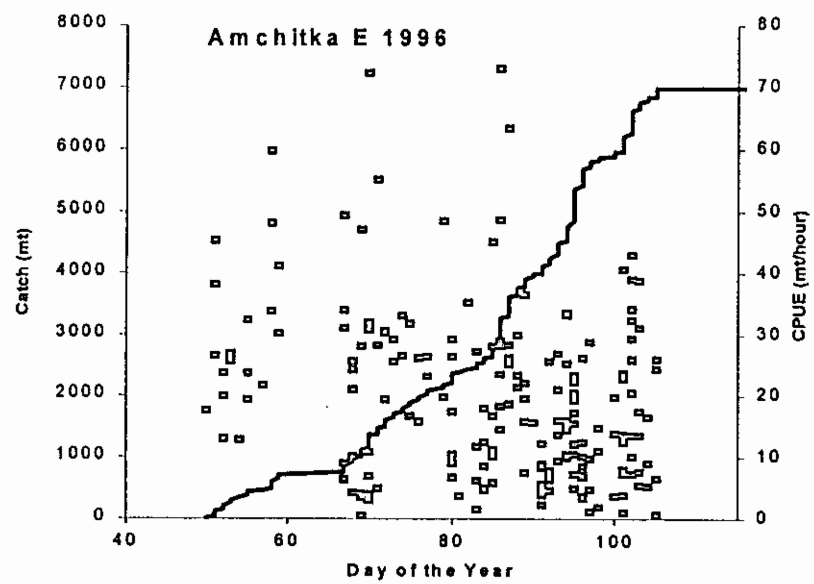
Amchitka E 1995
Catch (mt)
CPUE (mt/hour)
Day of the Year

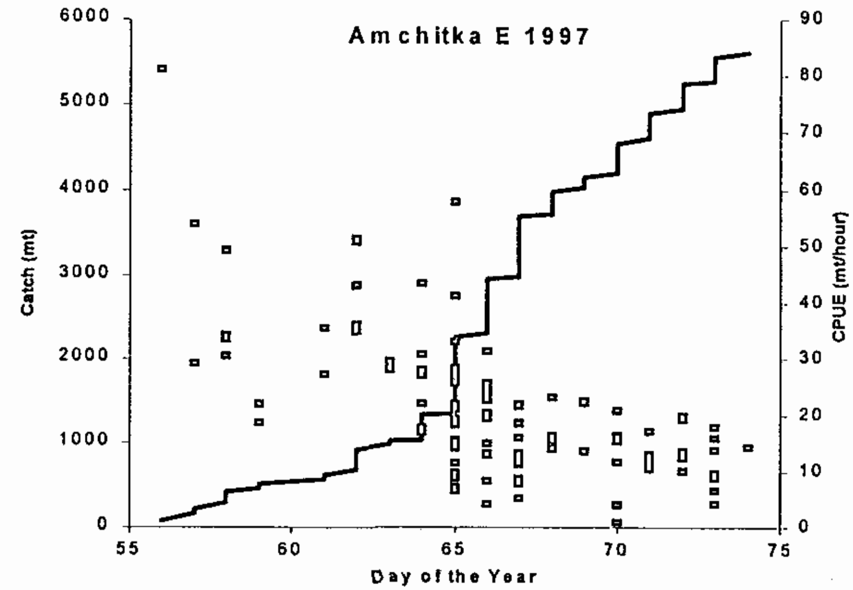


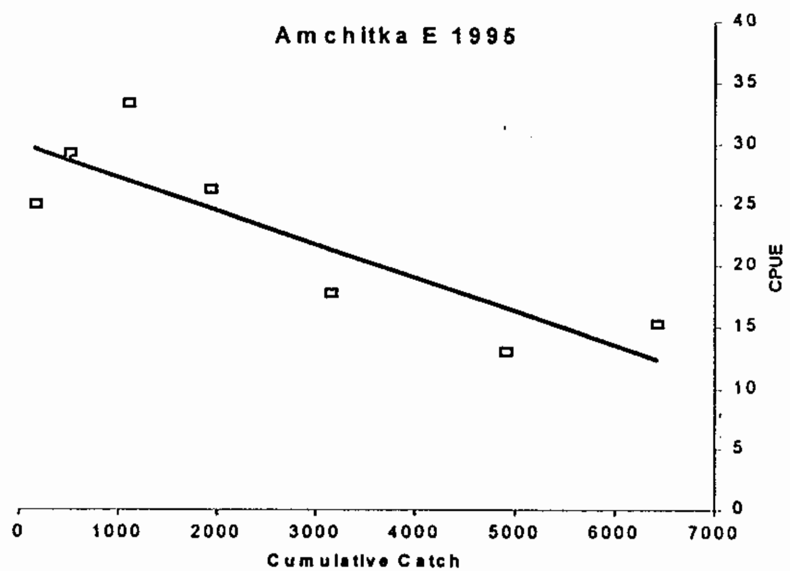
Amchitka E 1986
CPUE
Cumulative Catch

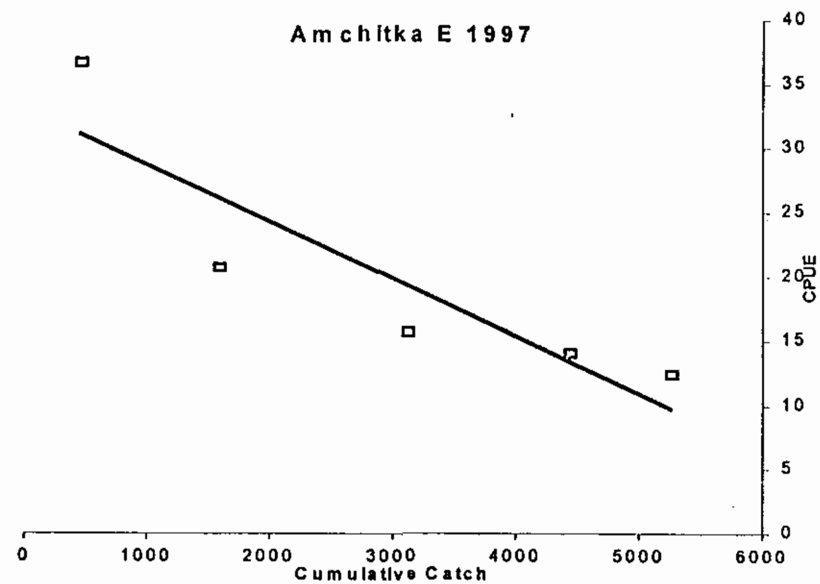


Amchitka E 1995
CPUE
Cumulative Catch


Amchitka E 1996
Catch (mt)
CPUE (mt/hour)
Day of the Year


Amchitka E 1997
Catch (mt)
CPUE (mt/hour)
Day of the Year


Amchitka E 1995
CPUE
Cumulative Catch

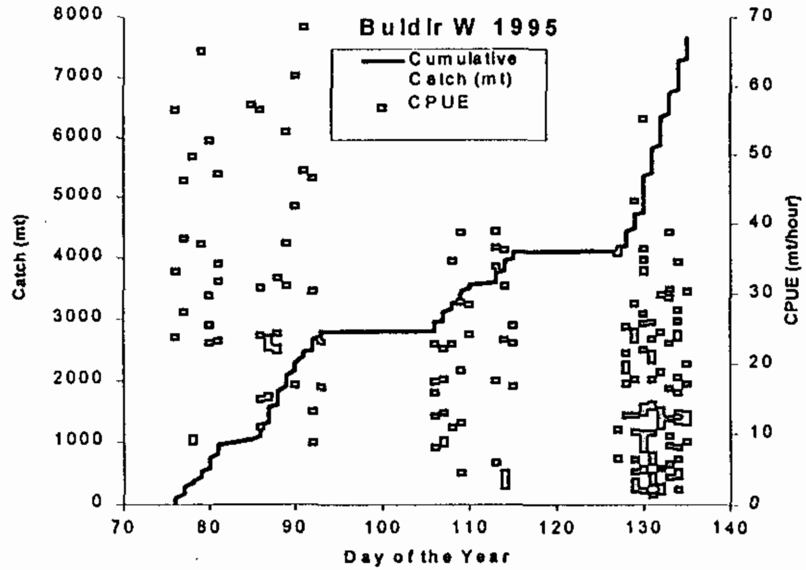

Amchitka E 1997
CPUE
Cumulative Catch

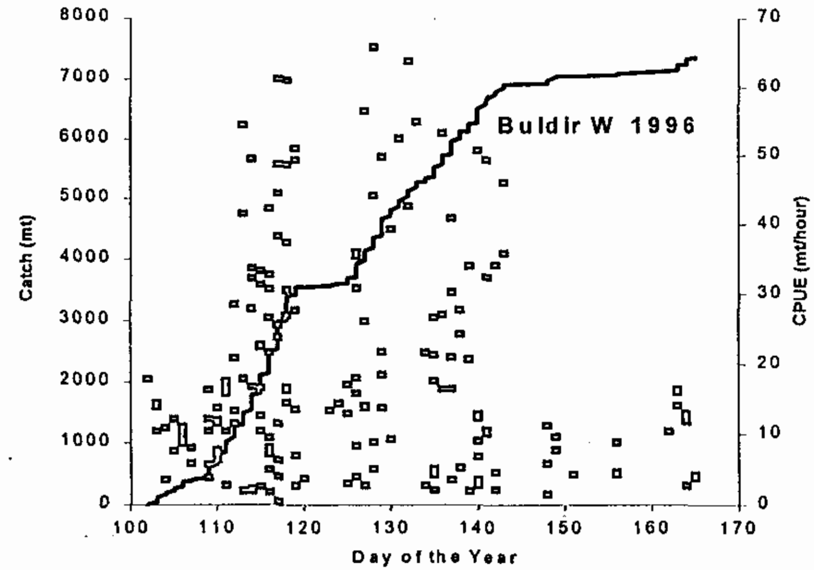
Buldir West

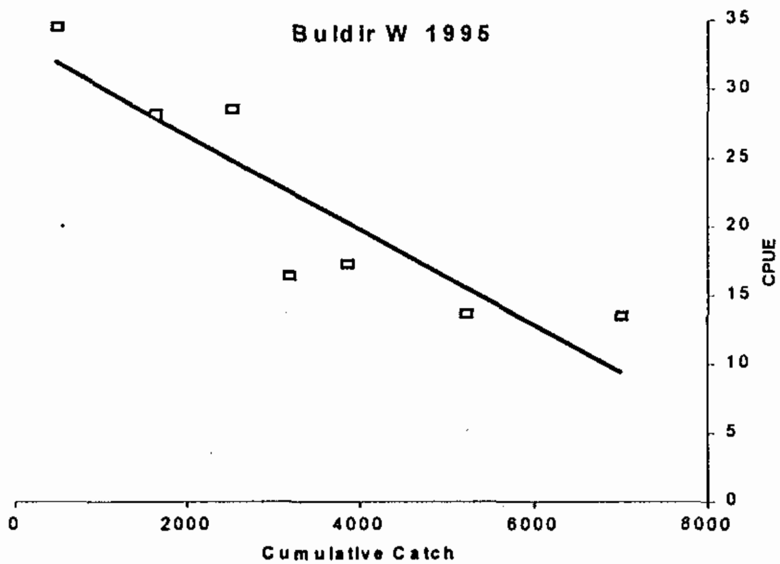
Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Slope	Harvest Rate	Smith Biomass
1995	17-Mar	15-May	32	7	6	190	7,660	9,738	0.0034	79%	8,953
	17-Mar	**24-Apr**	**22**	**hauls=10**	**1**	**80**	**3,960**	**6,050**	**0.0062**		
1996	11-Apr	13-Jun	47	10	6	186	7,376				
1997	6-Apr	18-Apr	13	3	1	85	2,632				

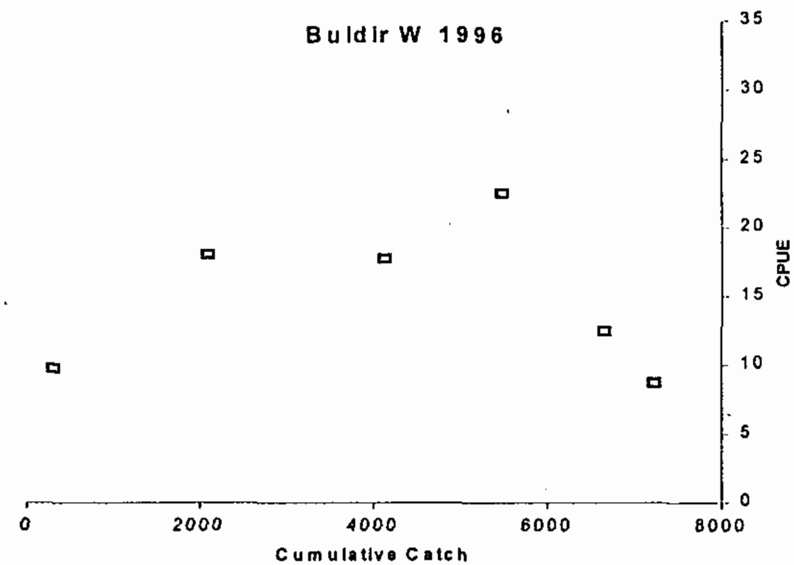
Buldir East

Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Slope	Harvest Rate	Smith Biomass
1995	22-Apr	15-May	24	3	11	205	5,142	5,449	0.0042	94%	5,217
	22-Apr	**6-May**	**15**	**hauls=8**	**7**	**64**	**2,755**	**5,119**	**0.0043**		
1996	14-Apr	23-Apr	10	2	5	86	3,285				combined 8,144
1996	13-Jul	22-Jul	10	2	5	63	2,569				
1997	16-Mar	17-Apr	33	4	8	197	7,994	10,114	0.0018	79%	9,634


Buldir W 1995
Cumulative Catch (mt)
CPUE
Catch (mt)
CPUE (mt/hour)
Day of the Year


