MEMORANDUM

TO: Council, SSC, and AP Members

FROM: Clarence G. Pautzke
Executive Director

DATE: June 16, 1989

SUBJECT: Gulf of Alaska Groundfish Fishery Management Plan

ACTION REQUIRED

(a) Review Shelikof Strait and adjacent Gulf of Alaska acoustic survey results and interim pollock status of stock report.

(b) Consider adjusting pollock Total Allowable Catch for the rest of 1989.

(c) Consider emergency action to implement the single species rule.

(d) Consider emergency action to provide for additional Pacific cod TAC in the Western Regulatory Area.

BACKGROUND

(a) 1989 Pollock Hydroacoustic Survey and Interim Stock Status Report.

In December 1988 the Council reviewed the status of the Gulf of Alaska pollock resource and set the 1989 pollock ABC in the Western/Central Gulf at 60,000 mt. At that time there were questions on whether the Shelikof Strait hydroacoustic survey still provides the best estimate of pollock biomass in the Western/Central Gulf of Alaska. There was also considerable debate on the "threshold concept" and whether managers should now use bottom trawl survey estimates. Though considered conservative by scientists, the bottom trawl survey produced a higher 1989 biomass estimate compared to the hydroacoustic estimate. The Council considered all this information in setting its 1989 pollock ABCs and TACs, and noticed the public that it had serious concern over the health of the pollock stock. However, the Council also stated that it would review its December ABC and TAC decisions at this meeting following the 1989 hydroacoustic survey.

At its April 1989 meeting, the Council heard requests from industry to increase the Total Allowable Catch level for pollock in the Gulf of Alaska. Industry was concerned that, due to rapid attainment of the Western/Central Gulf pollock quota by March 23, no pollock quota would be available for the remainder of the year. A consequence would be the mandatory discard of pollock caught incidentally to other groundfish fisheries during the rest of 1989. Also, industry expressed concerns that the shorebased fleet would be unable to prosecute the fall pollock fishery around Kodiak Island, thus idling a segment of the fleet and shorebased processing capacity. These concerns were prompted from fishing vessel reports of pollock schools in areas of the Gulf not surveyed by NOAA Fisheries in past years.

In response to the Council request, scientists from the Northwest & Alaska Fisheries Center are available to present the results of the 1989 hydroacoustic survey and provide an interim pollock stock assessment report.

(b) Consider Adjusting Pollock TAC and Allowing Retention of Pollock Bycatch.

The Council needs to consider taking action on a request from industry to adjust the Gulf pollock Total Allowable Catch. For the 1989 Gulf pollock fishery, the Council set ABC and TAC at 60,000 mt with TAC apportioned: 6,250 mt to Shelikof Strait and the remaining 53,750 mt to the Western/Central Gulf.

Acceptable Biological Catch (ABC) is a seasonally determined catch or range of catches that may differ from MSY for biological reasons. Given suitable justification by the plan team and/or SSC, ABC may be set anywhere between zero and the current biomass less the threshold value. Lacking other biological justification, ABC is generally the MSY exploitation rate multiplied by the exploitable biomass for the relevant time period. ABC is defined as zero when the stock is at or below its threshold.

Total Allowable Catch (TAC) is the harvest quota for a species and is set based on biological and socioeconomic information. TAC may be lower or higher than ABC if the Council believes that biological, conservation, or socioeconomic considerations warrant a harvest below or above ABC. Thus, the Council has the latitude to set TAC above ABC if deemed necessary; however, to date the Council has not set TAC above ABC in either the Gulf or the Bering Sea/Aleutian Islands groundfish fisheries.

If the Council decides that an increase in TAC is warranted, industry has requested that retention of pollock bycatch be allowed during other groundfish fisheries for the rest of 1989. This issue is before the Council in agenda item D-2(c) below. If the Council sets TAC sufficiently high, industry has also requested a directed fishery for pollock this fall.

(c) Emergency Action to Implement the Single Species Rule.

During the recent FMP amendment cycle, a proposal was received to implement the single species rule in the Gulf of Alaska. Such a management measure allows the Regional Director to close a groundfish fishery short of its TAC in order to permit other fisheries that take that species as bycatch to continue to fish and to retain the species. The Council approved this measure as a regulatory amendment at its January meeting. The regulatory amendment was forwarded to the Secretary in late May for approval and implementation. It is expected to be effective by mid-September, 1989.

Industry has expressed concern that the single species rule will not be available to NOAA Fisheries in time to close several fisheries which are nearing their TAC and to allow continued retention of those species when taken as bycatch in other fisheries [see item D-2(c)(1) attached]. The fisheries of most concern are Pacific cod in the Western Regulatory Area [agenda item D-2(d) below addresses this issue more fully], other rockfish in the Central Regulatory Area (approximately 70% of the 8452 mt TAC has been taken to date), and thornyhead rockfish (approximately 56% of the 3800 mt TAC has been taken).

It is difficult to project when quotas for any of these species will be taken, but it is reasonable to assume that all three fisheries listed above will be fully prosecuted relatively soon. For the RD to have the authority to invoke the single species rule for these fisheries and for pollock (if the Council increases its TAC) before mid-September an emergency rule is required. An emergency rule requires approximately 30 days to become effective after the Council decision.

(d) Emergency Action to Increase Pacific Cod TAC for 1989.

At its December 1988 meeting, the Council set the 1989 Pacific cod ABC at 71,200 mt and recommended TAC=ABC. The TAC was apportioned: Western Area, 13,500 mt (19%); Central Area, 52,000 mt (73%); and Eastern Area, 5,700 mt (8%).

The apportionment was based on bottom trawl survey results and was believed to represent the approximate distribution of cod biomass across the Gulf.

During the 1989 fishing year, industry has nearly attained the Pacific cod TAC in the Western Regulatory Area. According to preliminary data provided by NOAA Fisheries, the 1989 Gulf of Alaska Pacific cod harvest to date has been: Western Area, 11,607 mt (86% of TAC); Central Area, 15,220 mt (29% of TAC), and Eastern Area, 37 mt (1% of TAC), for a total of 26,864 mt.

A request has been received from industry for emergency action by the Council to raise the TAC for the Western Regulatory Area [item D-2(c)(2)] to allow for continued fishing for Pacific cod in the Western Area later this fall. Industry estimates 10,000-16,000 mt of additional TAC is needed. The Gulf of Alaska groundfish Plan Team reviewed this issue at its June 5-7, 1989 meeting. The Plan Team comments are attached under item D-2(c)(3).

The Council needs to review this information and consider taking action on the industry request.

AGENDA D-2(c)(3)
JUNE 1989

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Alaska Fisheries Science Center
Resource Ecology and Fisheries
Management Division
7600 Sand Point Way Northeast
BIN C15700, Building 4
Seattle, Washington 98115-0070

June 13, 1989 F/AKC2:JB

MEMORANDUM FOR: Mr. Bill Wilson - Plan Team Coordinator

FROM: J. W. Balsiger - Plan Team Chairman

SUBJECT: Plan Team Statement on Pacific Cod

The Gulf of Alaska Groundfish Plan Team reviewed the estimation of ABC for Pacific cod as described in the 1988 Resource Assessment Document (RAD). That document estimated 1989 exploitable biomass at 498,000 t, and identifies .143 as an appropriate exploitation rate. The multiplication of these two values provides an ABC estimate of 71,200 t. No new data are available and we consider this estimate to be still appropriate.

The Team believes the Gulf of Alaska Pacific cod resource is a single stock and that the TAC should be distributed approximately as the biomass is distributed to Regulatory Areas. Minor discrepancies would not be of concern.

AGENDA D-2(c)(1)
JUNE 1989

Alaska Groundfish Data Bank

May 4, 1989

John Peterson, Chairman
North Pacific Fishery Management Council
c/o Northwest and Alaska Fishery Center
Seattle, Washington

Sent by FAX

Dear John:

We have two issues we would like addressed at the June meeting of the North Pacific Fishery Management Council if it is possible to put them on the agenda.

1. Direction to NMFS to implement the Gulf of Alaska Single Species Rule by emergency regulation
2. Discussion of the appropriate fishing year for Gulf of Alaska pollock.

Single Species rule

As you know, the Alaska Regional Director, NMFS Juneau, was directed to implement a regulatory amendment to establish a single species rule for the Gulf of Alaska similar to the rule now in existence for the Bering Sea.

The rule will allow the regional director to close a directed fishery before TAC is reached in order to allow enough quota for retainable bycatch in other groundfish fisheries.

Because of the time required to develop the emergency bycatch regulations in the Bering Sea, NMFS Juneau has just this week finished the Gulf of Alaska single species rule and transmitted it to Washington, D.C.

Under the regulatory amendment process it will be another four months before the rule will be in effect.

Because the regulatory amendment is already in Washington, D.C. and in process NMFS feels in would only take two to three weeks to put it into effect if directed to do so by emergency rule.

We anticipate that the following Central and Western Gulf of Alaska groundfish species will be fully taken this summer:

1. Western Gulf Pacific Cod
    53% of quota taken as of Feb. 25 - Apr. 22.
    As of Apr. 22, 58% of quota taken.
    Anticipated closure at current rate - June 22

Chris Blackburn • Director • P.O. Box 2298 • Kodiak, Alaska 99615 • (907) 486-3033

2. Central Gulf Other Rockfish
   28% of Quota taken Mar. 25-Apr 22
   As of Apr. 22, 32% of quota taken.
   Anticipated closure at current rate - July 15
3. Gulfwide Thornyhead
   25% of quota taken March 25-Apr 22.
   As of Apr. 22, 29% of quota taken.
   Anticipated closure at current rate - July 15

(The catch figures and percentages are from NMFS, the projected closure date is my own based on the current catch rate).

The rockfish and thornyheads are taken as bycatch in the Dover sole fishery.

The Western Gulf Pacific cod will be taken as bycatch if there is a fall pollock fishery and any bottom trawl pollock fishing is done in the Western Gulf of Alaska. Further, some Pacific cod will be taken as bycatch in the Western Gulf longline black cod fishery.

Without quick action to implement a single species rule in the Gulf of Alaska by emergency regulation, all three of these species will become PSCs and will be discarded at sea during the prosecution of the remaining groundfish fisheries.

A rapid implementation of the single species rule will avoid the potential waste of these resources.

Gulf of Alaska pollock fishery year

NMFS has stated that the pollock biomass estimates which are to be presented to the council in June are the only new estimates that will be available during 1989. Therefore, the quota set in June will be the quota for the remainder of 1989 and all of 1990 -- "an 18 month quota."

This assumes that the fishing year remains Jan. 1 to Dec. 31.

In essence, the information presented in June is the information that ordinarily would be presented in September/December. All the SSC and Plan Team will be able to do is set an ABC based on the biomass estimate. It will be up to the council to decide how to apportion that quota between the remainder of 1989 and the end of 1990.

As you know, there have been discussions in Kodiak about changing the pollock fishing year so that the roe season comes at the end of the fishing year rather than the beginning. The dates April 1 to March 30 have been mentioned as have September 1 to August 30.

There is, at this time, no formal proposal, but there may be one developed over the following two-three weeks.

If there is no decision to ask for a change in the fishing year, then there will be a discussion of how to apportion the quota set in June among the next 18 months.

I realize the legal complications involved in changing the fishing year since it is now set by FMP and I also realize there may be some agency objections. There are ways around most of the problems, should there be an industry decision to request a change in the fishing year.

At the moment there does not appear to be a widespread industry awareness that reassessing the Gulf pollock quota in June means, in essence, setting an 18 month quota.

I have this week drafted a discussion paper for AGDB members and sent it over to the Kodiak Processors Association for their review. The processors meet next week.

Knowing that one way or another this issue will occupy some time, I thought it best to let the council know well ahead of time so that there could be any necessary public notice and the agenda could allow time for either a discussion of apportioning the pollock quota for 1989-90 over time or revising the pollock fishing year.

Ain't we all got fun.

Sincerely,

Chris Blackburn, Director
Alaska Groundfish Data Bank

Also faxed to Clarence Pautzke, Executive Director
North Pacific Fishery Management Council

AGENDA D-2(c)(2)
JUNE 1989

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Peter Pan
SEAFOODS, INC

Mr. John Peterson, Chairman
North Pacific Fishery Management Council
P.O. Box 103136
Anchorage, AK 99610

May 05, 1989

Dear John:

We are writing to request that the Council initiate a review of the DAP for pacific cod in the Western Gulf with a view toward increasing the DAP on an emergency basis for the remainder of 1989 and on a permanent basis for 1990.

As of April 22nd, 58% of the 13,500 m.t. DAP had been taken. We would guess that as of today it is closer to 65%.

Peter Pan began processing pacific cod at King Cove in March of 1987 using local boats on an experimental basis. We intended to restart in January of 1989, but the big boats were fishing joint ventures and the smaller boats could not handle the weather. Operations finally got underway on March 1st and since then we have done 7,500,000 lbs or 3,400 m.t.

It is our intent to continue processing as late in May as possible and resume production in September and go until mid December. We would resume production in January. We are currently running 120,000 to 140,000 pounds per day. That would be increased to 200,000 pounds by September and 300,000 pounds by January.

We are currently using one big boat and six smaller local boats in the 58 to 70 foot class. It was our intent to utilize the smaller local boats as much as possible, but we do need some bigger boats for the tough weather periods. A portion of our production has come from the Bering Sea, but most of it is from the Western Gulf.

In addition to floating processors and shore plants in Akutan and Dutch who utilize the Western Gulf to some degree there is a shore plant in Sand Point currently processing in the neighborhood of 300,000 pounds per day utilizing a local small boat fleet.

We are not sure how the ABC or TAC were calculated or how they could be increased proceedurally but, assuming the stocks are healthy enough to support an increased TAC, we hope some decision could be reached before the quota is taken.

Very truly yours,

Don Rawlinson, V.P.
Bristol Bay Operations

c.c. Clarence Pautzke ✓
Steve Pennoyer

**** PRELIMINARY REPORT ****
**** DO NOT CITE OR REFERENCE WITHOUT PERMISSION OF THE AUTHORS ****

GULF OF ALASKA WALLEYE POLLOCK: POPULATION ASSESSMENT AND STATUS OF THE RESOURCE IN 1989

by

Anne B. Hollowed and Bernard A. Megrey

1.1 INTRODUCTION

Walleye pollock, Theragra chalcogramma, are a semidemersal schooling species that are widely distributed throughout North Pacific temperate and subarctic waters. In the Gulf of Alaska, major exploitable concentrations are found primarily in the central and western regulatory areas (170-147° W longitude). Pollock from this region are managed as a unit stock since they are considered separate from those in the Bering Sea, Aleutian Islands and the eastern Gulf of Alaska (Alton and Megrey 1986). Shelikof Strait is a known major pollock spawning area in the Gulf of Alaska although other spawning locations in the western and central Gulf have been identified from the occurrence of eggs and larvae (Kendall and Picquelle, in prep), and observations of spawning fish in areas outside of Shelikof in 1989. In previous years, these areas were judged to be of minor importance relative to the Shelikof spawning area.

Estimates of the total biomass of the walleye pollock stock are derived from Gulf wide triennial bottom trawl surveys and annual hydroacoustic surveys of Shelikof Strait during the spawning period (March). Biomass estimates based on both kinds of surveys show a recent decline, however the magnitude of the decline differs between the two surveys. The biomass estimate from the bottom trawl survey in the summer of 1987 was 856,821 t, whereas, the hydroacoustic biomass estimate of the spawning stock in Shelikof Strait in the winter of 1988 was approximately 330,000 t.

In 1988 the North Pacific Fisheries Management Council established a quota of 90,000 t for the Western and Central Gulf of Alaska. All of this was allocated to domestic fisheries. Only 55,970 t of the 90,000 t quota was harvested in 1988. Virtually all of the catch was delivered to shoreside processors and roughly 50% of the catch was taken on the eastside of Kodiak in the fall.

In 1989, the NPFMC set a 1989 quota of 6250 t for Shelikof Strait and 60,000 t outside of Shelikof Strait. This decision was based on information indicating a severe decline in the biomass of the Gulf of Alaska pollock stock. The entire 1989 quota was taken in the first quarter of 1989. Over 50% of the quota in 1989 was taken by floating catcher/processors in a three week period. The remainder was taken by shoreside processors.

In this report current findings on the Central and Western Gulf of Alaska walleye pollock resource are presented in three main sections. First, summary catch statistics of pollock fisheries in the Gulf of Alaska from 1988 along with data from the spring 1989 fishery are presented including data through June, 1989. Second, the status of the resource is updated on the basis of an age-structured analysis that includes catch-at-age data through the spring fishery in 1989. Third, a series of forecasts of stock abundance and composition are presented.

1.2 CATCH HISTORY

1.2.1 Catches

Catches of pollock from the Gulf of Alaska in 1988 were taken by two distinct fisheries: a spring domestic fishery fishing primarily in Shelikof Strait, and a fall domestic fishery fishing entirely on the east side of Kodiak Island. The port sampling program, which was initiated in the spring of 1987 to sample catches from the domestic fisheries, was carried out again in 1988 and 1989. Domestic observers were also placed directly on the fishing vessels in 1988 and 1989. A complete description of the Domestic Observer Program in the Gulf of Alaska is presented in Vogeler and Brown (In Prep.).

The total pollock catch (commercial and bycatch combined) in the Gulf of Alaska in 1988 was 55,970 t--down 10% from 1987 (Table 1). In previous years (1983-85) harvest levels ranged from 100,000 to 200,000 t and the harvest was primarily taken by joint venture operations (Table 1). In 1988, the pollock fishery was completely a domestic fishery. The bycatch of pollock in joint venture fisheries for other species was 152 t in 1988. Domestic catch increased to 55,818 t in 1988 (Table 2). In total, 92% of the 1988 pollock harvest (51,376 t) was taken in the NPFMC Central Regulatory Area (Table 2).

1.2.1.2 1988 Domestic Fisheries

In 1988 the majority of the domestic fleet delivered their catches to shore-based processing plants on Kodiak Island. The domestic fleet was active during two periods in 1988. In the spring the fleet fished Shelikof Strait and in the fall they fished outside of Shelikof, concentrating their efforts on the east side of Kodiak Island (Figure 1).

The domestic fisheries in the Gulf of Alaska harvested 55,818 t of pollock (Table 1). Most (51,226 t, 92%) of this catch was taken from the NPFMC Central Regulatory Area (Table 2) although a small fraction (4,590 t, 8%) was harvested from the NPFMC Western Regulatory Area. In terms of temporal distribution (Table 2), 59% of the domestic catch (32,764 t) was taken in the fourth quarter. First, second and third quarter domestic catches amounted to 17,285 t (31%), 1,996 (4%) and 3,773 (7%), respectively.

1.2.1.3 1989 Spring Domestic Fisheries

In the spring of 1989 several new developments in fishing practices were observed. Due to the apparent decline in the pollock resource, a quota of 6,250 t was imposed for the Shelikof Strait area. Outside of Shelikof Strait a quota of 60,000t was allocated. A total of 64,929 t was taken during the first quarter of the year. Forty two percent of the catch was delivered to shoreside processors and 58% was harvested by catcher/processors. The catcher/processor fleet harvested 38,416 t within a 2-3 week period in March (Vogeler, In Prep).

The catcher/processors fleet was primarily fishing for roe, and concentrated their fishing efforts in offshore waters outside of Shelikof Strait (Figure 1). The catcher/processors initially fished in the Western NPFMC regulatory area near the Sanak Islands. A total of 11,314 t (17.4% of the total catch) was harvested in the Shumagin International North Pacific Fisheries Commission (INPFC) statistical area (Table 3). Subsequently, the catcher processor fleet moved northeast and fished two locations between near Chirikof Island (Figure 1).

The Kodiak based fleet fished four major areas; Shelikof Strait, Chiniak Gully, Barnabas Gully, and Marmot Gully (Figure 1). A complete description of the 1989 domestic fleet activities is provided by Vogeler and Brown (In Prep.). Total catches from Shelikof Strait (6,429 t) and the Kodiak INPFC area (18,813 t) represented 39% of the total harvest in 1989 (Table 3).

1.2.2 Length Composition

Estimates of length and age composition of pollock landed by fisheries in the Gulf of Alaska are based on data collected by port samplers and domestic observers. Nelson et al. (1981). described the sampling procedure used by observers to obtain length information and age structures, LaLanne (1979) described the procedures for determining the age of pollock from otoliths, and Kimura (1987) described the procedure for estimating the age composition of pollock catch. Additional information on the techniques used by domestic observers and port samplers are described in Vogeler (1989).

1.2.2.2 1988 Length Frequency Data

Pollock length frequency histograms from the 1988 spring domestic fishery were presented in Megrey (1988b). These histograms were constructed from data collected by the port sampling team and the fall domestic observers. All of this data came from Shelikof Strait. The histograms are multimodal with modal lengths ranging from 22 cm, 33-34 cm, 38-41 cm and 46-49 cm for males, from 22 cm, 34-36 cm, and 46-54 for females, and from 22 cm and 49 cm for the sexes combined (Figure 2).

Length frequency data from the 1988 fall fishery was collected by the Alaska Department of Fish and Game (ADF&G) observers and National Marine Fisheries Service (NMFS) port samplers. The Alaska Department of Fish and Game implemented an observer program in 1987. The data was not collected on a sex stratified basis. However, ADF&G did identify whether the collections were taken from vessels using bottom trawl gear or mid-water gear. Comparison of length frequency data from the fall of 1987 and 1988 show a dramatic difference between years and between gear types (Figure 3). The collections of bottom trawl samples were primarily comprised of large fish. Whereas, the mid-water collections were dominated by smaller size groups.

1.2.2.3 1989 Length Frequency Data

Biological information collected from the spring fishery in 1989 was stratified by geographic location. Six areas were identified: Sanak, Shelikof Strait, Marmot Gully, Chiniak Gully, Barnabas Gully and Chirikof. An approximation of the boundaries of each area is shown in Figure 1. None of the catch harvested in the Sanak area was sampled for biological data. Catches from the Shelikof Strait, Marmot Gully, Chiniak Gully and Barnabas Gully were delivered to shoreside processors on Kodiak Island. Data collected from the Chirikof area was collected by one domestic observer on board one catcher/processor.