Buldir W 1996
Catch (mt)
CPUE (mt/hour)
Day of the Year


Buldir W 1995
CPUE
Cumulative Catch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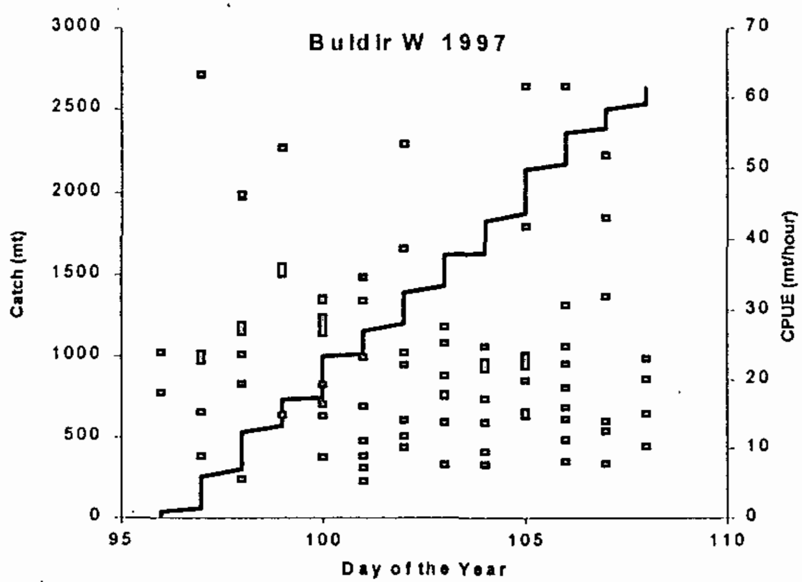
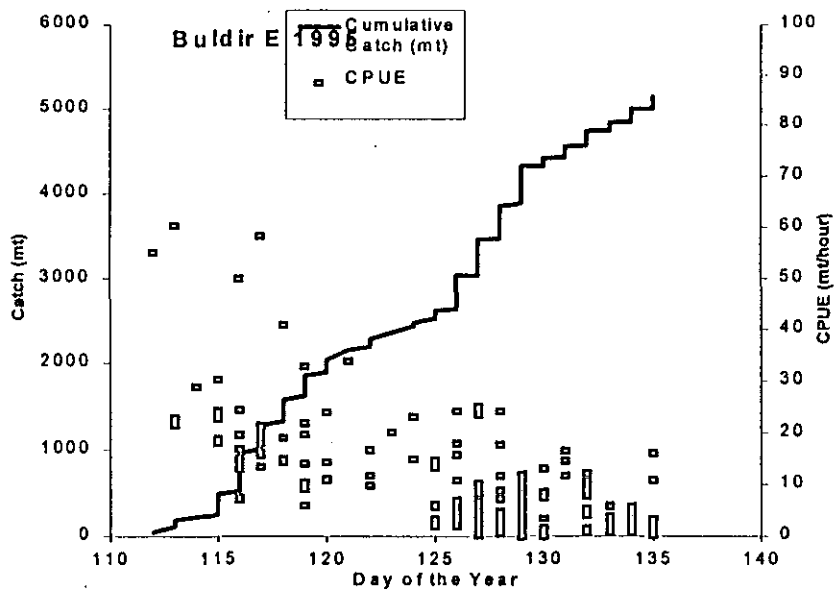
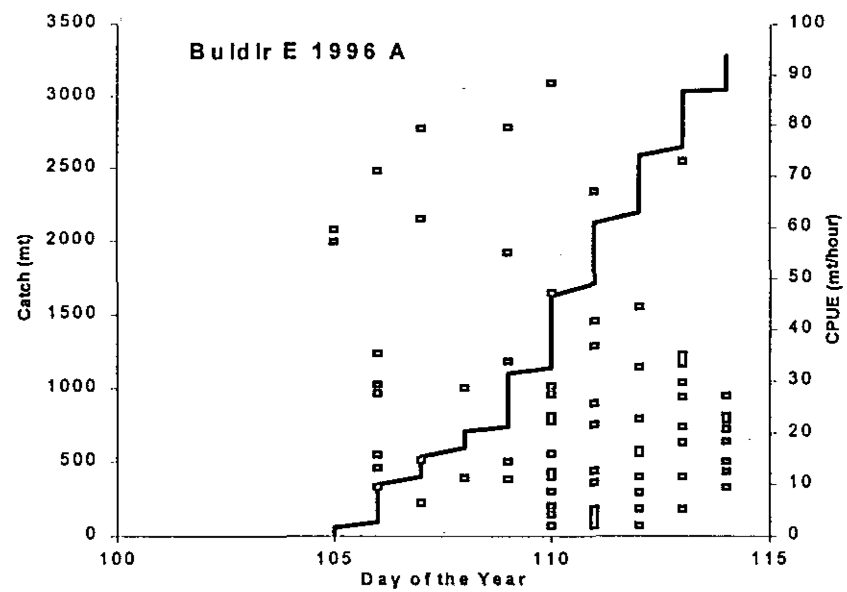
CPUE
Cumulative Catch

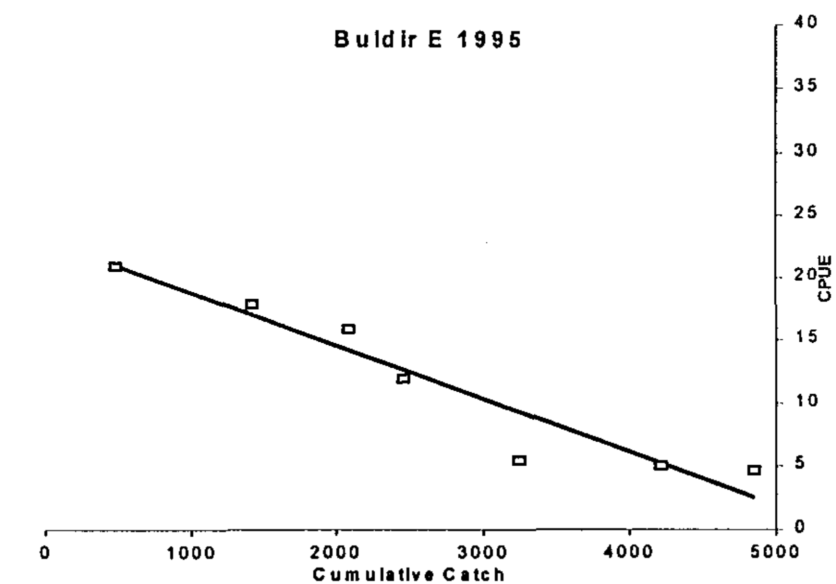


Buldir W 1997
Catch (mt)
CPUE (mt/hour)
Day of the Year
3000
2500
2000
1500
1000
500
0
95
100
105
110
70
60
50
40
30
20
10
0

Buldir W 1997
CPUE
Cumulative Catch
0
500
1000
1500
2000
2500
35
30
25
20
15
10
5
0


Buldir E 1995
Cumulative Catch (mt)
CPUE
Catch (mt)
CPUE (mt/hour)
Day of the Year


Buldir E 1996 A
Catch (mt)
CPUE (mt/hour)
Day of the Year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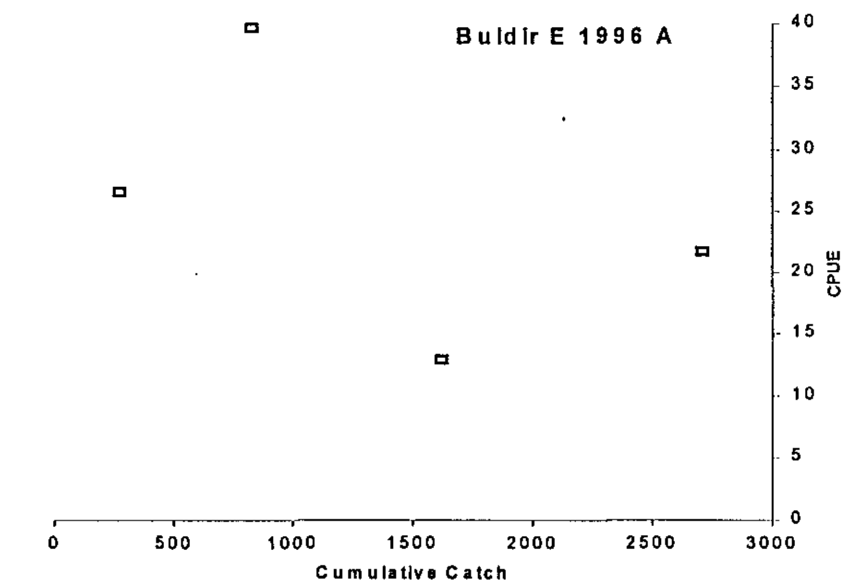
CPUE
Cumulative Catch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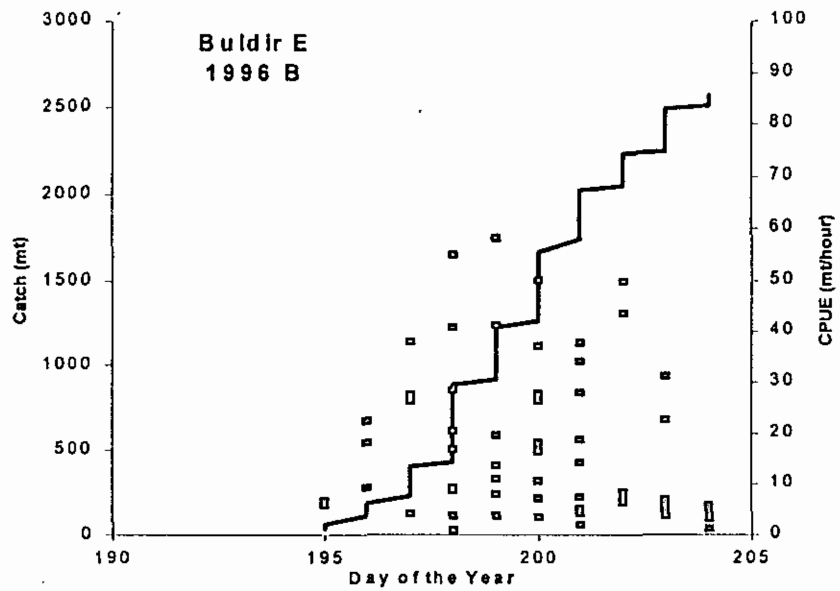
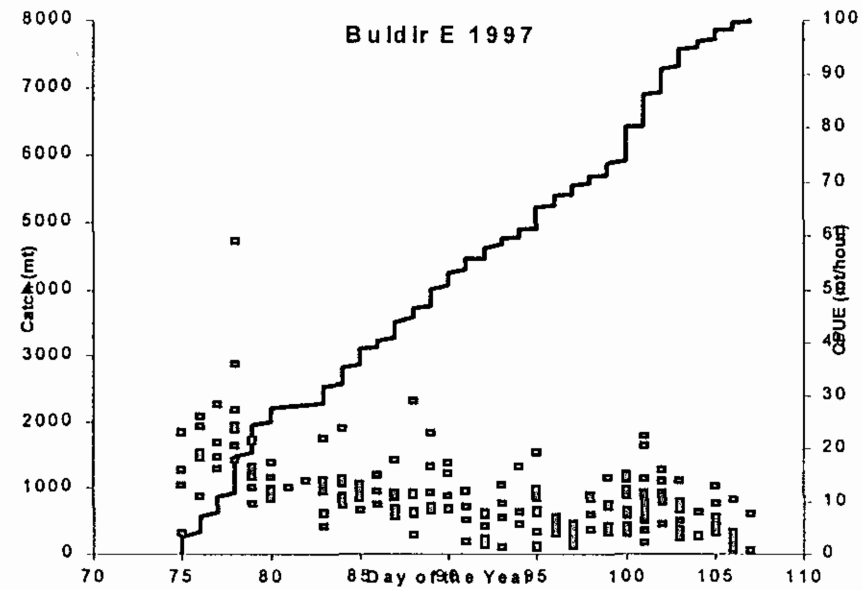
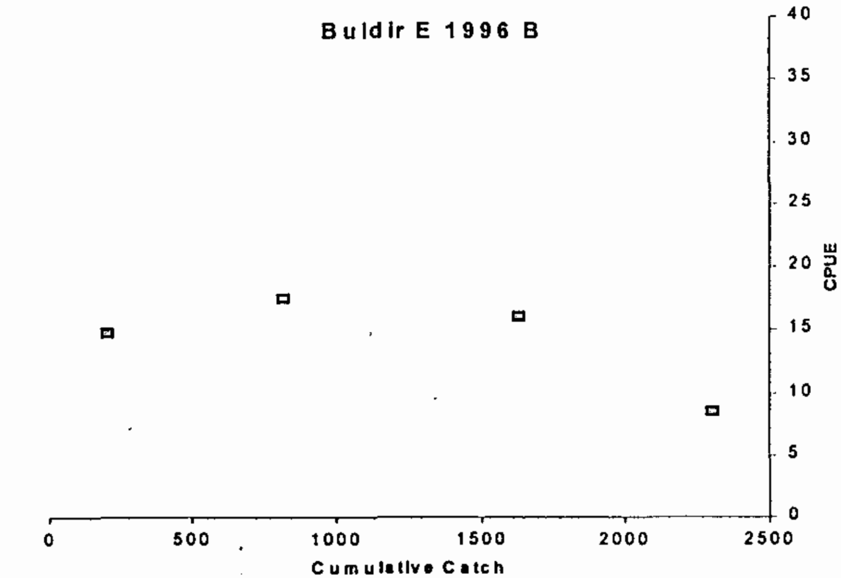
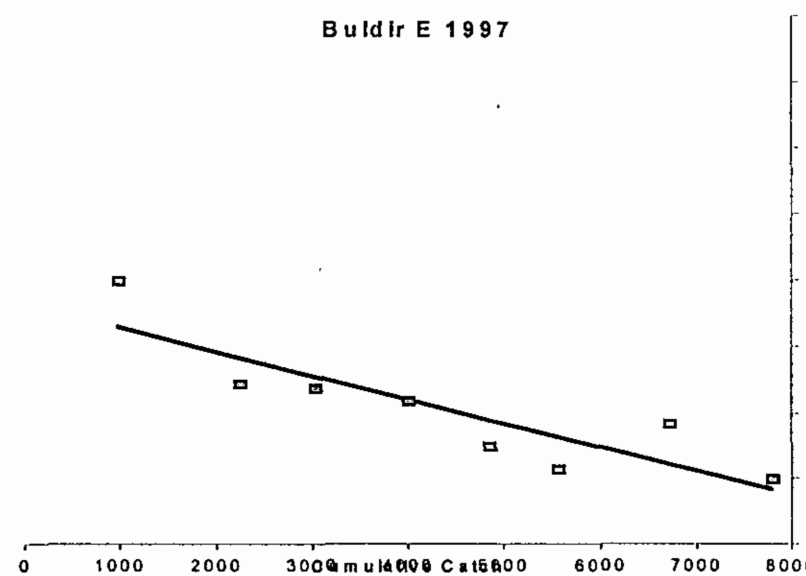
CPUE
Cumulative Catch


Buldir E
1996 B
Catch (mt)
CPUE (mt/hour)
Day of the Year


Buldir E 1997
Catch (mt)
CPUE (mt/hour)
Day of the Year


Buldir E 1996 B
CPUE
Cumulative Catch

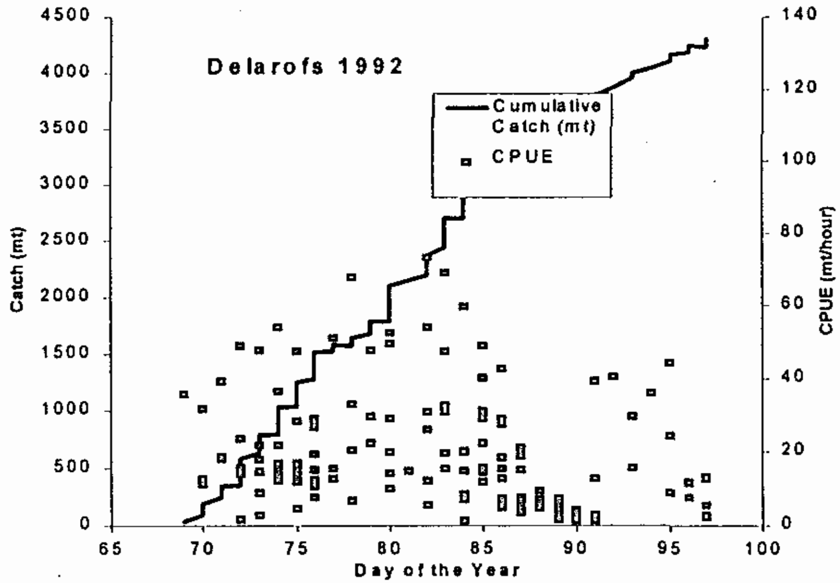

Buldir E 1997
CPUE
Cumulative Catch

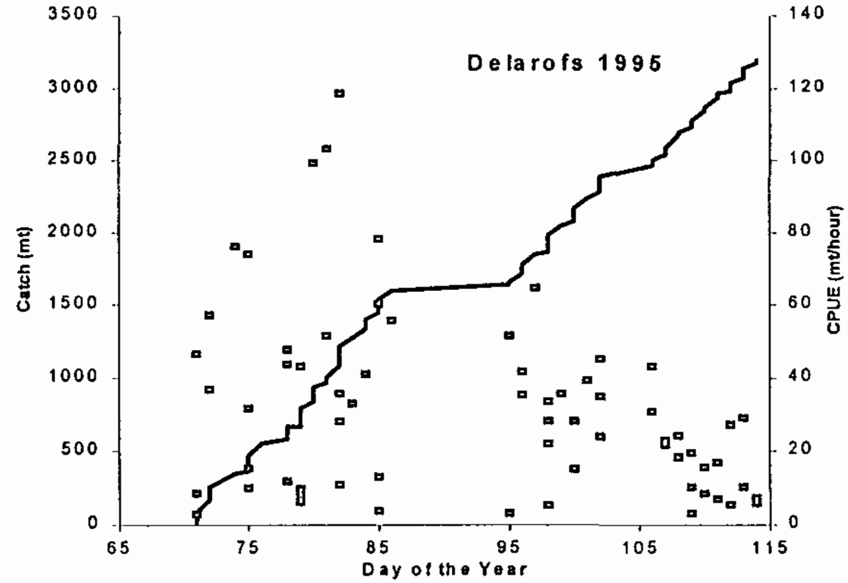
Delarofs

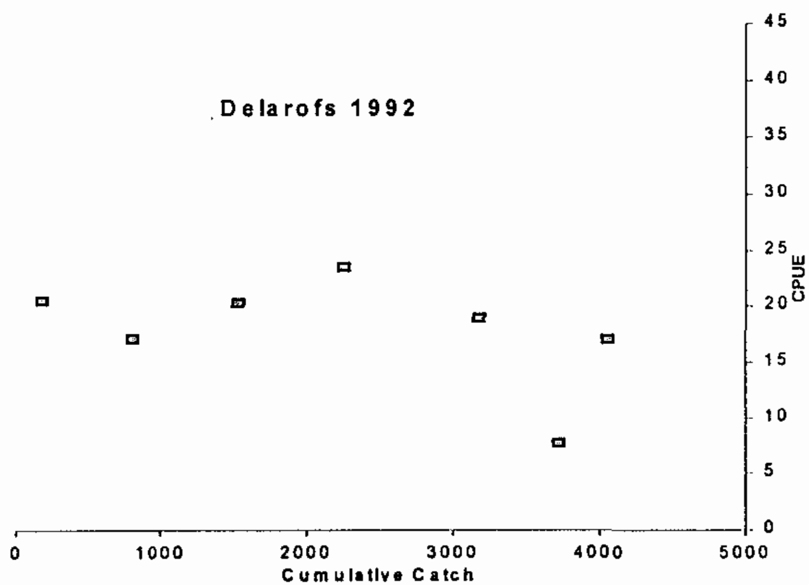
Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Slope	Harvest Rate	Smith Biomass
1992	10-Mar	6-Apr	29	4	2	144	4,311				
1994	5-Apr	29-Apr	21	5	3	51	2,200				
1994	7-May	19-May	11	2	3	60	1,767				
1995	12-Mar	24-Apr	31	9	1	69	3,202				
1996	15-Feb	12-Apr	51	7	6	263	9,170	10,615	0.0025	86%	9,885
	15-Feb	**24-Mar**	**38**	**hauls=9**	**5**	**99**	**4,756**	**8,280**	**0.0034**		
1997	5-Feb	2-Mar	23	6	3	65	2,938				4,471

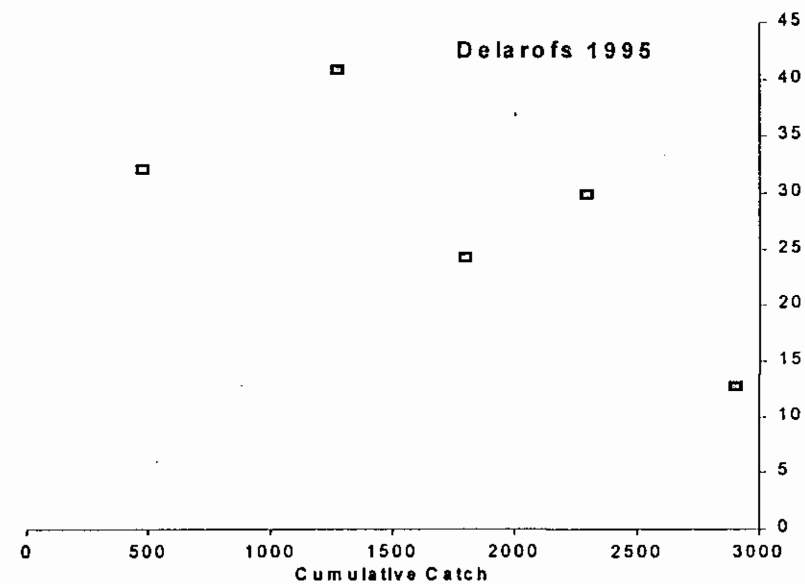
Tanaga Pass

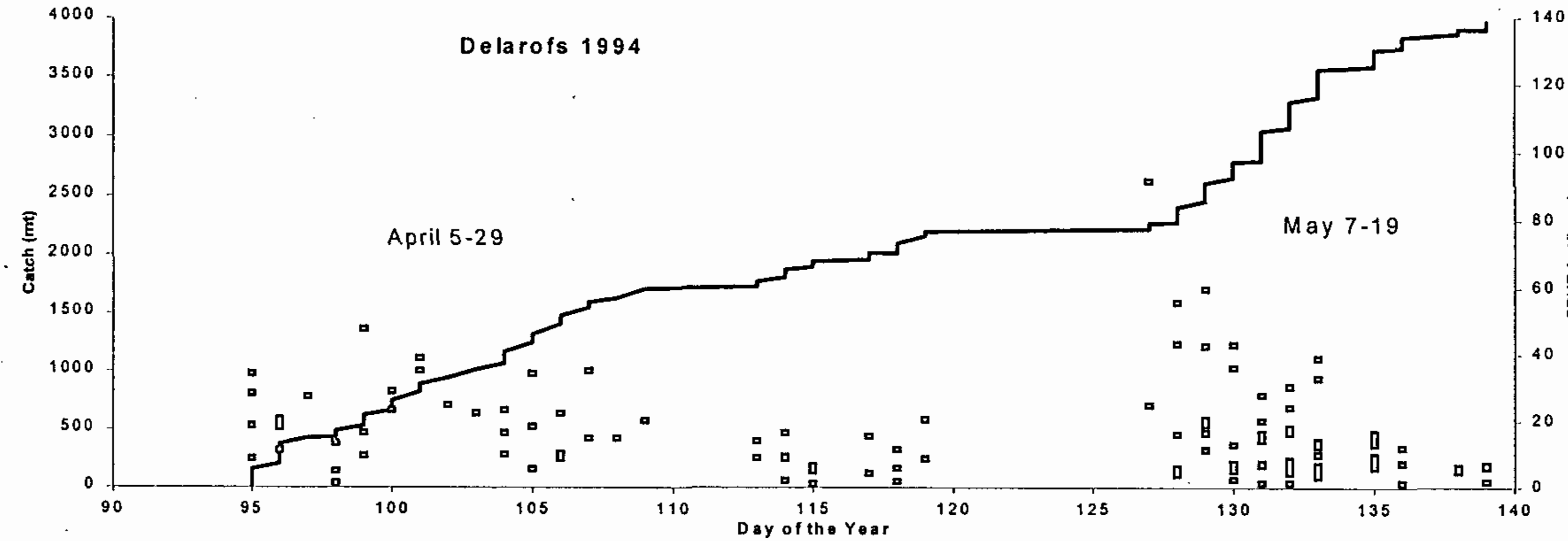
Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Slope	Harvest Rate
1994	19-Apr	7-May	19	3	3	85	2,291			
1995	11-Feb	17-Mar	22	2	6	77	2,671			

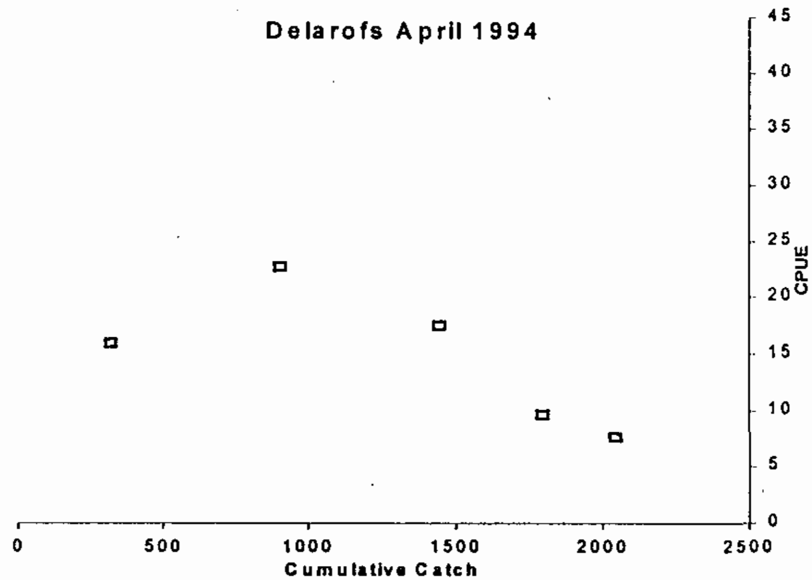

Delarofs 1992
Cumulative Catch (mt)
CPUE
Catch (mt)
CPUE (mt/hour)
Day of the Year