The length frequency data from the combined areas showed a broad mode between 35 and 45 cm (Figure 4). The absence of modes at smaller lengths suggests the 1986 and 1987 year classes were not strong. It would be unlikely that age 1 fish (the 1988 year class) would be observed in the 1989 commercial fisheries data.

The length frequency distributions from Shelikof Strait, Chiniak Gully, Marmot Gully, and Barnabas Gully were all similar (Figures 5-9). These length frequency plots showed a distinct mode at 40-45 cm. The smallest mean length for sexes combined was observed in Shelikof Strait (38.9 cm) followed by Chiniak (40.7 cm), Marmot Gully (44.2 cm), and Barnabas (45.4 cm) respectively.

The length frequency distribution from the Chirikof area was clearly distinguished from sub-areas near Kodiak Island. The mean length for sexes combined was much larger (50.4 cm) (Figure 9). Furthermore, there were no observations of fish under 38cm in the samples.

In the spring of 1989 there were five cases where the catch of a domestic fishing vessel was sampled on the fishing grounds by a domestic observer and then sampled again by the port sampler. The location and date of each of the five cases is described below.

CASE #	Location	Date
1	Shelikof Strait	March 10
2	Shelikof Strait	March 11
3	Shelikof Strait	March 16
4	Barnabas Gully	February 2
5	Marmot Bay	February 12

Double sampling of the catch was carried out to determine whether the port sample was giving a true representation of the length composition of the catch.

The length frequency histograms from the five cases are presented in Figures 10-14. Port samples of catches from Shelikof Strait (cases 1-3) were all comparable to the observer data (Figures 10-12). However, port samples of catches from Barnabas Gully (case 4) and Marmot Gully (case 5) had different distributions and mean lengths (Figures 13 and 14). The differences between estimates of mean length from port samples and observer samples were not consistent. In some instances the port sample mean was higher than the observer mean and visa versa.

Megrey (1988a, 1988b) speculated that differences between the length composition of samples taken at the port and on board ship may be due to the process of sampling the catch during off-loading. If settling occurs in the hold while the fishing vessel transits from the fishing grounds to the dock, then it is possible that the length samples may not reflect a random sample of the catch unless samples are taken at several intervals during the unloading procedure.

1.2.2.4 1989 Survey Length Frequency

In 1989 the NMFS hydroacoustic survey assessed three regions of the Gulf of Alaska; Chirikof, Marmot Gully and Shelikof Strait. The length frequency histograms from samples taken in each of the three areas are shown in Figure 15. The Shelikof Strait samples showed a clear mode of small fish (10-15 cm). The abundance of these small fish suggests that the 1988 year class may be strong.

1.2.3 1988 Age Composition

Age composition estimates from the 1988 commercial fisheries show different patterns between seasons. The spring 1988 commercial fishery data showed the 1983 (age 5), 1984 (age 4) and 1978 (age 10) year classes were the main contributors to the fisheries catch. (Figure 16). The appearance of the 1983 year class (age 5) as a dominant one in the catch is inconsistent with previous observations of this year class which indicated the 1983 year class was below average (Megrey 1988b). The appearance of a large component of 5-year-olds in the 1988 fishery may reflect the fact that this age group is fully recruited to the gear rather than being an indication that the year class is a strong one.

In the fall of 1988 the majority of the pollock were harvested from Marmot Gully and Barnabas Gully (Figure 1). The fall 1988 age composition was based on data collected from only the Marmot Gully area. The length frequency data from Marmot and Barnabas gullies were very similar (Figures 7 and 8). Therefore, age composition estimates from Marmot Gully were assumed to represent catches taken from the eastside of Kodiak.

The age composition estimates from the 1988 fall domestic fishery showed the 1985 (age 3) and 1984 (age 4) year classes were the dominant year classes in the catch (Figure 16). This finding was consistent with previous observations of the abundances of these two year classes. Megrey (1988b) noted that the fall domestic fishery in 1987 harvested young pollock with the 1984 year class contributing almost 40% to the total catch. The strong 1978 year class contributed only a minor amount to the fisheries on the eastside of Kodiak in 1989.

1.2.3.2 Survey Age Composition

Age composition estimates from the 1987 summer triennial bottom trawl survey showed the 1985, 1978 and 1981 year classes were predominant (Figure 17). At age 2, pollock are pelagic, therefore, the strong showing of 2-year-olds in the 1987 bottom trawl survey indicated that the 1985 year class was above average.

In the 1988 hydroacoustic survey in Shelikof Strait, the 1984 (age 4) and 1985 (age 5) year classes represented 82% of the population of fish ages 2 and above (Figure 17). The estimated number of two year-old fish (the 1986 year class) was 115.3 million and only represented 8.5% of the population age 2+. This estimate falls between the estimated of numbers at age 2 derived from the 1984 (the 1982 year class) and 1985 (the 1983 year class) hydroacoustic surveys (Table 4).

Age composition information from the 1989 hydroacoustic survey was not available for inclusion in this document. However, preliminary estimates of the abundance of one and two year-old fish could be made based on the estimated number of fish at length. At young ages, year classes can be easily distinguished on the basis of the length. In this analysis, age one fish were assumed to be 10-15 cm and age two fish were assumed to be 15-25 cm. Using this criteria, the estimated number of age 2 fish in 1989 was 89.4 million. This estimate is similar to the estimated abundance of the 1986 year class as age 2 in 1988.

1.2.3.2 Spring Age Composition in 1989

Age structures were collected by domestic observers and port samplers in 1989. A total of 2,222 otoliths were aged by the Alaska Fisheries Science Center (AFSC). These samples included 324 otoliths collected on board a catcher processor fishing in the Chirikof sub-area. The number of samples collected from the catcher processor was insufficient to construct a separate age-length key. Therefore, a single composite age-length key was constructed that included data from the eastside of Kodiak Island, Shelikof Strait, and Chirikof sub-area. Separate age composition estimates were derived for the catch processor and shoreside processor data by applying sub-area-specific length frequency data from to the composite age-length key as described in Kimura (1987).

The age composition of the catch derived from shoreside processor data was clearly different from that derived from the catcher processor data (Figure 18). The shoreside catch was primarily supported by the 1984 (age 5) and 1985 (age 4) year classes. Relatively few older fish were observed in the shoreside processor catch. In contrast, the catcher processor catch was composed of several older age groups (Figure 18). The two strongest year classes in the catcher processor age composition were the 1983 (age 6) and 1984 (age 5) year classes. The 1978 year class (age 11) represented approximately 7% of the catcher processor age composition.

1.2.3.2 Historical Age Composition of the Catch

The age composition of the catch since 1977 in INPFC areas Shumagin, Chirikof and Kodiak were examined. The purpose of this study was to investigate differences in the relative contribution of strong year classes to the catch in different areas. The analysis was restricted to sex, area and time cells that contained at least 50 age samples (Appendix 1 Tables 1 and 2). Comparisons between areas were made using samples from collected between May and August. At least 50 age samples from each area were available during the second season from 1977 to 1982 with the exception of one cell (Kodiak in 1981, Appendix 1 Tables 1 and 2).

Comparison of the age compositions between areas and years revealed some important differences between areas. In 1977 the age composition was dominated by the 1972 year class. The 1972 year class continued to support the fishery in the Shumagin area until 1979 (Figures 19 and 20). In the Shumagin area, the strong 1975-1979 year classes did not account for a large proportion of the age composition until age four. In contrast, the strong 1975-1977 year classes were clearly distinguished at ages two or three in the age compositions from the Kodiak and Chirikof areas age compositions (Figures 21-24). This finding indicated that strong year classes may reside in the Central Gulf as young fish and migrate to the Western Gulf as older fish. An alternative explanation for the differences in the age composition of the Western and Central Gulf may be due to changes in the characteristics of the fishing fleet (i.e. differences in gear bottom trawls vs midwater trawls).

2.1 CONDITION OF THE STOCK

2.1 Changes in Abundance Determined from Age-structured Analysis

The stock assessment analysis conducted this year is the most detailed and in-depth analysis conducted since 1985. In this years analysis, the strengths and weaknesses of the different data sources and assessment procedures, were all evaluated. We have endeavored to 1) simultaneously integrate as much information as possible about the Gulf of Alaska pollock stock into an analysis procedure and 2) analyze the available data with alternative stock assessment models. Use of more than one method can potentially identify problems with the data or underlying assumptions.

2.1.1 Available Data Resources

The fisheries data set used in this analysis consists of estimates of total catch biomass, and the age composition of the catch aggregated over all seasons, nations, vessel classes and INPFC statistical areas for years 1976-89 (Table 5).

Two fishery-independent data sets were available. The first consisted of hydroacoustic survey estimates of biomass and age composition of the Shelikof Strait spawning pollock population for calendar years 1981, 1983-86, and 1988-89. No absolute abundance estimate from the hydroacoustic survey was available for 1987 due to a technical malfunction (Nunnallee 1988). The second fishery-independent data set consisted of bottom trawl survey estimates of total population abundance and age composition for calendar years 1984 and 1987.

The fishery-independent data sets were incorporated into the stock assessment procedure to help calibrate the resulting abundance estimates to appropriate population levels.

The single set of average weight-at-age values used in four previous analyses (Alton and Deriso 1983, Megrey 1985, Megrey and Alton 1987, Megrey 1988a) were updated by re-analyzing the commercial fisheries statistics. The new average weight-at-age values are given in Table 6. A complete evaluation of seasonal and geographic differences in growth of pollock in the Gulf of Alaska was undertaken in 1989. The results of the analysis of growth are presented in Appendix 1. The estimates of weight-at-age derived from the study of growth are used throughout this document. Therefore, the Appendix was included for reference purposes.

2.2 Data Assumptions, Strengths and Weaknesses

Catch-at-age data

Estimates of age-specific catch data (in numbers) from the commercial fishery represents the primary input data source for any stock assessment model. There is no measure of effort from the Gulf of Alaska walleye pollock fishery. Ages 3 to 10 appear consistently in the catch. However, 2 and 11+ year old individuals are observed intermittently.

Catch-at-age data are not collected directly from the fishery. Estimates of catch-at-age in numbers are determined using the procedure developed by Kimura (1987). In this method, yield for a given sub-stratum is distributed by age using randomly sampled length frequencies from the stratum applied to age-length and weight-length keys. Every attempt was made to apply the catch biomass to age composition and length frequency samples from appropriate season, gear and area cells.

Assumptions: Estimates of total catch in biomass, average weight-at-age, and age composition are not biased and are estimated without error.

Strengths: During the period when the fishery was dominated by foreign and joint venture participants (1976 to around 1985) data from the commercial fishery was of high quality. This was due the high observer coverage (> 90% coverage in 1985), wide geographic coverage (catches came from the entire western Gulf of Alaska), seasonal coverage (all quarters of the year), and the large number of different participants (5 nations and fleet types in 1979).