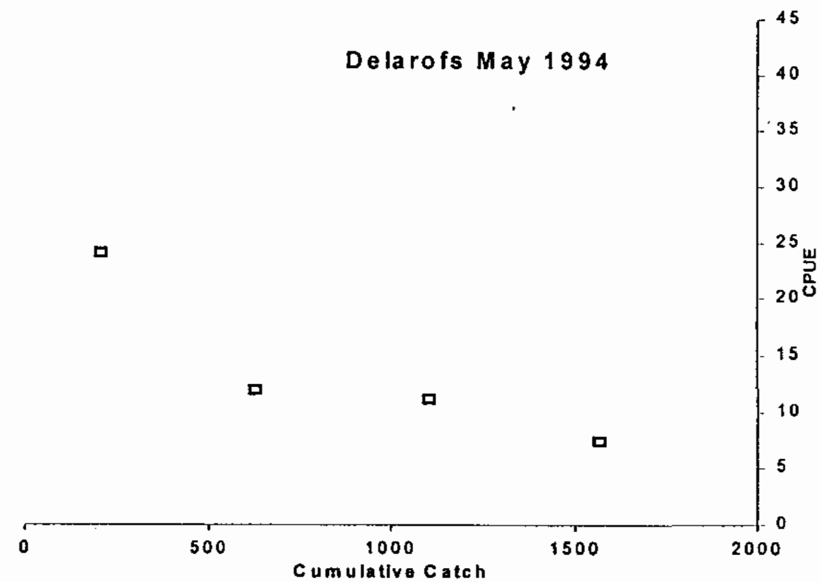

Delarofs 1995
Catch (mt)
CPUE (mt/hour)
Day of the Year

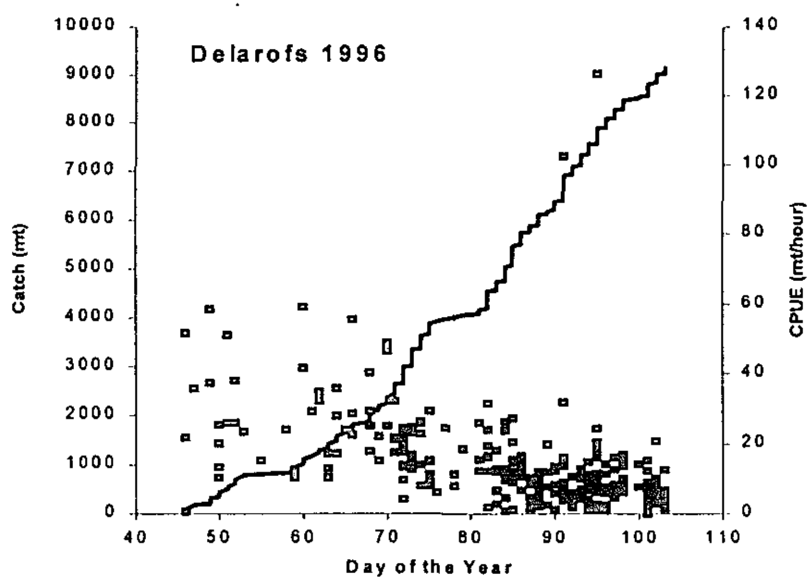

Delarofs 1992
CPUE
Cumulative Catch

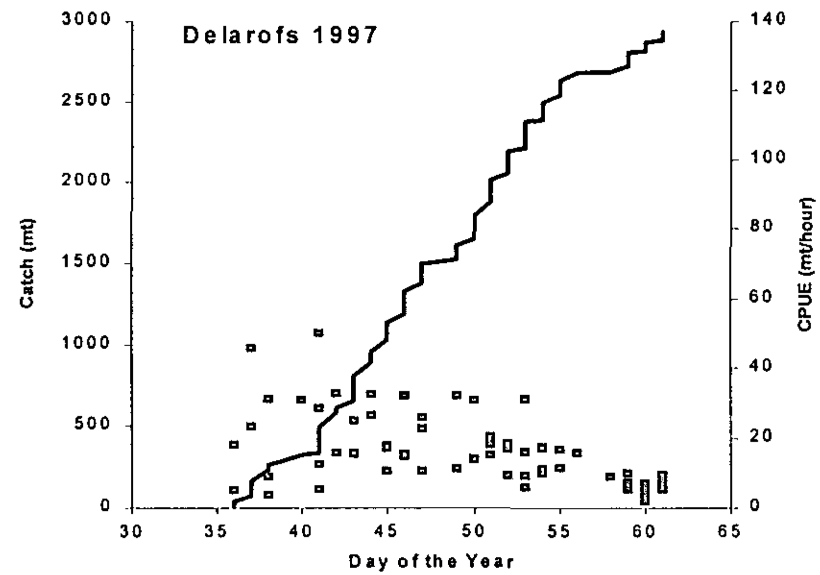

Delarofs 1995
CPUE
Cumulative Catch

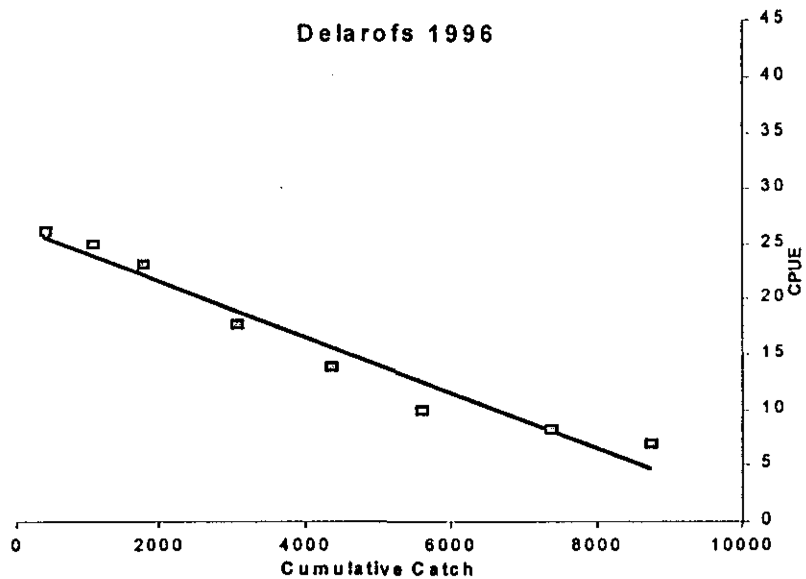

Delarofs 1994
April 5-29
May 7-19
Catch (mt)
CPUE (mt/hour)
Day of the Year
4000
3500
3000
2500
2000
1500
1000
500
0
140
120
100
80
60
40
20
0
90
95
100
105
110
115
120
125
130
135
140

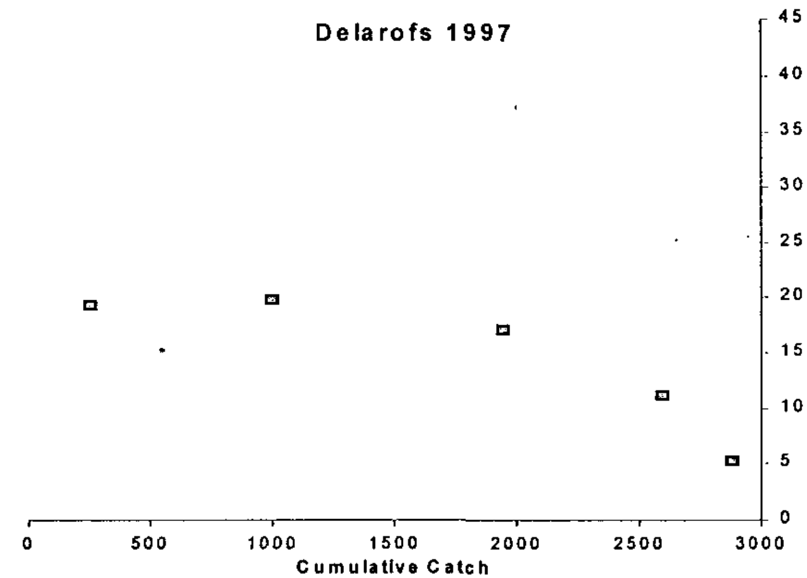

Delarofs April 1994
CPUE
Cumulative Catch
45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500

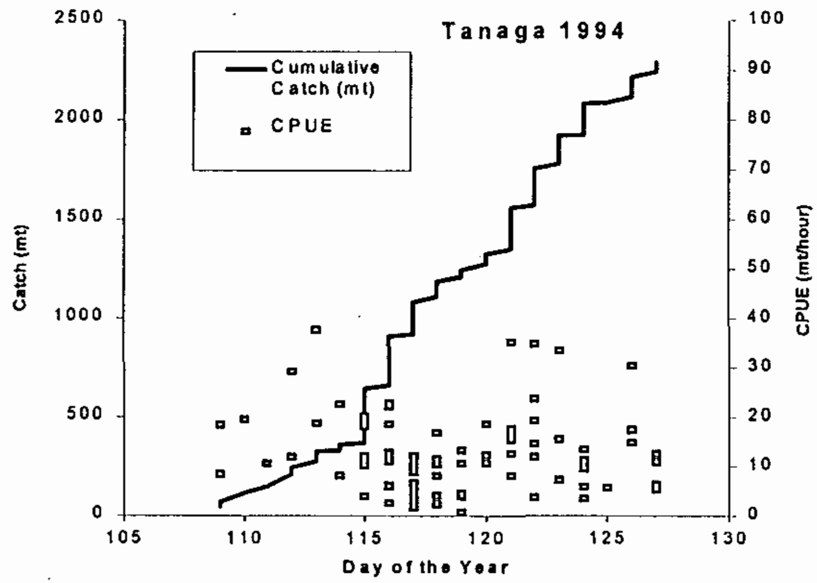

Delarofs May 1994
CPUE
Cumulative Catch
45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000

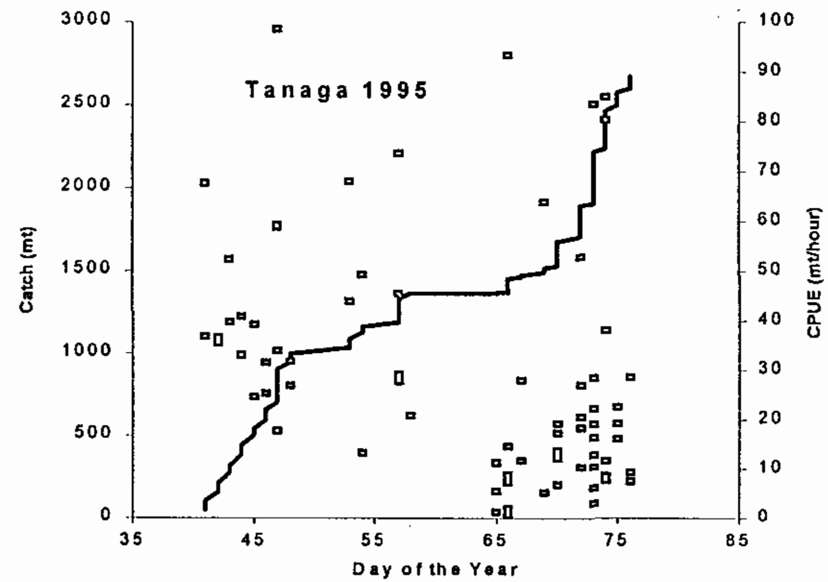

Delarofs 1996
Catch (mt)
CPUE (mt/hour)
Day of the Year

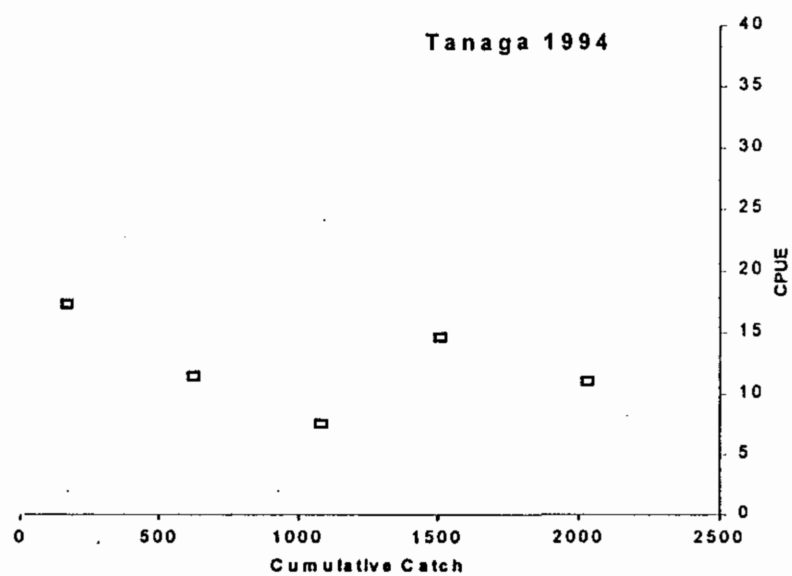

Delarofs 1997
Catch (mt)
CPUE (mt/hour)
Day of the Year

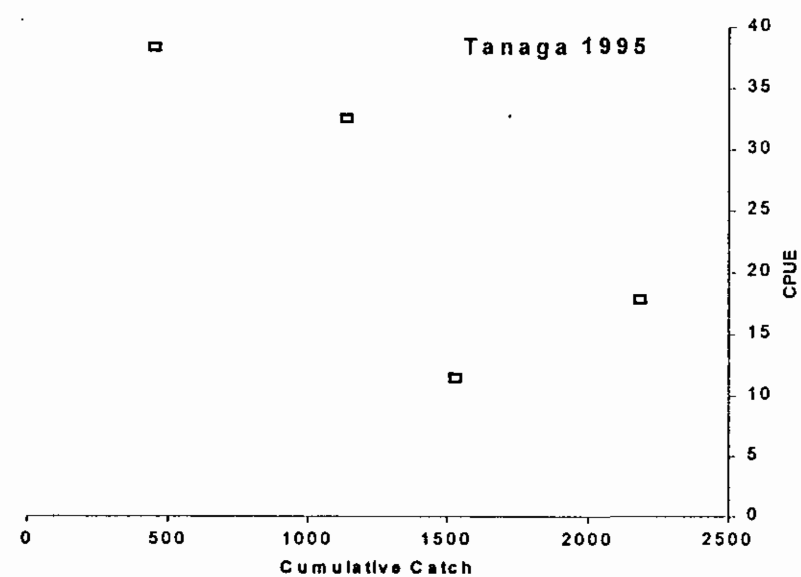

Delarofs 1996
CPUE
Cumulative Catch


Delarofs 1997
CPUE
Cumulative Catch


Tanaga 1994
Cumulative Catch (mt)
CPUE
Catch (mt)
CPUE (mt/hour)
Day of the Year

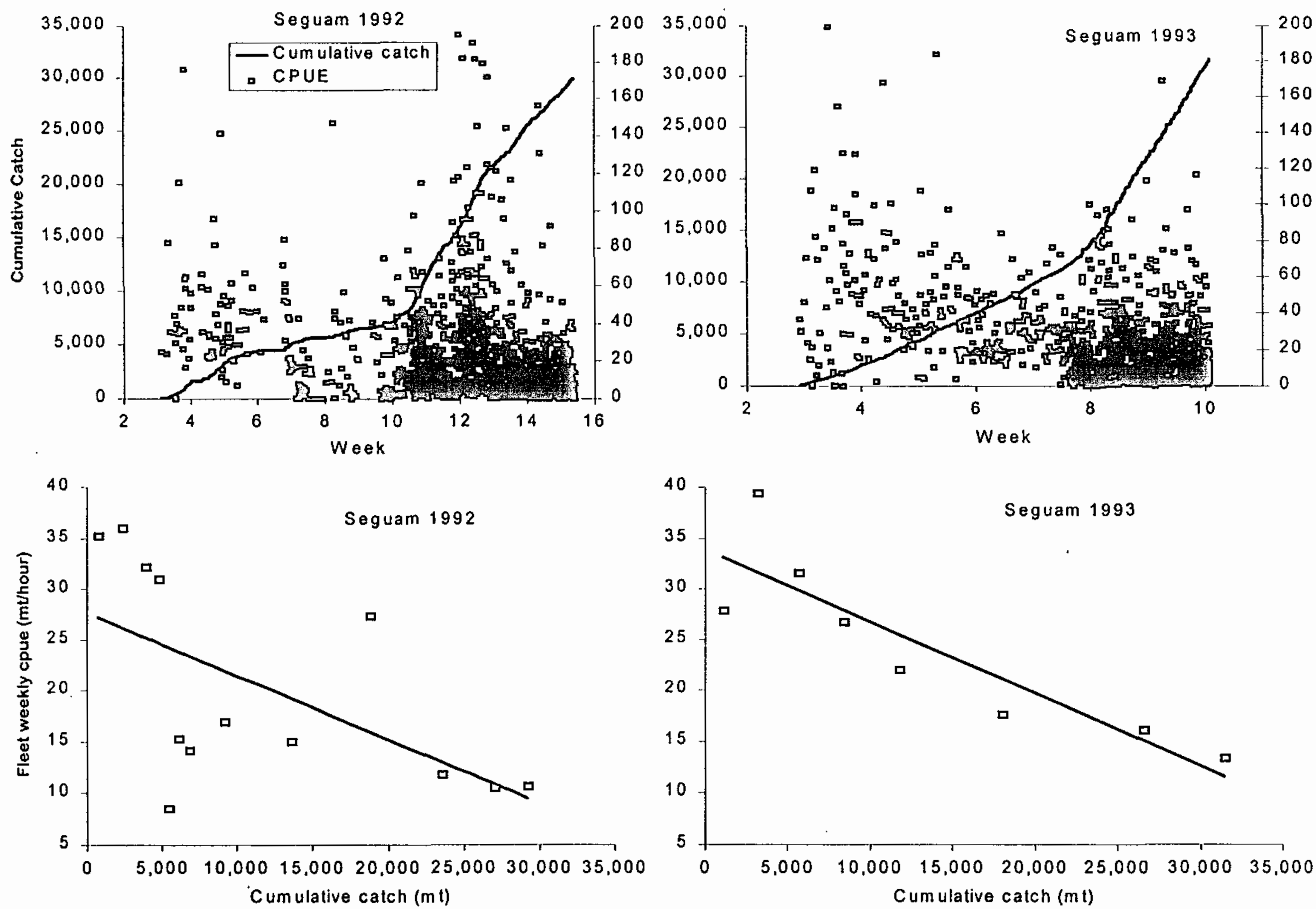

Tanaga 1995
Catch (mt)
CPUE (mt/hour)
Day of the Year

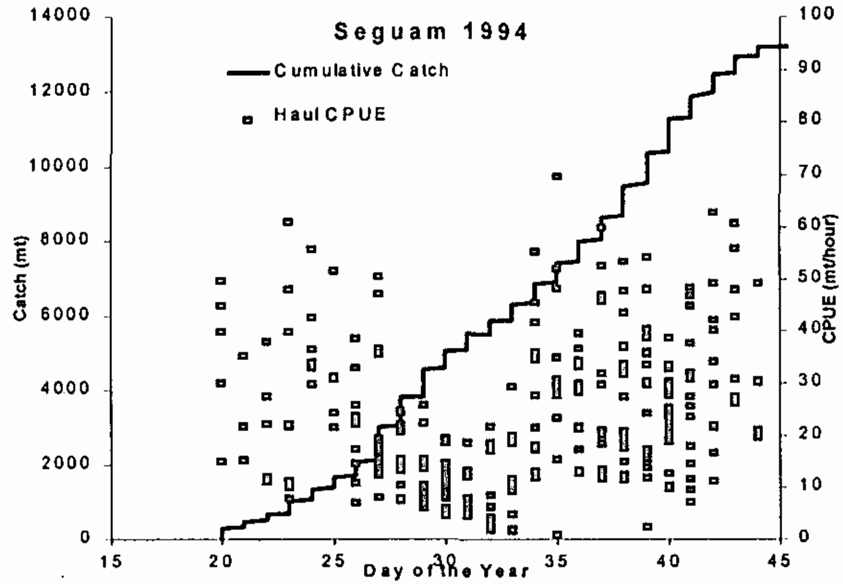

Tanaga 1994
CPUE
Cumulative Catch

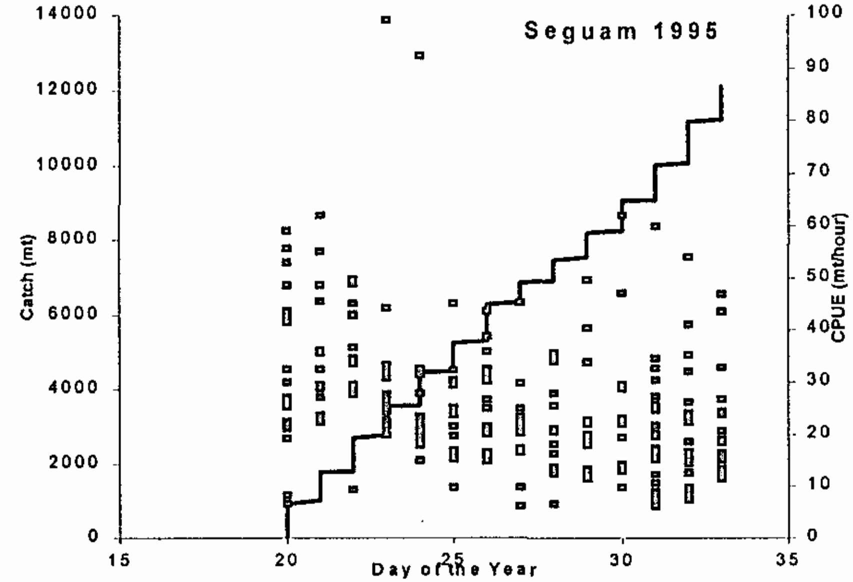

Tanaga 1995
CPUE
Cumulative Catch

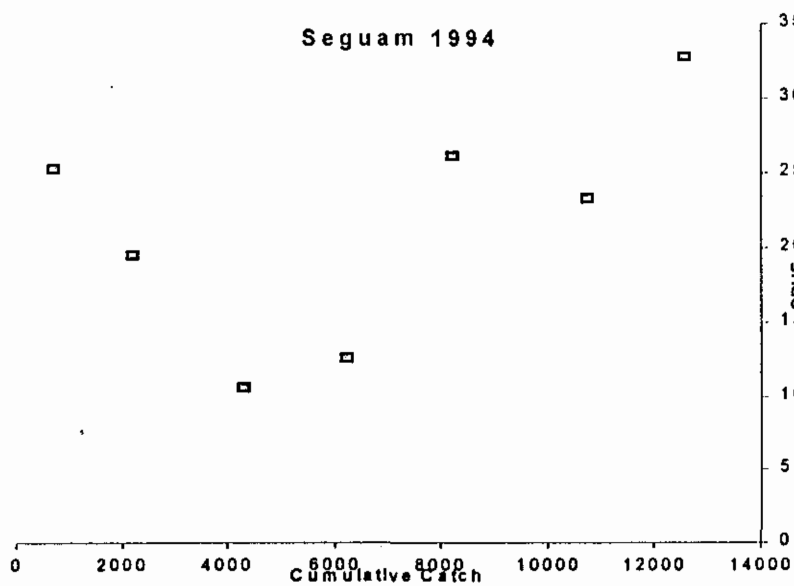
Seguam

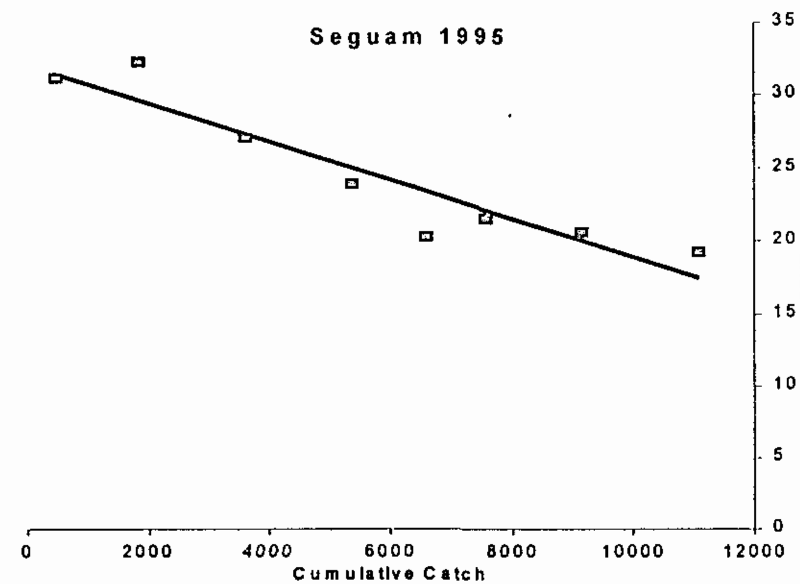
Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Slope	Harvest Rate	Smith Biomass
1992	21-Jan	16-Apr	86	7	25	1,326	29,909	44,535	0.0006	67%	41,211
1993	20-Jan	11-Mar	50	7	21	1,030	31,704	47,493	0.0007	67%	45,304
	20-Jan	11-Mar	50	hauls=20	21	1,030	31,704	47,957	0.0007		
	20-Jan	11-Mar	50	tons=1000	21	1,030	31,704	44,981	0.0008		
	20-Jan	**27-Feb**	**39**	**tons=1000**	**14**	**413**	**15,979**	**28,350**	**0.0014**		
1994	20-Jan	13-Feb	25	3.5	7	284	13,198				
1995	20-Jan	2-Feb	14	2	9	213	12,126	24,432	0.0013	50%	22,950
1996	20-Jan	14-Feb	26	4	9	418	21,120				combined 58,131
1996	3-Jul	8-Jul	6	1	8	113	4,873				
1997	20-Jan	4-Feb	16	2	8	211	15,117				

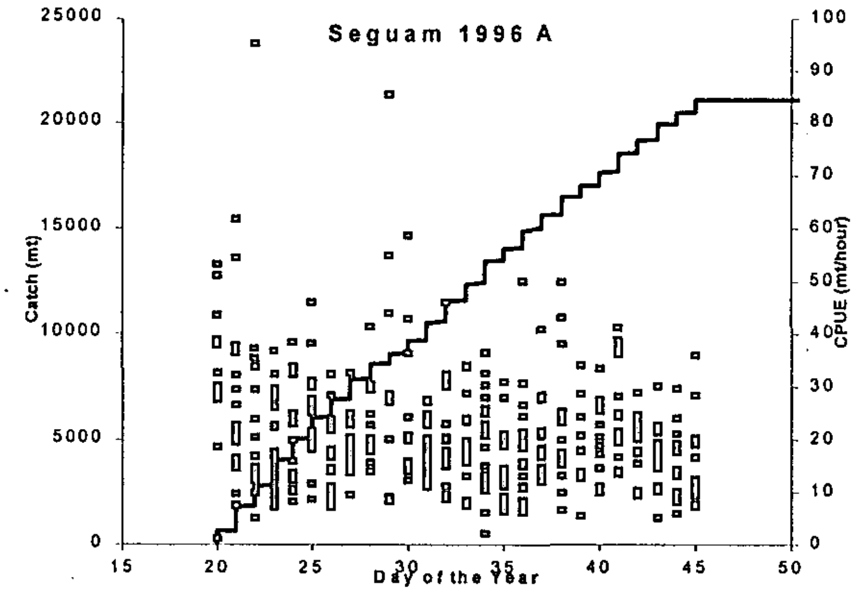

Seguam 1992
Cumulative catch
CPUE
Cumulative Catch
Week
Seguam 1993
Week
Seguam 1992
Fleet weekly cpue (mt/hour)
Cumulative catch (mt)
Seguam 1993
Cumulative catch (mt)