Weaknesses: Recently (1987-89) the biological information from the fishery are not as representative of the population as they were prior to 1987. For example, no biological data was collected on the catch that occurred in the Shumagin areas. The vessels that deliver to shoreside processors on Kodiak Island operate in restricted geographic areas (Shelikof Strait and east side of Kodiak Island) and the catch is taken in a much narrower temporal window (spring and fall). In 1989, the entire quota was taken in the first quarter of the year.

Bottom Trawl Research Survey Data

Bottom trawl surveys are conducted by the National Marine Fisheries Service every three years in the Gulf of Alaska. Early survey information is available from 1973-75 (Hughes and Hirschhorn 1979), however these surveys do not overlap with the catch-at-age data time series. Recent survey data is available from 1984 and 1987. This survey covers the entire shelf area in the western Gulf of Alaska during the summer months. The survey, which covers from Cape Saint Elias (145 W longitude) to Amukta Island (170 W longitude), provides a synoptic survey of the entire Gulf of Alaska. Brown et al. (1989) provide details on the geographic coverage, gear description and survey methodology.

The bottom trawl survey did not target on pollock, however, pollock represented a large of the total estimated bottomfish biomass in the Gulf of Alaska (Brown et al. In Prep.). Pollock ages 2 through 15 are taken in this survey. The survey provides estimates of total pollock abundance in units of biomass and numbers and estimates of age composition.

Up until this year only the 1984 bottom trawl abundance estimate was available. This is the first year that both the 1984 and 1987 abundance estimates are available to tune the assessment model.

Assumptions: Catchability is 1.0.

Strengths: The bottom trawl survey is a synoptic survey and provides a Gulf-wide population estimate.

Weaknesses: There are only two years of survey data with which to tune the stock assessment model. Because the survey is a bottom trawl survey it may not accurately assess the pelagic component of the pollock population. The survey estimates the biomass of pollock only in areas where trawling can be attempted. The portion of the stock that inhabits unsuitable areas for trawling is only approximated.

Hydroacoustic Survey Data

The hydroacoustic survey is conducted by the National Marine Fisheries Service in the spring of the year in Shelikof Strait. The survey has been carried out every year since 1981 with the exception of 1982. In 1987 technical difficulties were encountered which precluded the derivation of absolute population estimates. Relative estimates are available for 1987 as well as age composition estimates (Nunnallee 1988).

With echo integration techniques, the hydroacoustic survey estimates the biomass present at the time of spawning. Biological sampling similar to U.S. Observer sampling provides estimates of length frequency, weight, and age composition. From these biological data estimates of abundance in numbers can be derived. Population estimates in units of biomass are more accurate than estimates of abundance in numbers (Nunnallee, pers. comm.).

Assumptions: Biomass estimates from Shelikof Strait represent an estimate of the adult stock of pollock in the Gulf of Alaska. Implicit in this assumption is the further assumption that no significant spawning aggregations occur outside of Shelikof Strait. Population estimates in units of numbers-at-age assume that total catch in biomass, average weight-at-age, and age composition are not biased and are estimated without error. It is also assumed that the survey coincides with the period of peak spawning and that this period of peak spawning does not exhibit any interannual variation or variation with the age composition of the stock.

Strengths: There is a relatively long time series (7 years) of survey results relative to the catch-at-age time series with which to tune the stock assessment model. Biomass estimates of the pelagic component of the stock are highly accurate. A large geographic area can be surveyed in a relatively short period of time.

Weaknesses: The on-bottom component of the population is not assessed accurately because of technical limitations with the echo integration equipment (Nunnallee, 1988). The scaling of acoustic signal to underlying biomass is extremely sensitive to the target strength parameter (Nunnallee, 1988). Yoklavich and Bailey (in prep.) found evidence that the peak period of spawning may be occurring later in the year. The 1989 hydroacoustic survey and the domestic fishery demonstrated that other spawning aggregations could be found on the east side of Kodiak (Williamson In Prep.).

Natural Mortality = 0.4

Natural mortality is a difficult parameter to ascertain however in the Gulf of Alaska pollock stock a constant value of M=0.40/yr has routinely been used. Megrey (1989) has recently investigated the validity of this assumption. Using three stock assessment models (Paloheimo 1980, Fournier and Archibald 1982, Deriso et al. 1985) and the methods of Alverson and Carney (1975) and Pauly (1980). He concluded that the assumption of a natural mortality rate of M=0.40/yr was not unreasonable, especially in light of the high variability in the individual estimates.

2.3 Assessment Model Description and Methods

The following description of the stock assessment model assumptions and methods is provided so that the reader can thoroughly evaluate the basic premises upon which the stock assessment was performed.

2.3.1 The CAGEAN Model

The CAGEAN separable non-linear log catch model of Deriso et al. (1985) was applied to the all-nation catch-at-age data in order to estimate age-specific selectivities, fishing mortalities and absolute estimates of population abundance.

Assumptions: 1) Catch-at-age is modeled by a stochastic Baranov catch equation that incorporates a lognormal error random variable; 2) natural mortality is constant for all ages and years and is equal to 0.4; 3) selectivity-at-age trends are modeled with the selectivity model described below; 4) fishing mortality can be separable into an age-dependent factor and a year-dependent factor; 5) fishing mortality represents a significant mortality component compared to natural mortality; 6) full recruitment fishing mortality parameters from the log catch model can differ from fishery-independent estimates of the same quantity by a lognormally distributed random variable; 7) catchability is constrained to be equal to an assumed value of 1.0; 8) the effort sum of squares weighting factor is fixed at an assumed value of 0.75; 9) the catch sum of squares weighting factor is fixed at an assumed value of 1.0; and 10) average weight-at-age does not change significantly over the 1976-88 time period. Bootstrap means (Efron 1982) are based on 50 bootstrap replications. Because the CAGEAN model is a statistical description of the catch data, a measure of how well the model fits the data is provided in the residual sum of squares statistic.

The selectivity model used in the analysis is slightly different from the one used last year (Megrey 1988b). Because the fishery changed in 1982 from a foreign freezer trawler fishery using bottom trawls to a joint-venture fishery using midwater trawls the model is configured to annually partition age-specific selectivities into two independent selectivity vectors, a pre-1982 (1976-81) group and a post-1982 (1982-88) group. For the pre-1982 group, selectivities are estimated for ages 3 to 6 over the period 1976-81. Ages 7 to 10 are assumed to be fully recruited (i.e. selectivity=1.0) over the pre-1982 period so parameters for these selectivities are not estimated. For the post-1982 group, selectivities for ages 3 to 10 are estimated relative to a 5-year old which is assumed to be fully recruited to the gear. Last year selectivities for ages 3 to 6 in the post-1982 group were constrained to be equal to the 1976-81 values, while selectivities for ages 7 to 10 were estimated from the 1982-87 period. Use of this approach permitted the incorporation of temporally stratified selectivity vectors and avoided problems with model instabilities that arose due the relatively short data series available in the second temporal selectivity partition. Both last year and this year the CAGEAN model that contained the temporally stratified selectivity feature fit the data better (as determined by the residual sum of squares) when compared to a run where one selectivity vector was fit to the entire 1976-88 catch series.

In previous reports auxiliary data in the form of fishery-independent estimates of absolute population biomass from hydroacoustic surveys were used to calibrate the age-structured stock assessment results. In this years application of the CAGEAN model estimates of population abundance from bottom trawl surveys (in numbers) were also used to tune the assessment model. To determine fishery-independent fishing mortality values the procedures suggested by Deriso et al. (1987) were applied to the data in Table 7. Unfortunately the CAGEAN model as distributed by the International Pacific Halibut COmmission cannot simultaneously accommodate both bottom trawl and hydroacoustic surveys as auxiliary data.

Fishery-independent population biomass estimates from the hydroacoustic survey for ages 3 to 10 (Bh) were used along with the catch biomass estimates for ages 3 to 10 (Bc) to calculate an annual full-recruitment exploitation fraction (μ=Bc/Bh) for years 1981, 1983-86, and 1988-89. Hydroacoustic biomass values were used for all years except for 1987. Annual catch biomass estimates were calculated using observed catch-at-age data (in numbers) multiplied by the average weight-at-age values provided in Table 6. The calculated exploitation fractions, along with an estimate of natural mortality (M), were used to estimate the annual instantaneous full-recruitment fishing mortality rate (F) using the nonlinear equation

$$\mu = \frac{Bc}{Bh} = \frac{F}{F + M - G}\,[1-\exp(-F-M+G)] \qquad [1]$$

Equation [1] was solved for F given values of Bc, Bh, and M=0.4 with a Newton-Raphson root finding algorithm. Solutions for F from equation [1] were used as estimates of annual effective fully recruited fishing effort, which were then substituted into the auxiliary effort sums of squares term. Since the catchability coefficient were constrained to be equal to 1.0, these values correspond to alternative estimates of full-recruitment fishing mortality.

In the procedure described above, growth is assumed to be negligible relative to total mortality. Technically this assumption is not valid. The hydroacoustic survey is conducted in the spring before the growing season and recently the fishery has shifted to a fall fishery and much of the catch biomass is taken after the growing season is complete. These caveats offset one other. In the final analysis the consequences of a no growth assumption is not critical since the relationship between CAGEAN's estimate of fully-recruited fishing mortality derived from the catch-at-age data is only loosely related to the fishery-independent estimate of the same quantity (derived from the hydroacoustic survey biomass estimates).

When tuning the CAGEAN model to bottom trawl abundance estimates (in numbers) the more familiar formulation of the catch equation was used to estimate F. A slight modification is required since the bottom trawl survey represents mid-year abundance estimates and the assessment model is estimating abundance at the beginning of the year. To make the population estimates comparable, estimates of abundance from the bottom trawl survey (Nbt) were adjusted upwards to account for the catches (Cn) and natural mortality (M/2) that occurred in the first half of the year. Predicted abundance estimates available at the beginning of the year (N) were calculated by

$$N = (Nbt + Cn)\ \exp(M/2) \qquad [2]$$

Estimates of full recruitment fishing mortality from the bottom trawl survey were estimated using equation [3] based on estimates of the population numbers at the beginning of the year (N) from [2] and the annual catch in numbers (C), along with an estimate of natural mortality (M=0.4)

$$\mu = \frac{C}{N} = \frac{F}{F + M}[1-\exp(-F-M)] \qquad [3]$$

Annual effective effort parameters estimated from the CAGEAN model can be different from values calculated from equations [1] or [3]. The degree of difference depends on how strongly the auxiliary effort sum of squares term is weighted (see equation 9, Deriso et al. 1985). Normally the auxiliary data should be restricted to only the age group(s) fully recruited to the fishery since the goal is to provide an alternate estimate of full-recruitment fishing mortality. However, to cover any uncertainty regarding age determination the analysis presented in this report used total abundance population estimates (biomass or numbers) to calculate the auxiliary fishing mortality values from equation [1] or [3]. Because these calculations include age classes other than the fully recruited age class, the weighting factor for the effort auxiliary sum of squares term was set to 0.75. Adoption of this convention allowed the incorporation of the fishery independent data into the catch-at-age analysis but weights the auxiliary data (fishing mortality values) less than the primary data (catch-at-age).

One of the critical assumptions regarding the validity of results from catch-at-age models is that fishing mortality is a significant mortality component. If it is not then, theoretically, abundance estimates do not accurately reflect the true dynamics of the underlying population. To compensate for this possible deficiency, the influence of the fishery-independent information was increased relative to the catch-at-age information.

The specific weighting factor value of 0.75 is slightly higher than last year when a value of 0.5 was used. One of the reasons that the influence of the fishery-independent auxiliary information in this years analysis was adjusted slightly upwards relative to last year was because the catch in 1987 was one of the lowest on record (Table 7). The corresponding exploitation fraction from bottom trawl numbers in 1987 (Table 7) is also very low (0.0643) indicating that the estimate of full recruitment instantaneous fishing mortality (0.0809) is no longer a significant component of total mortality. Note that the fraction of the total deaths in 1987 due to fishing (F/F+M) would be 0.17 using the values listed in Table 7. Compare this to 1985 when the fraction of total deaths due to fishing (from hydroacoustic survey estimates) was 0.58.

2.3.2 Stock Synthesis Model

Previous assessments have relied on the results of separable stock assessment models tuned to hydroacoustic biomass estimates. The CAGEAN model of Deriso et al. (1985) has been the primary assessment tool. In the current form of the CAGEAN model, several important data sources are not utilized in the assessment of catch-at-age (Figure 25 and 26). The CAGEAN model does not directly utilize information on total catch biomass, age composition of the surveys, and does not provide a direct method for incorporating the biomass or abundance estimates provided from the surveys.

Methot (1986) developed an analytical model that combines the analysis of catch, abundance, and age composition data. The synthesis model is more similar to that of Fournier and Archibald (1982) than Deriso et al (1985). Estimates of age specific catch and abundance calculated from the deterministic population model are transformed to provide expected values for comparison to the different sources of information (Methot in Press). The relative fit of the model is determined using log likelihoods. The parameter values which provide the best fit are found by an iterative procedure based on numerical calculation of the gradient and curvature of the log-likelihood with respect to each parameter.

The Stock Synthesis (SS) model has been applied to several fisheries; Pacific hake (Hollowed et al. 1988), sablefish (Methot and Hightower, 1988), and northern anchovy (Methot In Press). Trial applications for all west coast rockfish assessments are in progress. The basic structure of the model is diagramed in Figure 27. The synthesis model calculations are described in Appendix 2. Lognormal error is assumed for estimates of survey abundance (numbers and/or biomass). Multinomial error structure is assumed for analysis of the survey and fishery age compositions. It is possible to incorporate lognormal error structure for the analysis of age composition data rather than multinomial error. The overall log likelihood is the weighted sum of the calculated log likelihood for each type of data. These weighted (e.g. emphasis) factors should all be equal to 1.0 in a perfectly described model. However, since some estimates are considered less subject to error, the emphasis factors can be adjusted by the user in a manner analogous to the adjustment of lambda in the CAGEAN model.

Estimates of natural mortality at age can be estimated using the SS model. The model fits a three parameter function wherein, natural mortality is assumed to be constant until an estimated transition age. The model then assumes that natural mortality increases linearly to a maximum level at a given end point age.

The user provides initial estimates of constant natural mortality, the transition age, and the end point age level.

3.0 STOCK ASSESSMENT

3.1 CAGEAN and Stock Synthesis Model Comparisons

Two comparisons of results from the CAGEAN and SS models were conducted using the 1976-88 fisheries and survey data. First, status quo runs were made tuning the models to hydroacoustic survey biomass. The second comparison was made tuning the models with bottom trawl population numbers. For the purposes of comparison to CAGEAN, the lognormal error structure was assumed for the analysis of the age composition data when using the SS model. Comparisons were also made assuming that the fish age 3 to 10 were fully available and fully recruited to the surveys. Since the SS model tunes the data to total catch biomass, the annual catch biomass estimates were revised to equal the sum of the product of the number-at-age and the mean weight-at-age value for the second season (Table 6).

The results of the two assessment models were similar when the hydroacoustic biomass data was incorporated (Figure 28). However the two models produced differing results when tuned with bottom trawl numbers (Figure 29).

There are two explanations for the observed differences between the CAGEAN and SS model results when tuned to bottom trawl data. First, only two abundance estimates were available from the bottom trawl surveys whereas, seven biomass estimates were available from the hydroacoustic survey.

Second, the fit to the catch-at-age data in the CAGEAN application was weighted more heavily than the auxiliary information. To examine the influence of this assumption on the results, an additional SS run was made placing a higher emphasis (10) on the age composition data which de-emphasizes the influence of bottom trawl abundance estimates. Results of this run are considerably closer to those of the CAGEAN model (Figure 30). Comparison of the SS model's expected estimates of abundance to the observed bottom trawl abundance levels shows the added emphasis on catch-at-age data negatively impacts the fit to auxiliary data (Figure 31). Based on these results the CAGEAN estimate of population biomass of approximately six million t in 1981 was considered unreasonably high (Figure 29, panel A and Figure 30, panel A).

3.2 Additional Synthesis Runs

Based on the results of the comparison runs, we concluded that the SS model provided a reasonable description of the catch-at-age data. Therefore, additional runs of the SS model were conducted utilizing abundance or biomass estimates from the surveys, observed catch biomass, and estimates of the age composition of the population derived from the survey data.

The 1989 age composition data from the commercial fishery and the preliminary 1989 hydroacoustic biomass estimates were incorporated in the additional synthesis runs. The preliminary hydroacoustic biomass estimate for fish age 2+ in Shelikof Strait was 308,212 t (Neal Williamson, Pers. Commun., Alaska Fisheries Science Center, Seattle, WA, June 1989). This estimate was determined from an estimate of the biomass at length for all fish greater than 15 cm.

Several of the assumptions imposed in the CAGEAN model were relaxed or modified in the additional runs of the SS model. These modifications included: a) expanding the age groups to include fish age 2 and 11+, b) changing the error structure used in the analysis of the age composition data, c) incorporating an annual weight at age vector (see Alton (1983) for 1976-1981, and Appendix 1, Table 7 for 1982-1989), and d) grouping age groups that represented 1% or less of the population with adjacent age groups. The likelihood comparisons were made on the combined age group. The first two modifications are justified below.

The number of age groups considered in the model was altered to include younger and older fish since these fish may represent a substantial proportion of the population. Close analysis of the age composition data revealed that the estimated number of fish at age 10 sometimes included fish 10 and above. Therefore, the age composition data was truncated at age 9 and fish 10+ were accumulated.

Examination of the age composition data also revealed that the contribution of two year old fish was often large when there was a strong incoming year class. Therefore, age 2 fish were included in the analysis. Preliminary runs including age 2 fish revealed large deviations between the observed and expected proportion at age. Therefore, the model was configured so that age 2 fish contributed to the catch, however, only ages 3-9 were considered in the evaluation of the relative fit of the model to the observed age composition data.

The error structure on the catch-at-age data was assumed to be multinomial rather than log-normal. This assumption was made because the log normal error structure can place a high emphasis on the fit to age groups that do not significantly contribute to the total population (Methot, pers. commun., Northwest and Alaska Fisheries Center, Seattle, WA, April 1989).

In addition to the assumptions described above, the following assumptions regarding the availability and selectivity of pollock to the surveys were examined using three different configurations of the SS model:

1. Model A -- Pollock are not fully recruited to the bottom trawl and/or hydroacoustic surveys and age specific selectivity or availability values can be estimated for each survey. Natural mortality is constant at 0.4. At the current time selectivity and availability can not be differentiated therefore, the two factors were modeled as a single variable. Under this assumption age-specific selectivity values estimated from by the model were those values that provided the best fit of the model to the combined sources of information.

2. Model B -- All pollock are fully recruited to the bottom trawl and/or hydroacoustic gear at age 3 and the fish remain fully recruited throughout their lives. Natural mortality varies with age and is estimated by the model. The values of M-at-age estimated from the model were those values that provided the best fit of the model to the combined sources of information.

3. Model C -- All pollock are fully recruited to the bottom trawl and/or hydroacoustic gear at age 3 and the fish remain fully recruited throughout their lives. Natural mortality is constant at 0.4.

Preliminary SS runs were made under the assumption that pollock are partially recruited to the survey gear using either the hydroacoustic survey data or the bottom trawl data to tune the models. The estimates of age specific selectivity from each of the runs tied to a single survey data set were used in the composite run using the combined survey datasets.

3.2.1 Results of Additional SS Runs

Preliminary SS runs made assuming partial recruitment to the surveys showed favorable results. The runs were made using only bottom trawl survey data and only hydroacoustic data. Biomass estimates from the two runs show similar trends in biomass (Figure 32). In both cases, the ending biomass level was approximately 750,000 t and the peak biomass was approximately 3 million t.

Based on the similarities of the two runs tuned to bottom trawl or hydroacoustic survey data, subsequent runs were conducted in which both survey data sets were incorporated simultaneously into the analysis. The following discussion of the results of models A-C are limited to the cases when the hydroacoustic and bottom trawl data were used simultaneously to tune the SS model.

The pattern of natural mortality estimated by the SS model under the assumption that pollock were fully recruited to the surveys (model B) is shown in Figure 33. The model estimated a low level of natural mortality 0.125 up to age 4.4 and a level of 1.13 at the maximum age (10). These levels of natural mortality are not reasonable considering the previous studies by Megrey (1989) described earlier that suggest that an estimate of 0.4 is reasonable.

The estimates of age specific selectivites to the fisheries for models A-C are shown in Figure 34. For all three models, the foreign fishery selectivity pattern exhibited an asymptotic pattern (Figure 34, panel A). A dome shaped selectivity pattern was estimated for the domestic fishery in all three models (Figure 34 panel B). However, the estimated domestic selectivity was considerably higher for older age groups in models B and C than in model A.

Estimates of age specific selectivity to the bottom trawl and hydroacoustic surveys illustrate important differences between the models. In models B and C the estimates of selectivity to the hydroacoustic and bottom trawl surveys were forced to be high at all ages (Figure 34, panels C and D). In contrast, a dome shaped selectivity pattern was estimated for both the bottom trawl and hydroacoustic data in model A (Figure 34, panels C and D). Comparison of the age specific selectivities for each survey type in model A, shows younger fish are more available to the hydroacoustic survey than the bottom trawl survey (Figure 34, panels C and D). The estimated selectivity to the hydroacoustic survey for model A shows sharp decline for older ages (8-10) (Figure 34, panel D).

The estimated mean biomass levels for ages 3+ from the three models were substantially different (Figure 35). As expected, the biomass estimates are generally higher for model A than for models B and C. In 1981 and 1982, the estimated biomass of age 3+ pollock was approximately 3 million t for model A, 2.5 million t for model B, and 1.8 million t for model C. The estimated biomass levels in

1989 for models A, B and C were 720,627 t, 319,102 t and 197,186 t respectively (Figure 35, Table 8).

Comparison of all three models using both surveys revealed important distinctions between the models. The estimated number of older fish in the population was considerably higher under the assumption of partial recruitment to the survey (Model A) than under the assumption of full recruitment (Models B and C) (Figure 36).