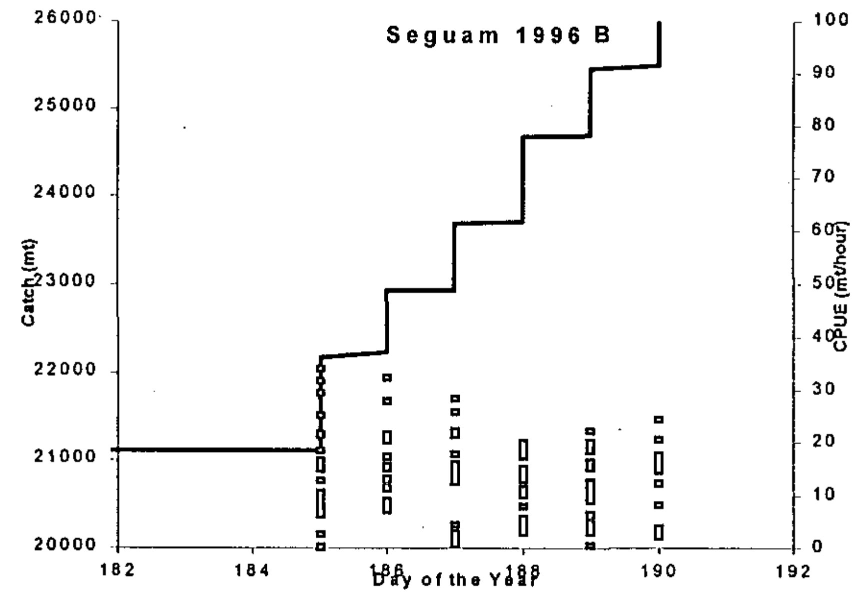

Seguam 1994
Cumulative Catch
Haul CPUE
Catch (mt)
CPUE (mt/hour)
Day of the Year

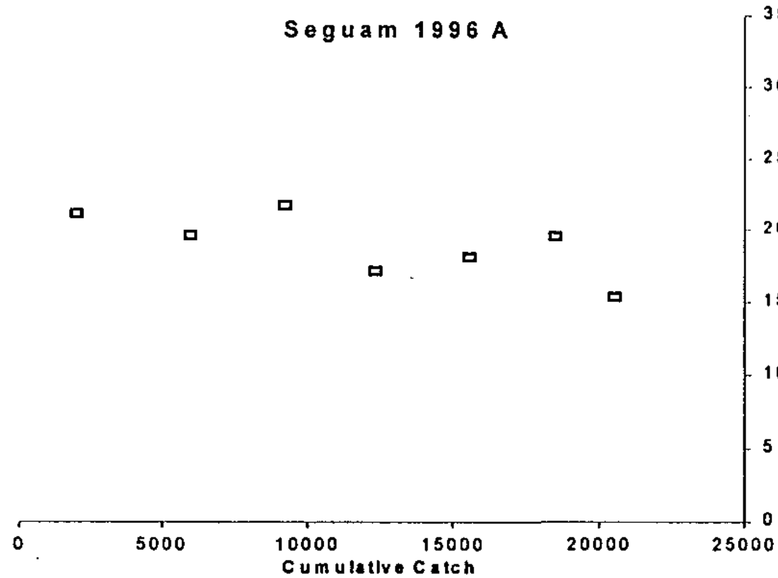

Seguam 1995
Catch (mt)
CPUE (mt/hour)
Day of the Year

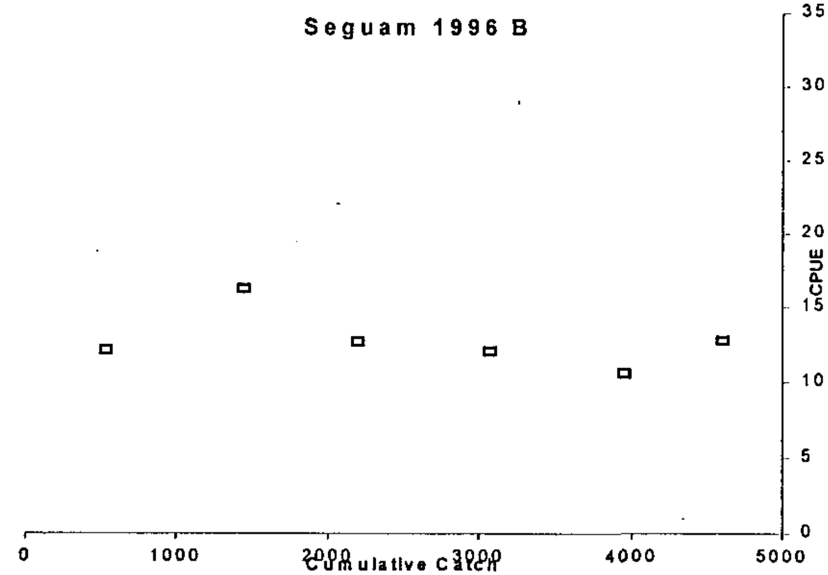

Seguam 1994
CPUE
Cumulative Catch

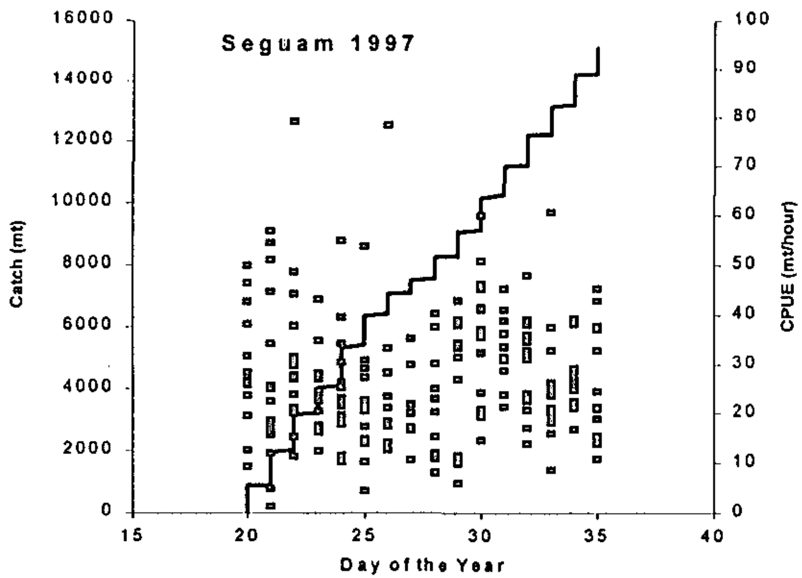

Seguam 1995
CPUE
Cumulative Catch

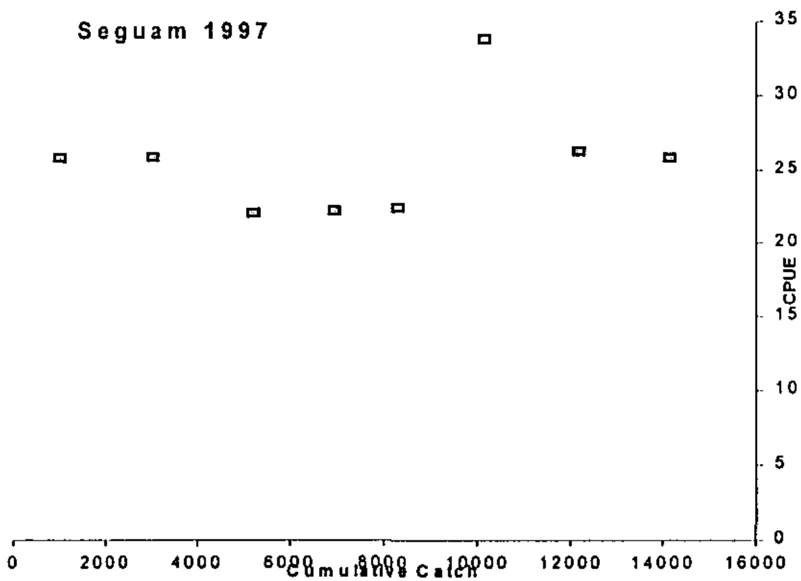

Seguam 1996 A
Catch (mt)
CPUE (mt/hour)
Day of the Year


Seguam 1996 B
Catch (mt)
CPUE (mt/hour)
Day of the Year


Seguam 1996 A
CPUE
Cumulative Catch

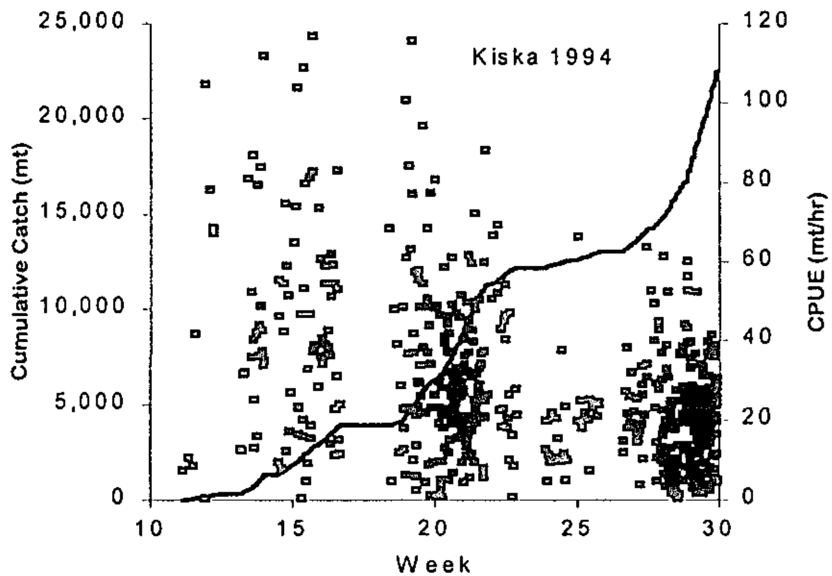

Seguam 1996 B
CPUE
Cumulative Catch

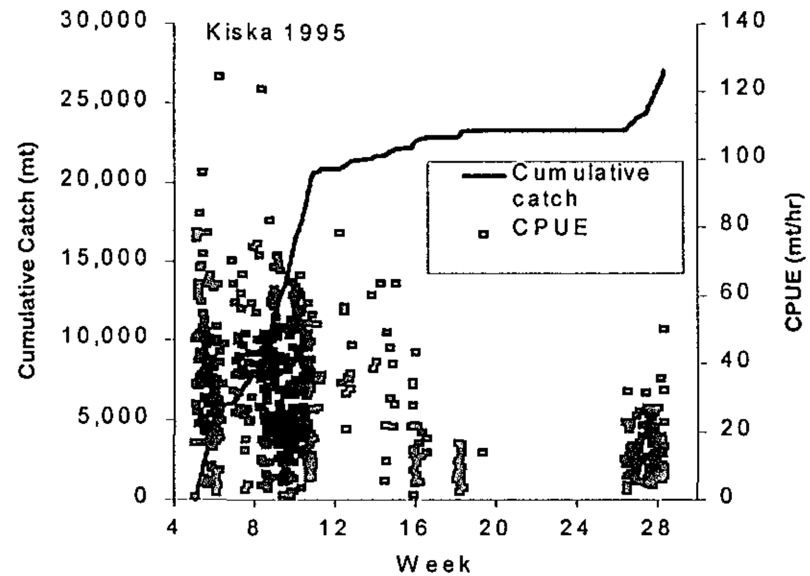

Seguam 1997
Catch (mt)
CPUE (mt/hour)
Day of the Year
0
2000
4000
6000
8000
10000
12000
14000
16000
0
10
20
30
40
50
60
70
80
90
100
15
20
25
30
35
40

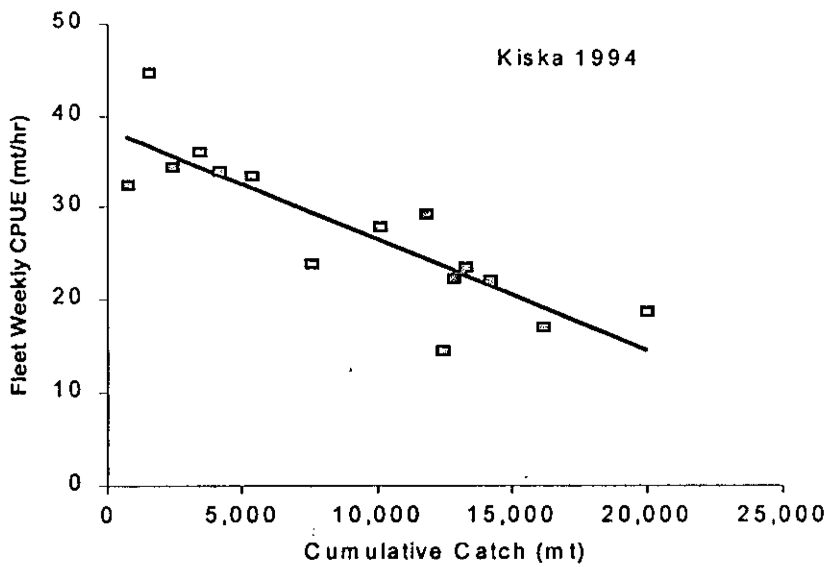

Seguam 1997
CPUE
Cumulative Catch
0
5
10
15
20
25
30
35
0
2000
4000
6000
8000
10000
12000
14000
16000

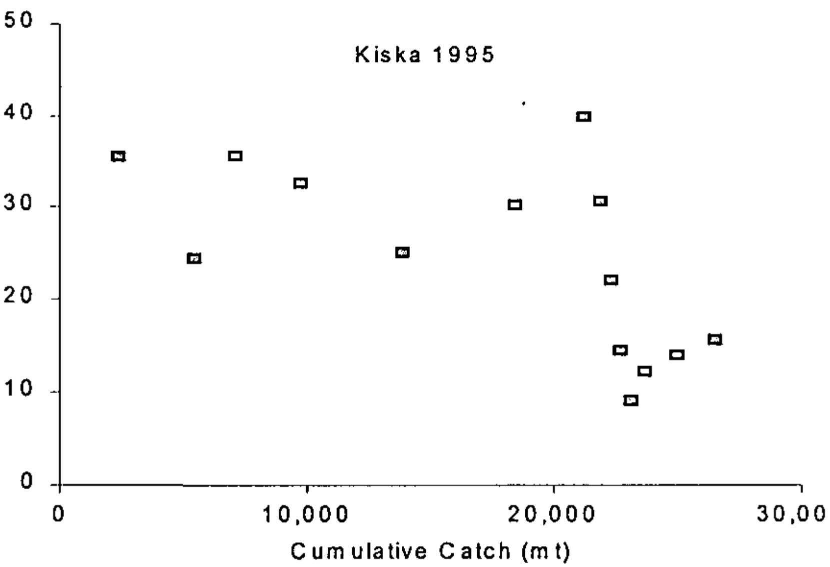
Kiska

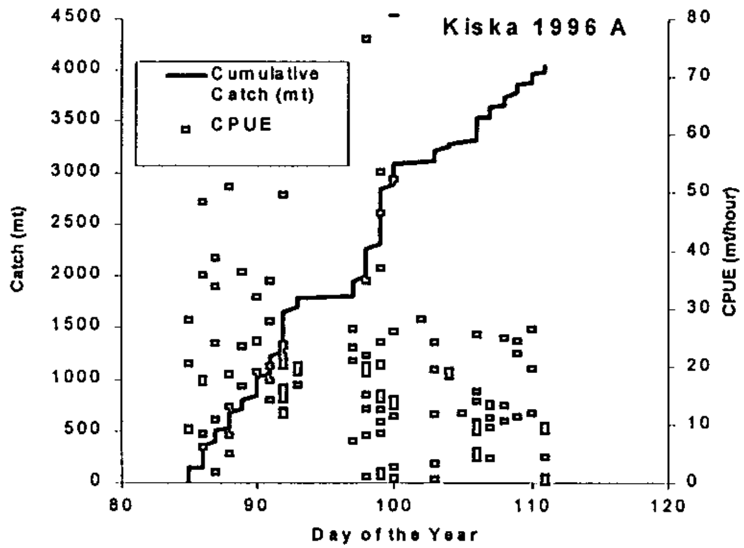
Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Slope	Harvest Rate	Smith Biomass
1994	2-Apr	28-Jul	92	7	11	583	22,467	32,161	0.0012	70%	28,647
	2-Apr	28-Jul	92	hauls=20	11	583	22,467	36,466	0.0010		
	2-Apr	28-Jul	92	tons=750	11	583	22,467	37,726	0.0010		
	2-Apr	**17-Jun**	**76**	**tons=750**	**6**	**300**	**11,223**	**26,385**	**0.0014**		
1995	4-Feb	8-May	68	7	11	501	23,232				
1996	25-Mar	20-Apr	23	5	5	122	4,047				
1996	22-Jul	6-Sep	46	6	7	296	12,961	31,825	0.0006	41%	combined 40,970
						using CPUE of 1 vessel		27,705	0.0007	47%	
1997	1-Mar	21-Apr	48	6	8	281	14,729				

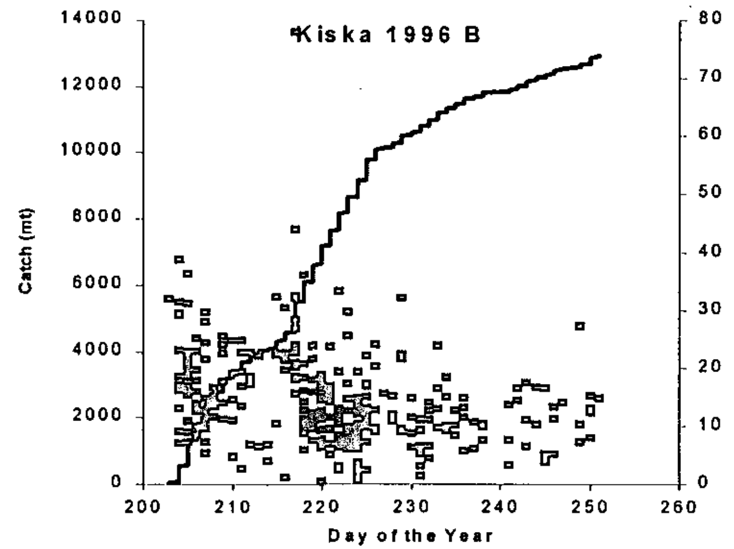

Kiska 1994
Cumulative Catch (mt)
CPUE (mt/hr)
Week

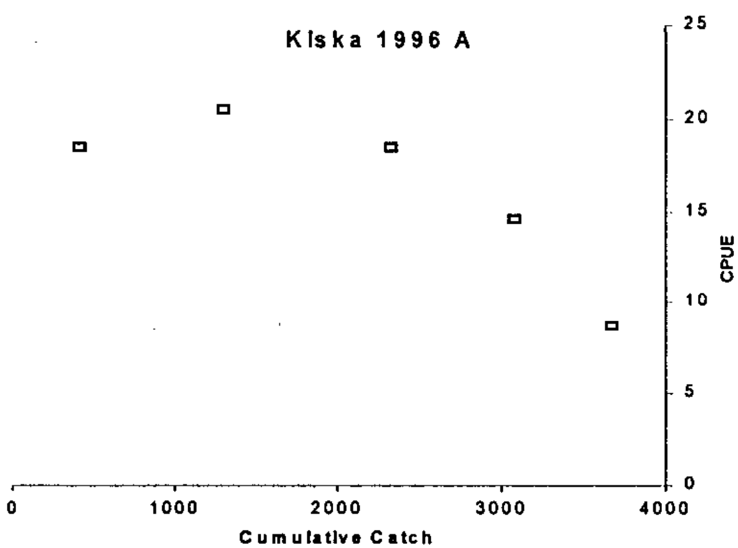

Kiska 1995
Cumulative Catch (mt)
CPUE (mt/hr)
Week
Cumulative catch
CPUE

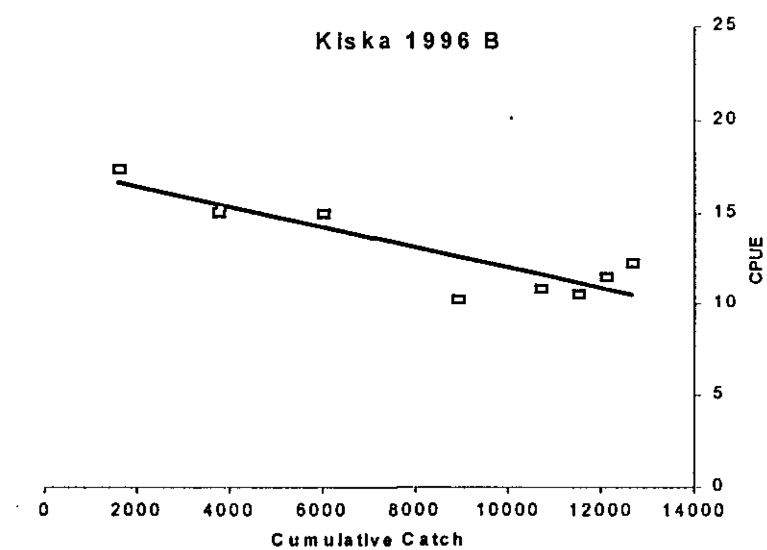

Kiska 1994
Fleet Weekly CPUE (mt/hr)
Cumulative Catch (mt)