The estimates of recruitment at age 3 were higher for Model A than the full recruitment models (Models B and C) (Figure 37). In all three models, the estimated abundance of the 1986 year class is extremely low (Figure 37).

Comparison of the fit to the survey estimates of stock biomass or abundance are shown in Table 9. In all cases, the 1981 expected biomass after imposing selectivity was substantially less than the observed hydroacoustic estimate (Figure 38). The expected biomass in 1985 was higher than observed for both models A and B (Figure 38).

3.3 Summary of Additional SS Runs

These results present three alternative explanations as to why more older individuals of the strong 1975-79 year classes are not seen in the population. Either the fish survive the fishery but are not available to the fishing gear (Model A), the older fish are always fully available to the gear but they that they die at an accelerated rate (Model B), or the 1975-79 year classes were considerably lower than expected (Model C).

We feel that Model A is the likely explanation for the following reasons. The natural mortality values estimated by the Synthesis model as being most consistent with the data are absurdly high for a gadoid. Also the dense aggregations discovered by the factory trawlers in the spring of 1989 outside of Shelikof were composed of a high percentage of older fish (predominately the 1978 year class). This is one of two year classes that was responsible for the sharp decline in estimated abundance from the hydroacoustic survey in 1985. Between 1984 and 1985 the hydroacoustically assessed biomass dropped from 1,840,000 t to 700,000 t (Nelson and Nunnallee 1986) and most of this decrease was due to a poor showing of the 7 and 8-year-olds in 1985. There was no explanation for the drop. The severity of the decline implied unusually large mortalities had taken place and that these were inconsistent with expected population decreases. In retrospect, data from the 1989 outside Shelikof fishery suggests that perhaps this year class did not return to Shelikof.

4.1 PROJECTIONS OF BIOMASS

Stock projections have been made using the age-structured stock projection model used last year (Megrey 1988b). The stock projections were made assuming no fish younger than age 3 were included in the fishery. The model was modified to accumulate fish at ages 10+ to account for the large percentage of older fish expected under model A.

Projections of biomass (age 3-and-older fish) in Shelikof Strait for 1989-93, are given for two recruitment scenarios, four annual catch schedules, and two initial starting conditions. The initial population size used to begin the simulations are derived from the SS models A and B. These two SS runs represent two extremes with respect to current stock condition: an optimistic outlook (Model A) and an pessimistic outlook (Model B). Projections using initial starting conditions from Model B also included the assumption of age-specific trends in natural mortality.

4.2 Recruitment Schedule Calculations

Recruitment is defined as the number of 3-year-old fish present at the beginning of the year. Three recruitment levels (poor, average and strong) were needed for the stock projection analysis. As a guide for assigning the different recruitment levels realistic values, age 3 abundance estimates from the updated catch-at-age analysis were used to estimate the three recruitment levels.

Recruitment estimates for the projections were derived by first grouping year class abundance estimates from the catch-at-age analysis according to whether they were from poor (0.3 billion), average (0.90 billion), or strong (1.5 billion) year classes. The two recruitment scenarios considered in the analysis were:

		Recruitment scenario (age 3 population in million fish)	
Year	(Year) (class)	A	B
1988	1985	900	900
1989	1986	30	300

1990	1987	30	300
1991	1988	900	900
1992	1989	900	900
1993	1990	900	900

Recruitment scenario A is the more pessimistic of the two, indicating that the 1985 year class is average, followed by two failed (30 million) year classes. We arbitrarily defined this new recruitment category (failed) as being an order of magnitude lower than a poor year class. The 1988 year class is considered average because the number of 1-year-old pollock seen in the 1989 Shelikof survey is similar to that observed for the 1984 and 1985 year classes (Figure 15, Neal Williamson, pers. comm., Alaska Fisheries Science Center, Seattle, WA). Recruitment scenario B is the most optimistic which has the 1985 year class as average and the 1986 and 1987 year classes as poor (300 million).

4.3 Catch Schedules

For each recruitment schedule four projections were made, each having a different annual catch schedule. These schedules begin with the known catches in 1988 and the first quarter of 1989.

	Catch scenario (1st half of year/2nd half of year) (1,000 t)				
Catch Schedule	1988	1989	1990	1991	1992
1	0/58	65/0	0/0	0/0	0/0
2	0/58	65/35	0/0	0/0	0/0
3	0/58	65/0	25/25	25/25	25/25
4	0/58	65/35	25/25	25/25	25/25

Catch schedule 1 corresponds to no annual harvest in the latter half of 1989. Catch schedule 2 provides a harvest level of 100,000 t in 1989 and no harvest in 1990. In catch schedule 3 no additional quota is released in 1989, and a 50,000 t harvest is allowed in 1990-92. Catch schedule 4 provides a harvest of 100,000 t in 1989 and 50,000 t in 1990-92.

Catch schedules 1 and 2 explore the consequences of releasing an additional 35,000 t in the fall of 1989 on estimated 1990 abundance levels. Catch schedules 3 and 4 explore the consequences on abundance levels in 1991-93 of a 50,000 t harvest in 1990-92 with (Catch schedule 4) and without (Catch schedule 3) an additional catch in 1989.

4.4 Initial Population Vector Schedules

In order to explore the possibility that the Shelikof survey is only assessing a fraction of the gulf-wide population, the projections were initialized with two different starting population vectors; a) the partial recruitment run of the SS model (Model A) and b) the full recruitment/variable natural mortality run of the SS model (Model B). In order to explore the consequences of allocating additional quota for the fall of 1989, the projections were started using the population vectors in 1988.

4.5 Projection Results

Projection results based on the various recruitment, catch, and initial population vectors are presented Figure 39. All of the biomass estimates represent the expected biomass at the beginning of the year for ages 3+. In all four configurations of the model, the assumptions made about expected recruitment influence the results much more than the catch. In all four configurations, the assumption of imposing a 50,000 t quota in 1990, 1991 and 1992 results in a difference of approximately 100,000 t in the total biomass estimates. The conclusion that fishing does not severely alter the projection of stock biomass is somewhat misleading because linkages between spawners and recruits have not been considered.

When the projection model is initialized with the 1988 population vector from Model A, the projections show the population will decline in 1989, and 1990 (Figure 39 top two panels). In Scenario A (1986 and 1987 year classes are failures) the biomass estimates drop to a minimum of approximately 600,000 t in 1990. In Scenario B (1986 and 1987 year classes are poor) the projected biomass declines to a minimum of approximately 750,000 t in 1990. Under the assumption of average recruitment for the 1988-90 year classes, the stock recovers to between 0.9 million t or 1.1 million t (Figure 39 top two panels).

When the projection model is initialized with the 1988 population vector from Model B, the biomass estimates in 1989 and 1990 fall between 200,000 t and 450,000 t. The stock recovers quickly because a reduced natural mortality (0.125) is imposed on the younger ages (up to 4.4). Natural mortality does not exceed 0.4 until age 6 (Figure 33). The ending biomass estimates for the beginning of 1993 range from 1.0 million t to 1.3 million t (Figure 39 bottom two panels).

5.0 ACCEPTED BIOLOGICAL CATCH

The assessment provided this year has utilized essentially all available information on the Gulf of Alaska pollock resource. However, the stock projections remain sensitive to the initial population vectors and the recruitment assumptions. The 1989 commercial fishery located fishable concentrations of pollock outside of Shelikof Strait. These concentrations contained a substantial number of older fish and were located in deep water.

These two observations are consistent with the assumption that there is an age specific selectivity pattern that can be applied to the survey data (ie Model A is valid). Therefore, projections made using the initial population estimates derived from Model A are favored over those derived from initial population estimates from Model B.

At the current time there is only preliminary information on the abundance of the 1986-88 year classes. The extremely low estimate of recruitment at age 3 in 1989 may have been biased by the behavior of the fleet. When age composition data becomes available from the 1989 hydroacoustic survey, the estimate may be modified. However, it is important to note that it is unlikely that the 1986 year class is average or above average, since year classes of that magnitude are recognized as age 2 and 3 in the hydroacoustic and fisheries data.

If the 1986 and 1987 year classes are poor and the 1984 and 1985 year classes are average, then the stock will quickly decline to low levels as the 1984 and 1985 year classes are discounted by natural mortality and fishing mortality. If the 1988-90 year classes are not average or above average the stock would not begin to recover in 1991.

A tentative bottom trawl survey has been planned for the summer of 1989. This survey may provide useful information on the relative abundance of younger fish ages 1-3 in the population. If the survey is approved and the station grid overlaps with areas traditionally fished by the fleet then additional information will be collected. If the survey does not take place a small fishery may be necessary in the fall of 1989 to assess the magnitude of the 1986 year class.

Considering the uncertainty in the current condition of the stock, we recommend that no additional quota is released in 1989 if there is no fall bottom trawl survey. This decision is based on three factors: a) preliminary evidence shows the 1986 and 1987 year classes are failures, b) the hydroacoustic survey estimates did not show a substantial increase form the 1988 estimate, c) the contribution of the older component of the stock (age 11+) will be minimal in future years.

A recommendation for the 1990 ABC will not be made until the fall. This recommendation will incorporate additional information on the age composition of the stock based on hydroacoustic survey data.

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Table 1.--Catch of pollock (1000 t) in the Gulf of Alaska by fishery category, 1977-89.

	Fishery Category			
		Domestic		
Year	Foreign	JVP	DAP	Total
1977	117.8	--	0.2	118.0
1978	96.4	T	1.0	97.4
1979	103.2	0.6	2.0	105.8
1980	113.0	1.1	0.9	115.0
1981	130.3	16.9	0.6	147.8
1982	92.6	73.9	2.2	168.7
1983	81.4	134.1	0.1	215.6
1984	99.3	207.1	0.3	306.7
1985	31.6	237.9	15.4	284.9
1986	0.1	62.6	21.3	84.0
1987	0.0	22.8	39.2	62.0
1988	0.0	0.2	55.8	56.0
1989*	0.0	0.0	64.9	64.9

*Through June, 1989.

T: Trace (< 100 t).

Sources: Foreign and joint venture catches 1977-84--Berger et al. (1986); 1985-88--Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.
Domestic catches 1978-80--Rigby (1984); 1981-89--PacFIN.

Table 2.--Catch (t) of pollock in the Gulf of Alaska by fishery category, quarter, and International North Pacific Fisheries Commission regulatory area, 1988.

Area	Fishery Category	Quarter				Total
		1	2	3	4	
Shumagin	DAP	13	253	46	4280	4592
	JVP	0	0	0	0	0
	Total	**13**	**253**	**46**	**4280**	**4592**
Chirikof	DAP	827	167	0	18	1011
	JVP	0	0	8	0	8
	Total	**827**	**167**	**8**	**18**	**1019**
Shelikof	DAP	9,783	1,262	3	773	11,821
	JVP	0	0	0	0	0
	Total	**9,783**	**1,262**	**3**	**773**	**11,821**
Kodiak	DAP	6,662	314	3,724	27,693	38,394
	JVP	0	2	142	0	144
	Total	**6,662**	**316**	**3,866**	**27,693**	**38,536**
Total	DAP	17,285	1,996	3,773	32,764	55,818
	JVP	0	2	150	0	152
	Total	**17,285**	**1,998**	**3,923**	**32,764**	**55,970**

Source: Pacific Fishery Information Network (PAcFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.

Table 3.--Catch (t) of pollock in the Gulf of Alaska by fishery category, and International North Pacific Fisheries Commission regulatory area, for the first four months of 1989. Data current through June 1989.

Area	Fishery Category	Month				Total
		Jan.	Feb.	Mar.	Apr.	
Shumagin	DAP	TR	690	10,590	33	11,314
	JVP	0	0	0	0	0
	Total	**TR**	**690**	**10,590**	**33**	**11,314**
Chirikof	DAP	0	16	27,660	697	28,373
	JVP	0	0	0	0	0
	Total	**0**	**16**	**27,660**	**697**	**28,373**
Shelikof	DAP	505	875	5,049	0	6,429
	JVP	0	0	0	0	0
	Total	**505**	**875**	**5,049**	**0**	**6,429**
Kodiak	DAP	3,342	9,789	5,629	53	18,813
	JVP	0	0	0	0	0
	Total	**3,342**	**9,789**	**5,629**	**53**	**18,813**
Total	DAP	3,848	11,370	48,928	783	64,929
	JVP	0	0	0	0	0
	Total	**3,848**	**11,370**	**48,928**	**783**	**64,929**

Source: Pacific Fishery Information Network (PAcFIN), Pacific Marine Fisheries Commission, Metro Center, Suite 170, 2000 SW. First Avenue, Portland, OR 97201.

TR - Trace < 1t.

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Table 4. Estimated number at age in 1981, 1983-1986 and 1988 derived from the NMFS hydroaoucstic surveys.

	POPULATION NUMBERS (MILLIONS)					
AGE	81	83	84	85	86	88
2	3704.6	757.8	74.2	218.6	1993.1	115.3
3	1490.7	325.7	258.9	92.4	287.7	753.6
4	885.5	1410.0	231.1	194.9	44.3	349.6
5	3480.1	1270.3	700.9	111.5	81.7	83.8
6	1464.1	761.7	1045.0	214.0	52.3	18.2
7	258.6	648.4	464.8	269.2	89.5	6.0
8	151.2	145.2	239.8	103.5	151.3	6.0
9	115.7	19.5	42.1	26.0	62.1	4.1
10	31.4	11.9	3.7	2.9	11.7	9.3
11	3.5	4.1	0.0	1.5	1.8	1.8
12	0.0	1.9	0.9	0.6	0.0	1.9
Total	11585.4	5356.5	3061.4	1235.1	2775.5	1349.6
Total 3+	7880.8	4598.7	2987.2	1016.5	782.4	1234.3
Total 3-10	7877.3	4592.7	2986.3	1014.4	780.6	1230.6

Table 5.--Estimated catch (1000's) of pollock by foreign trawl, joint venture, and domestic fisheries in the North Pacific Fisheries Commission Western and Central Regulatory Areas of the Gulf of Alaska, by age 1976-88.

	Year													
Age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	13,562	7,676	111,332	76,305	30,514	33,106	62,435	22,438	31,186	5,399	20,355	14,026	20,800	1,356
4	94,005	18,821	13,819	55,977	54,838	75,760	102,612	127,293	49,487	32,680	10,116	7,998	26,947	15,944
5	32,137	92,616	19,338	9,669	31,910	54,959	73,869	123,189	131,309	38,420	19,131	6,894	11,927	25,663
6	8,997	24,204	34,446	7,661	11,586	16,861	50,899	57,617	159,392	73,288	7,316	6,435	5,102	16,323
7	2,515	8,990	7,684	14,473	6,787	4,630	7,631	44,822	53,302	120,345	8,701	7,180	3,447	7,852
8	2,515	1,823	2,669	4,951	7,150	3,770	1,081	11,529	23,736	35,191	9,782	4,194	1,623	4,684
9	1,561	795	1,488	1,591	2,914	3,744	736	1,141	5,731	9,588	2,133	9,951	339	1,623
10	1	1,105	548	708	925	687	173	62	139	2,557	800	1,455	2,916	1,097
Total	**155,293**	**156,030**	**191,324**	**171,335**	**146,624**	**193,517**	**299,436**	**388,091**	**445,113**	**317,468**	**78,314**	**58,133**	**73,101**	**74,542**

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Table 6.--Average weight-at-age values used as input data to the stock assessment and projection models.

COMMERCIAL FISHERY

Age (yrs)	Jan - Apr Weight-at-age (kg)	May - Aug Weight-at-age (kg)	Sep - Dec Weight-at-age (kg)
2	0.128	0.214	0.274
3	0.294	0.388	0.455
4	0.460	0.542	0.612
5	0.602	0.665	0.735
6	0.712	0.756	0.827
7	0.794	0.823	0.893
8	0.854	0.871	0.941
9	0.897	0.905	0.975
10	0.927	0.929	0.999
11	0.949	0.946	1.015
12	0.964	0.958	1.027
13+	0.975	0.954	1.024

SURVEY

Age (yrs)	Bottom Trawl Weight-at-age (kg)	Hydroacoustic Weight-at-age (kg)
2	0.187	0.085
3	0.407	0.211
4	0.622	0.367
5	0.800	0.528
6	0.936	0.679
7	1.034	0.812
8	1.103	0.925
9	1.151	1.018
10	1.184	1.093
11	1.206	1.153
12	1.221	1.201
13+	1.231	1.238

Table 7.--Fishery-independent estimates of full-recruitment fishing mortality using information from NMFS hydroacoustic and triennial bottom trawl surveys. All estimates based on ages 3 through 10. M=0.4

Year	Hydroacoustic Estimate (million t)	Catch Estimate (t)	Exploitation Fraction (u)	Effective Effort f (q=1.0)
1981	3.412	114,322	0.0335	0.0414
1982	--	--	--	--
1983	2.368	251,198	0.1061	0.1370
1984	1.829	316,078	0.1728	0.2331
1985	0.680	240,736	0.3540	0.5477
1986	0.492	49,765	0.1011	0.1302
1987	--	--	--	--
1988	0.311	41,693	0.1341	0.1764
1989	0.300	51,508	0.1714	0.2310

Year	Bottom Trawl Estimate (billions)	Catch Estimate (millions)	Exploitation Fraction (u)	Effective Effort f (q=1.0)
1984	1.149	445.113	0.3874	0.6171
1985	--	--	--	--
1986	--	--	--	--
1987	0.904	58.132	0.0643	0.0809

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Table 8. Estimates of mean biomass in 1989 for ages 3+ and ages 10+ from the stock assessment models.

I. Stock Synthesis

NAME	MEAN BIOMASS (tons)	AGE 10+ BIOMASS (tons)
A	720,627	130,459
B	319,102	19,530
C	197,186	29,760

Table 9. Comparison of the relative fit of different stock synthesis model scenarios to the survey abundance and biomass estimates.

I. Fit to Hydroacoustic Biomass Estimates (81, 83, 84, 85, 86, 88, and 89)

Scenario	SUME/SUMO	MEAN DEV.	STD.DEV.
A	0.887	-0.120	0.415
B	0.862	-0.027	0.350
C	0.616	0.320	0.297

II. Fit to Bottom Trawl Numbers (84 and 87)

Scenario	SUME/SUMO	MEAN DEV.	STD.DEV.
A	1.066	0.041	0.699
B	1.243	-0.123	0.661
C	0.940	0.118	0.518

SUME - Sum of expected
SUMO - Sum of observerd

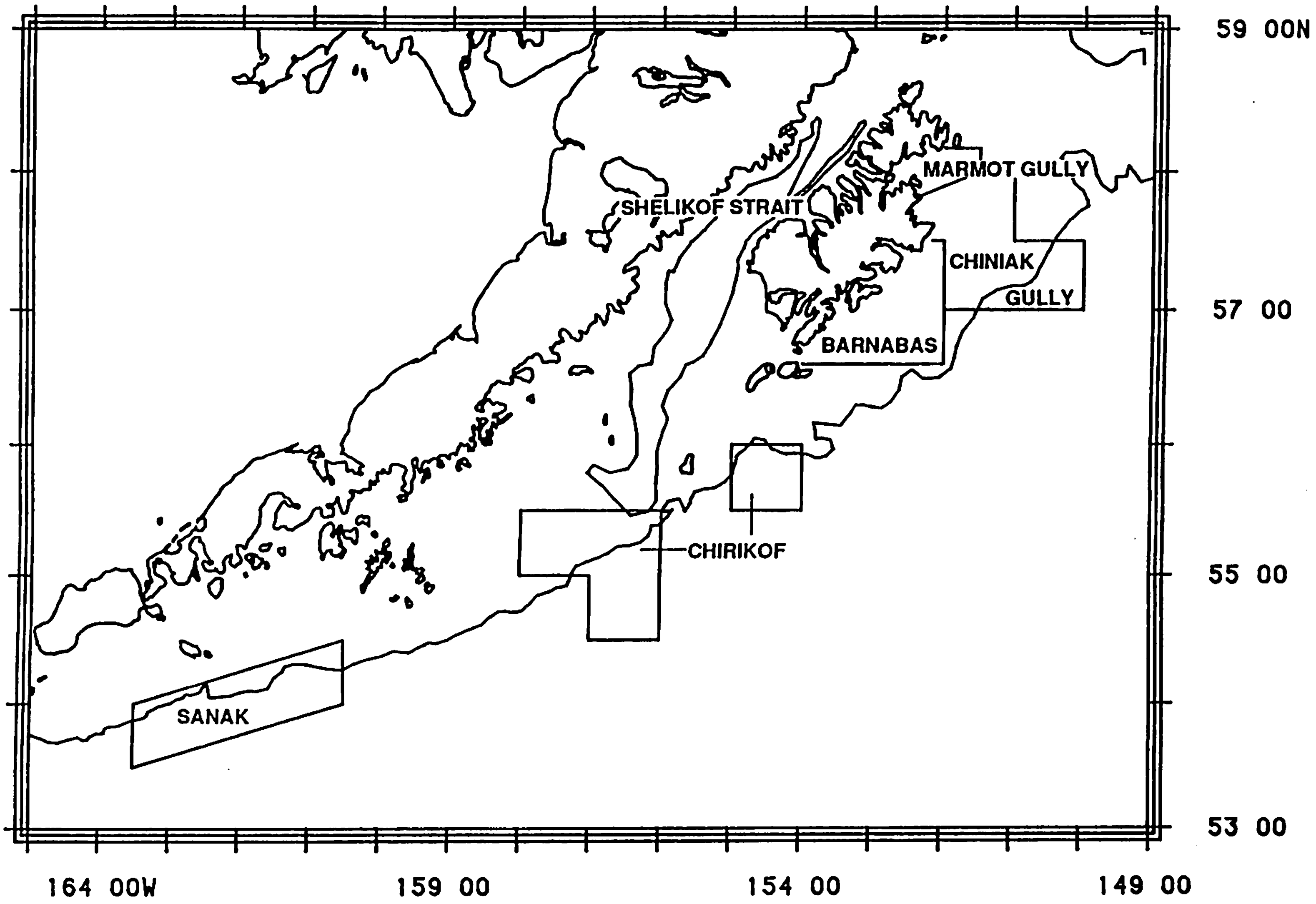


Figure 1.--Locations of domestic fishery reporting sub-areas, January-March 1989.