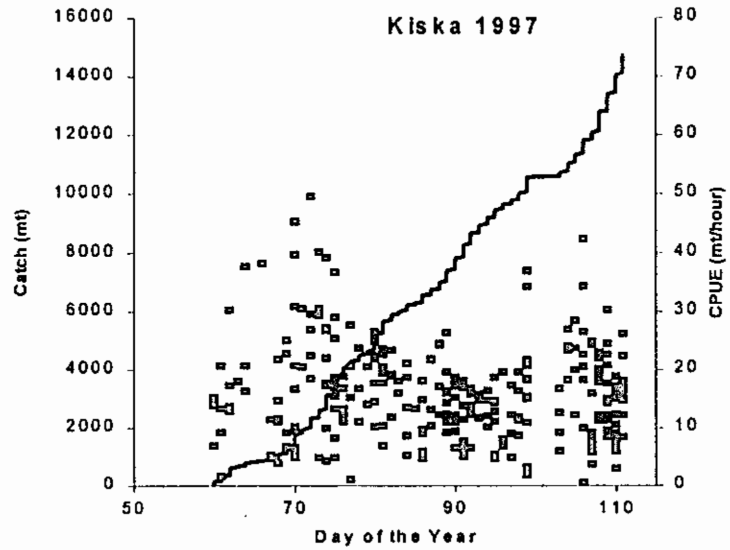

Kiska 1995
Cumulative Catch (mt)

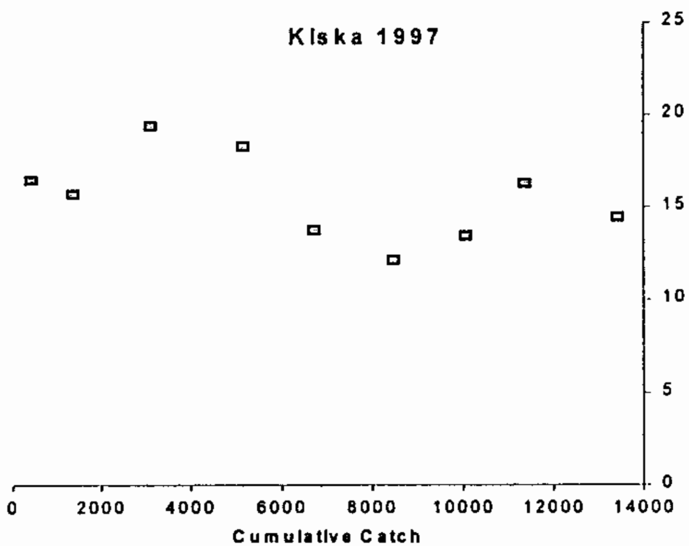

Kiska 1996 A
Cumulative Catch (mt)
CPUE
Catch (mt)
CPUE (mt/hour)
Day of the Year


Kiska 1996 B
Catch (mt)
CPUE (mt/hour)
Day of the Year


Kiska 1996 A
CPUE
Cumulative Catch

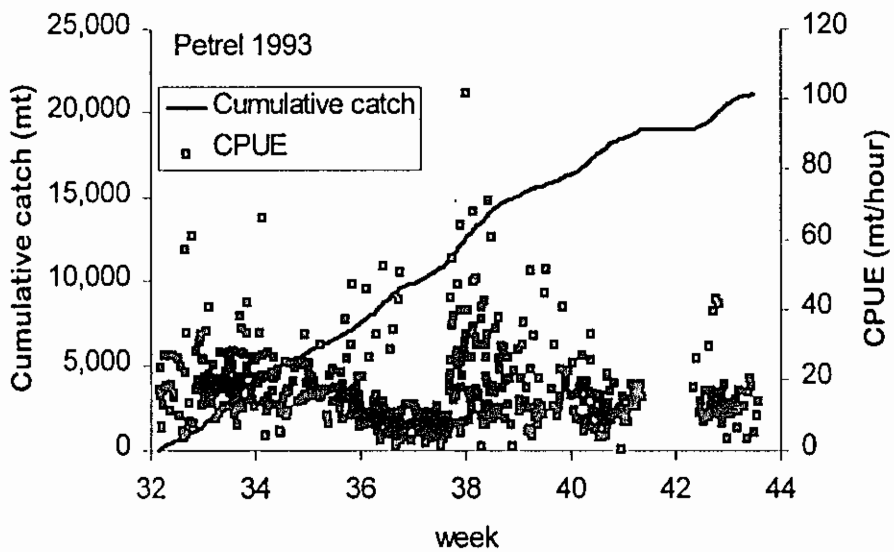

Kiska 1996 B
CPUE
Cumulative Catch

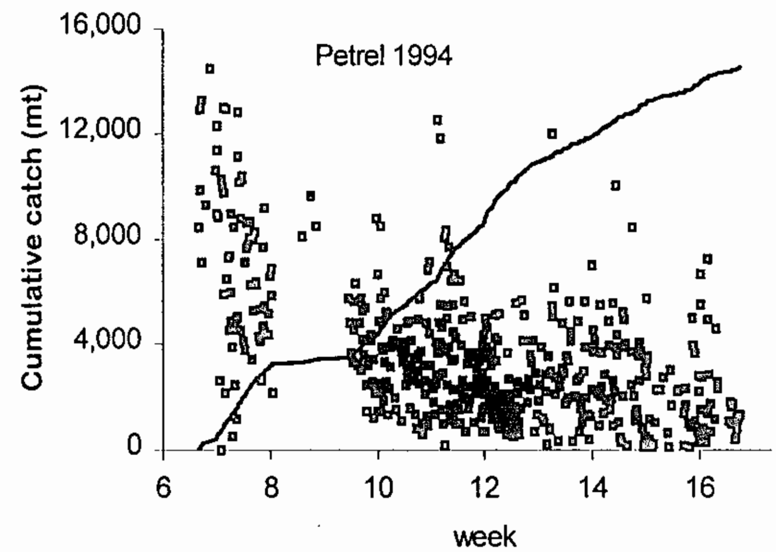

Kiska 1997
Catch (mt)
CPUE (mt/hour)
Day of the Year
16000
14000
12000
10000
8000
6000
4000
2000
0
50
70
90
110
80
70
60
50
40
30
20
10
0

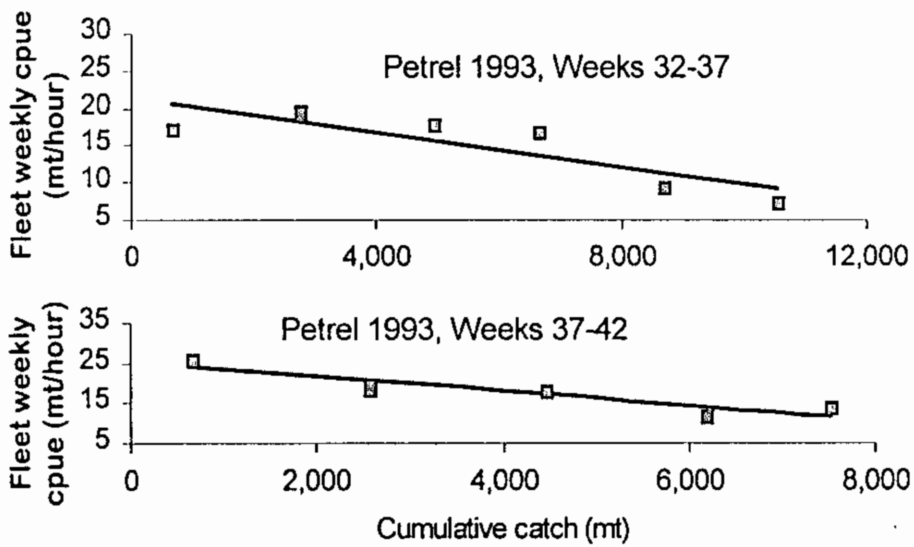

Kiska 1997
CPUE
Cumulative Catch
0
2000
4000
6000
8000
10000
12000
14000
25
20
15
10
5
0

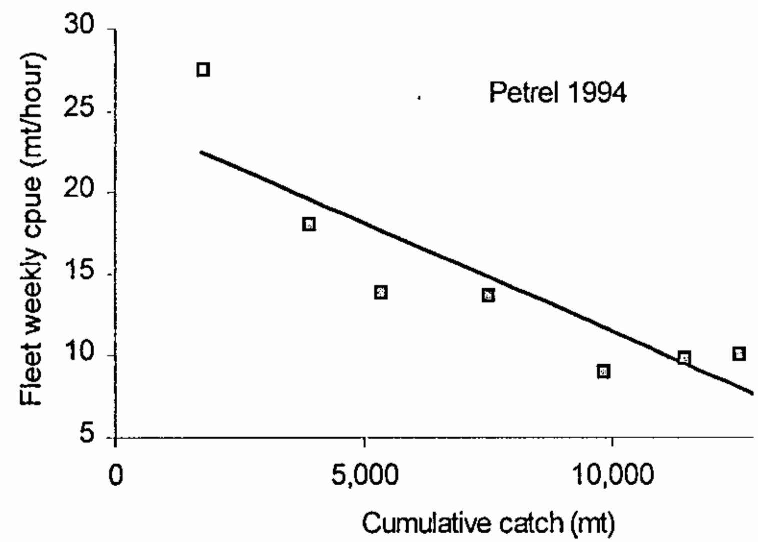
Petrel

Year	Date Started	Date Finished	# Days	Period Length (days)	# Vessels	# Hauls	Total Catch	Initial Biomass	Slope	Harvest Rate
1993	13-Aug	20-Sep	31	7	5	321	11,268	18,395	0.0012	61%
1993	21-Sep	1-Nov	42	7	7	243	7,784	14,045	0.0018	55%
1994	15-Feb	27-Apr	72	7	9	496	14,530	18,585	0.0013	78%
	15-Feb	**19-Mar**	**33**	**hauls=14**	**5**	**195**	**7,050**	**11,161**	**0.0027**	


Petrel 1993
Cumulative catch
CPUE
Cumulative catch (mt)
CPUE (mt/hour)
week
25,000
20,000
15,000
10,000
5,000
0
120
100
80
60
40
20
0
32
34
36
38
40
42
44


Petrel 1994
Cumulative catch (mt)
week
16,000
12,000
8,000
4,000
0
6
8
10
12
14
16


Petrel 1993, Weeks 32-37
Fleet weekly cpue (mt/hour)
30
25
20
15
10
5
0
4,000
8,000
12,000
Petrel 1993, Weeks 37-42
Fleet weekly cpue (mt/hour)
35
25
15
5
0
2,000
4,000
6,000
8,000
Cumulative catch (mt)


Petrel 1994
Fleet weekly cpue (mt/hour)
Cumulative catch (mt)
30
25
20
15
10
5
0
5,000
10,000

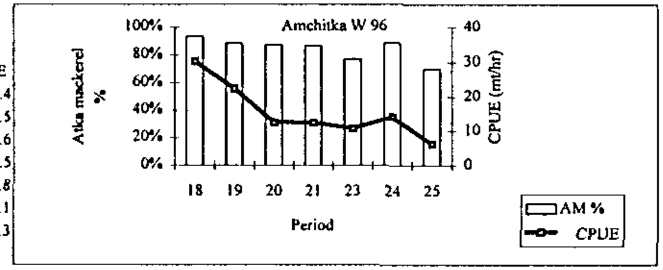
13.0 APPENDIX 3. NUMBER OF VESSELS, AND PERCENT ATKA MACKEREL IN HAULS

Appendix 3. Atka mackerel Percentage in Sampled Hauls by Period and Vessel and CPUE of Atka mackerel vessels by period.

Data detail the vessel-by-vessel and period-by-period changes in the percentages of Atka mackerel in pooled hauls (by period) used in the Leslie depletion analyses. Period refers to the time period over which catch and effort were pooled (see Appendix 1 for period length in each time-area fishery). All percentages are tons of Atka mackerel divided by total catch estimate for the haul (in tons). Included are (1) the number of vessels that fished in each period for reference, (2) the fleet CPUE for each period, and (3) a plot of changes in fleet CPUE and Atka mackerel percentages over time.

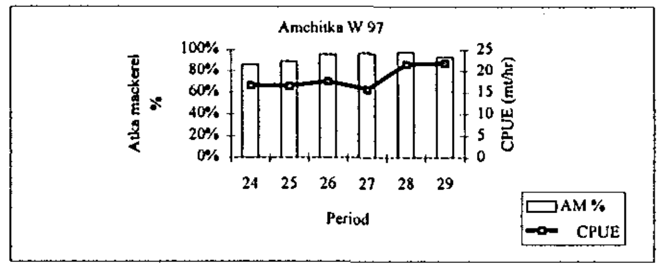
Amchitka West 1996 Significant Decline in CPUE

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	AM %	CPUE
18	1		93%						93%	30.4
19	1		88%						88%	22.5
20	3	76%	89%	87%					87%	12.6
21	4	70%	93%	72%			93%		87%	12.5
23	3		77%	73%		80%			77%	10.8
24	2		88%				92%		88%	14.1
25	3				36%	76%		70%	70%	6.3
All Periods	7	73%	88%	82%	36%	77%	93%	70%	85%	



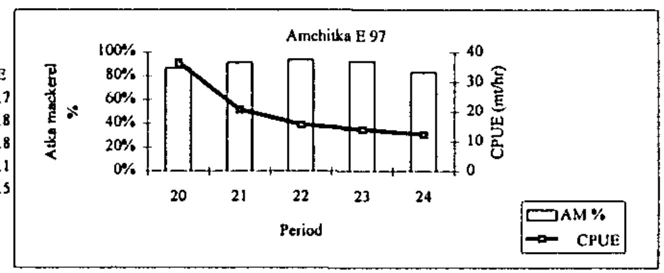
Amchitka West 1997

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	AM %	CPUE
24	1	86%			86%	16.8
25	1	89%			89%	16.7
26	2	97%		87%	96%	17.7
27	2	99%		91%	96%	15.8
28	2	98%	91%		98%	21.8
29	1	93%			93%	22.0
All Periods	3	94%	91%	90%	93%	



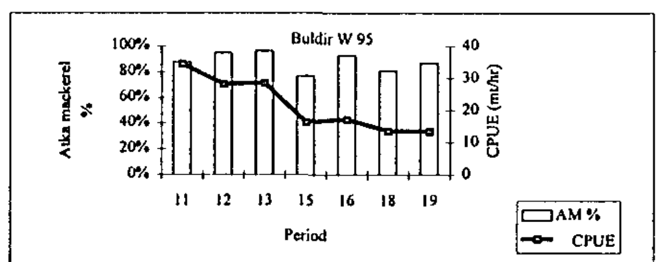
Amchitka East 1997 Significant Decline in CPUE

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	AM %	CPUE
20	2			81%	87%				87%	36.7
21	6	95%	88%	90%	92%		96%	87%	91%	20.8
22	5	87%	95%	93%		94%	97%		93%	15.8
23	4	96%	96%		95%	87%			93%	14.1
24	3	44%	95%		96%				83%	12.5
All Periods	7	81%	93%	89%	91%	92%	97%	87%	90%	



Buldir West 1995 Significant Decline in CPUE

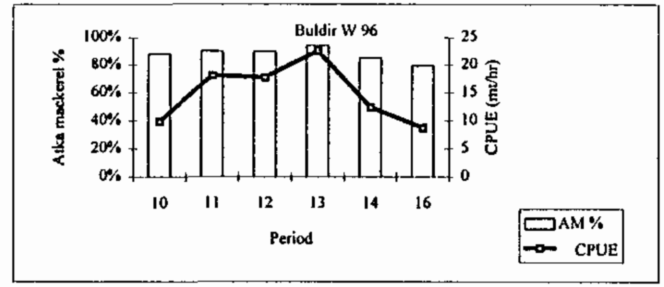
Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	AM %	CPUE
11	1		87%					87%	34.6
12	1		94%					94%	28.3
13	1		96%					96%	28.6
15	1		76%					76%	16.5
16	1		93%					93%	17.4
18	6	82%	76%	85%	78%	72%	87%	81%	13.7
19	6	89%	79%	94%	93%	69%	83%	87%	13.6
All Periods	6	84%	88%	89%	82%	71%	86%	86%	



Appendix 3. Atka mackerel Percentage in Sampled Hauls by Period and Vessel and CPUE of Atka mackerel vessels by period.

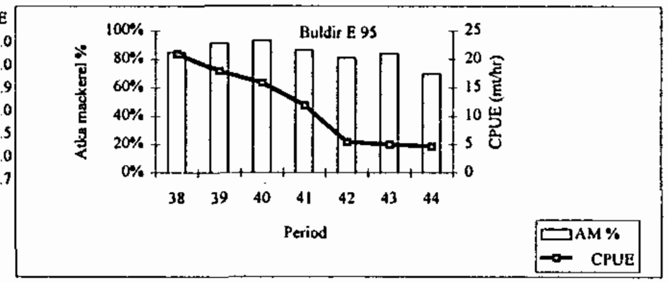
Buldir West 1996

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	AM %	CPUE
10	4	92%			92%	88%	87%	88%	9.9
11	5	84%	86%	94%	95%		94%	90%	18.2
12	3			94%	84%		88%	90%	17.9
13	2			94%			94%	94%	22.7
14	3			91%	83%		73%	85%	12.5
16	1				79%			79%	8.8
All Periods	6	85%	86%	93%	85%	88%	89%	90%	



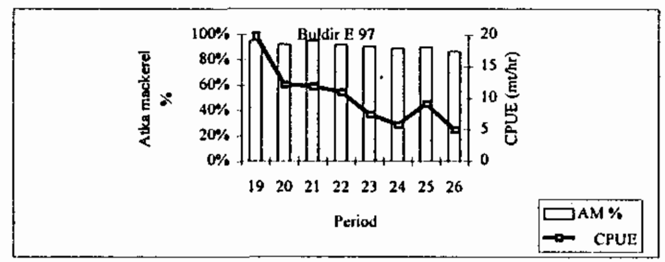
Buldir East 1995 Significant Decline in CPUE

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	Ves 8	Ves 9	Ves 10	Ves 11	AM %	CPUE
38	4	79%				89%	82%		89%				85%	21.0
39	3	87%				97%			88%				91%	18.0
40	2					94%			91%				93%	15.9
41	3					91%		93%		48%			86%	12.0
42	8		60%	67%	78%	93%		77%		81%	71%	57%	81%	5.5
43	7	91%	62%	76%	87%			93%		75%		82%	84%	5.0
44	3		76%	59%								71%	70%	4.7
All Periods	11	83%	73%	63%	79%	92%	82%	83%	89%	75%	71%	76%	83%	



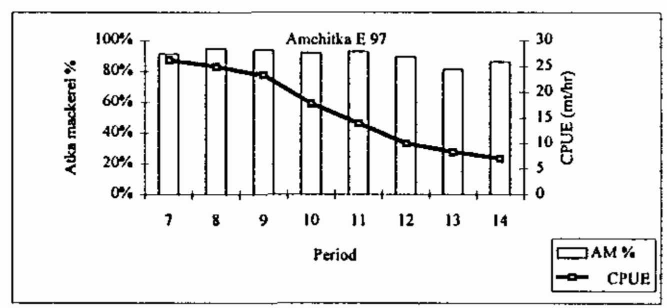
Buldir East 1997 Significant Decline in CPUE

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	Ves 8	Ves 9	AM %	CPUE
19	7	98%	92%	90%	96%		92%	99%	96%		95%	19.9
20	3	97%			93%		91%				92%	12.3
21	3	96%				90%	97%				95%	11.9
22	3	88%		88%				96%			92%	11.0
23	3	86%					93%	96%			91%	7.5
24	4	83%					90%		91%	91%	89%	5.8
25	6			83%	95%	94%	92%		94%	87%	90%	9.2
26	4			97%	77%		80%	95%			87%	5.1
All Periods	9	91%	92%	86%	94%	93%	92%	96%	95%	88%	92%	



Delarofs 1996 Significant Decline in CPUE

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	AM %	CPUE
7	2			81%			92%	91%	26.3
8	1						94%	94%	25.0
9	2	93%					94%	93%	23.3
10	4	89%			82%	93%	92%	92%	17.8
11	3				78%	97%	93%	93%	14.0
12	3		84%		91%		87%	89%	10.0
13	4	85%	87%		88%		61%	81%	8.4
14	2				94%		59%	86%	7.1
All Periods	6	89%	87%	81%	89%	94%	88%	89%	



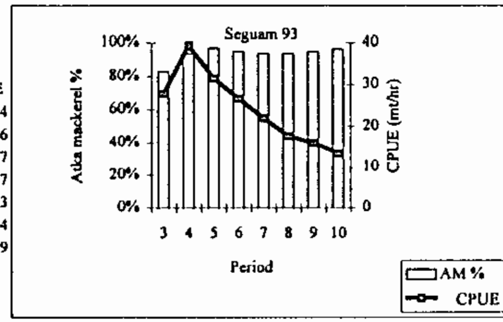
Appendix 3. Atka mackerel Percentage in Sampled Hauls by Period and Vessel and CPUE of Atka mackerel vessels by period.

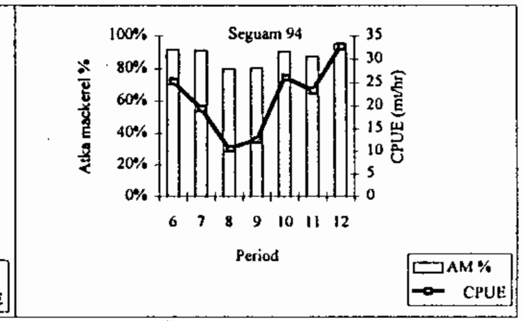
Seguam Bank 1993 Significant Decline in CPUE

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	Ves 8	Ves 9	Ves 10	Ves 11	Ves 12	Ves 13	Ves 14	Ves 15	Ves 16	Ves 17	Ves 18	Ves 19	Ves 20	Ves 21	AM %	CPUE
3	4	99%						91%					64%				98%						83%	27.9
4	4	97%						91%					94%				93%						93%	39.4
5	4	99%						96%					92%				98%						97%	31.7
6	4	98%						94%					91%				95%						94%	26.8
7	12	97%	74%					95%	97%			77%	95%	77%	97%	95%	97%		90%	95%			94%	22.1
8	17	97%	87%		91%	94%	97%	97%	92%			65%	94%	86%	95%	95%	96%	93%	93%	98%		95%	93%	17.7
9	21	97%	88%	94%	97%	90%	99%	96%	98%	96%	97%	78%	96%	85%	95%	95%	96%	94%	95%	99%	99%	95%	95%	16.1
10	12				98%			96%	97%	91%			94%	89%		97%	96%	84%		100%	97%	95%	96%	13.5
All Periods	21	98%	85%	94%	97%	92%	98%	94%	96%	95%	97%	72%	89%	85%	95%	95%	96%	93%	94%	98%	98%	95%	94%	

Seguam Bank 1994

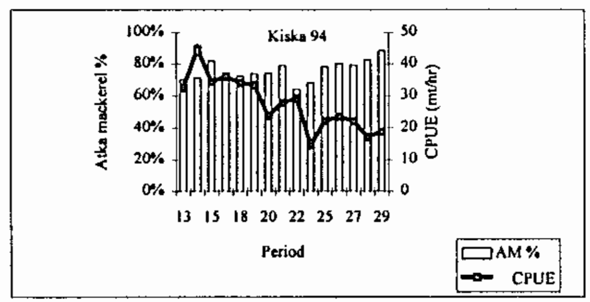
Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	AM %	CPUE
6	3	91%	87%					95%	92%	25.4
7	7	93%	98%	81%	84%	93%	86%	96%	91%	19.6
8	7	89%	81%	74%	72%	91%	70%	97%	80%	10.7
9	6	90%	79%		64%	90%	70%	95%	80%	12.7
10	7	94%	95%	78%	91%	81%	90%	92%	90%	26.3
11	7	93%	95%	76%	92%	92%	92%	90%	87%	23.4
12	4	94%	99%	93%		97%			95%	32.9
All Periods	7	92%	92%	78%	81%	91%	84%	95%	87%	





Kiska 1994 Significant Decline in CPUE

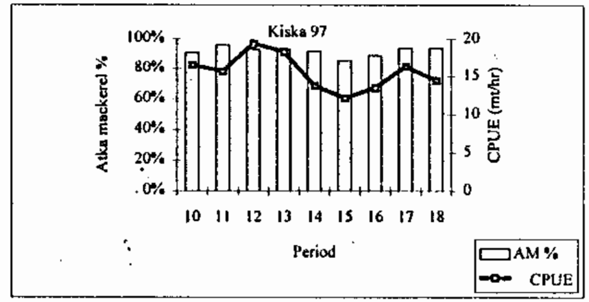
Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	Ves 8	Ves 9	Ves 10	Ves 11	AM %	CPUE
13	2						64%		78%				70%	32.6
14	2						70%		84%				71%	44.8
15	2						79%		85%				82%	34.5
16	2						63%		89%				73%	36.2
18	2						80%		69%				72%	34.1
19	3						77%		78%			55%	74%	33.5
20	6	81%		78%			65%		79%	67%		56%	74%	24.0
21	6	81%		87%			73%		88%	80%		76%	79%	28.0
22	2						78%					54%	64%	29.4
24	1								68%				68%	14.7
25	1								78%				78%	22.3
26	2								81%	79%			80%	23.6
27	4				75%	93%			84%	76%			79%	22.2
28	8	83%		82%	83%	84%	76%		88%	83%	89%		82%	17.2
29	10	92%	74%	84%	92%	92%	90%	81%	93%	91%	87%		88%	18.9
All Periods	11	84%	74%	82%	84%	85%	74%	81%	81%	81%	88%	63%	78%	



Appendix 3. Atka mackerel Percentage in Sampled Hauls by Period and Vessel and CPUE of Atka mackerel vessels by period.

Kiska 1997

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	Ves 8	AM %	CPUE
10	2	92%						89%		90%	16.5
11	5	94%			96%	95%		96%	95%	96%	15.7
12	7	94%	67%	96%	97%		91%	95%	96%	93%	19.4
13	5		85%	96%	90%		96%	97%		93%	18.3
14	3			91%	88%			96%		91%	13.8
15	4		79%	92%	84%			96%		85%	12.2
16	4		85%	99%	84%			90%		89%	13.5
17	4		95%	96%	90%			82%		93%	16.3
18	5		95%	95%	89%		97%	95%		94%	14.5
All Periods	8	92%	86%	95%	89%	95%	95%	94%	96%	92%	



Petrel Bank 1994 Significant Decline in CPUE

Period	Number of Vessels	Ves 1	Ves 2	Ves 3	Ves 4	Ves 5	Ves 6	Ves 7	Ves 8	Ves 9	AM %	CPUE
7	3	87%		91%	95%						92%	27.6
9	3	98%	81%		92%						92%	18.2
10	3	93%	94%		97%						94%	13.9
11	5		90%	78%		79%		98%	81%		94%	13.8
12	5		71%	70%		86%		97%	89%		85%	9.1
13	1		67%								67%	9.9
14	3	72%	85%				63%				81%	10.2
15	4	59%	81%				34%			79%	64%	6.9
16	3	57%	79%	60%							69%	7.2
All Periods	9	81%	82%	83%	95%	86%	41%	98%	88%	79%	86%