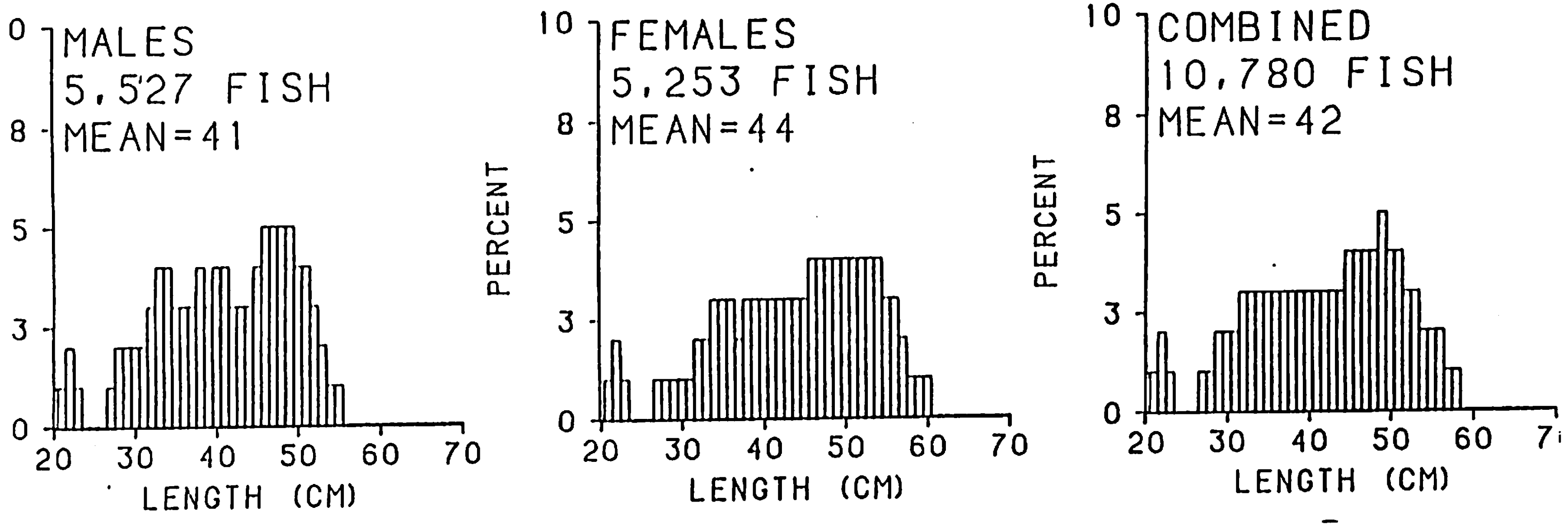
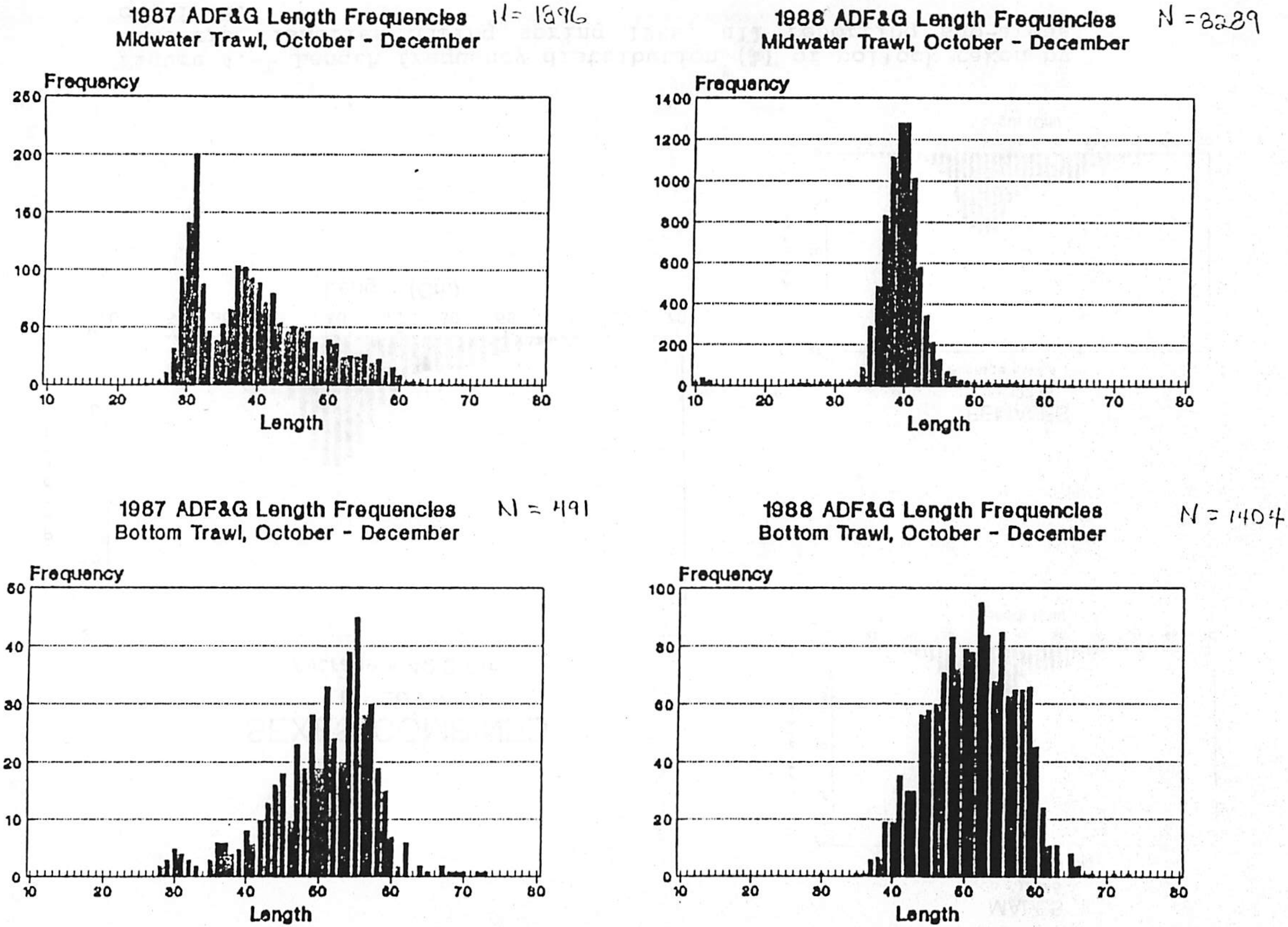


Figure 2.--Length frequency distribution (%) of pollock taken from the Shelikof Strait reporting area by Gulf of Alaska domestic fisheries during spring 1988.



1987 ADF&G Length Frequencies N= 1896
Midwater Trawl, October - December

1988 ADF&G Length Frequencies N =8229
Midwater Trawl, October - December

1987 ADF&G Length Frequencies N = 491
Bottom Trawl, October - December

1988 ADF&G Length Frequencies N = 1404
Bottom Trawl, October - December

Figure 3.--Comparison of length frequency distribution taken from the east side of Kodiak Island by domestic fisheries in the fall of 1987 and 1988 by midwater and bottom trawls.

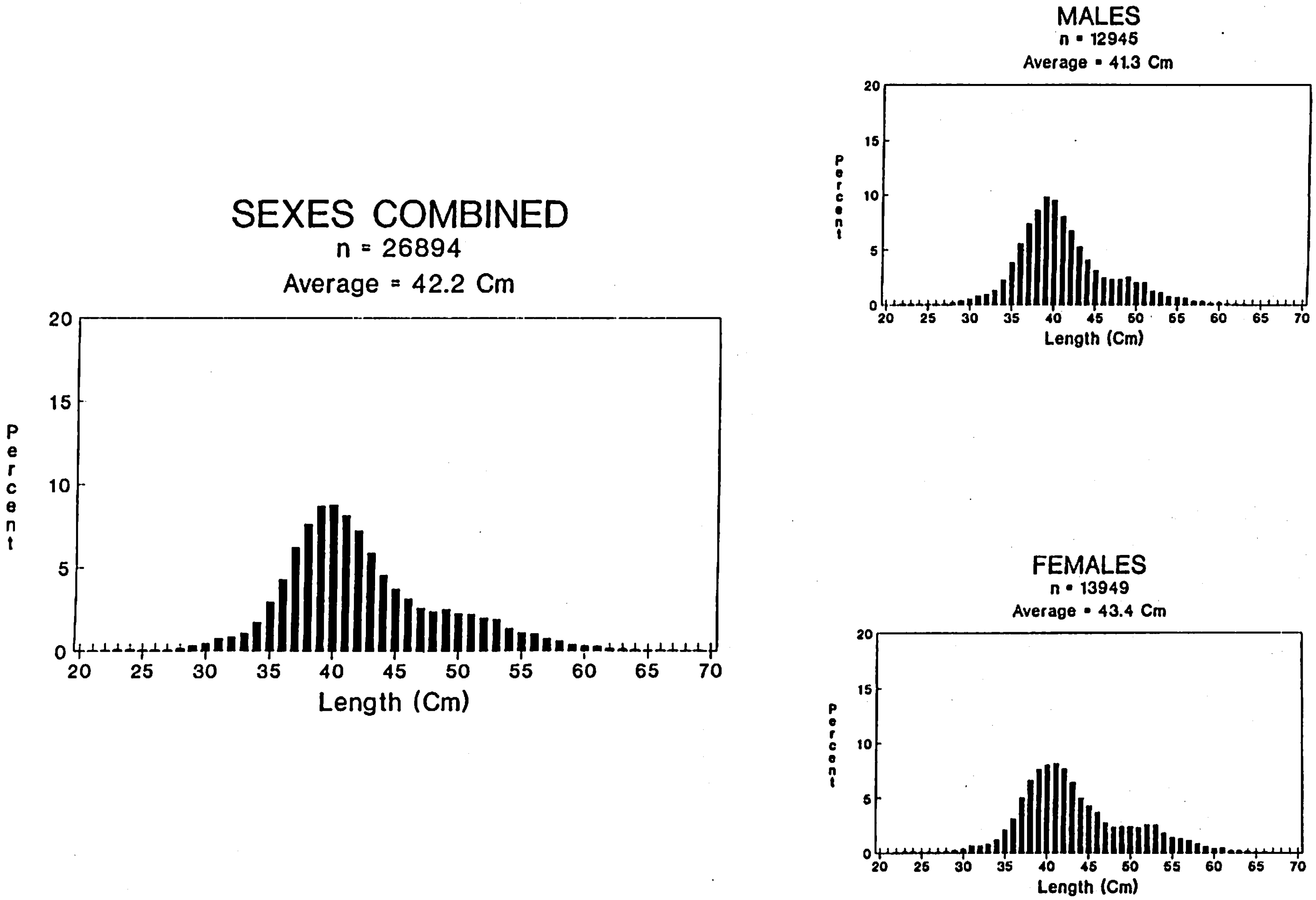
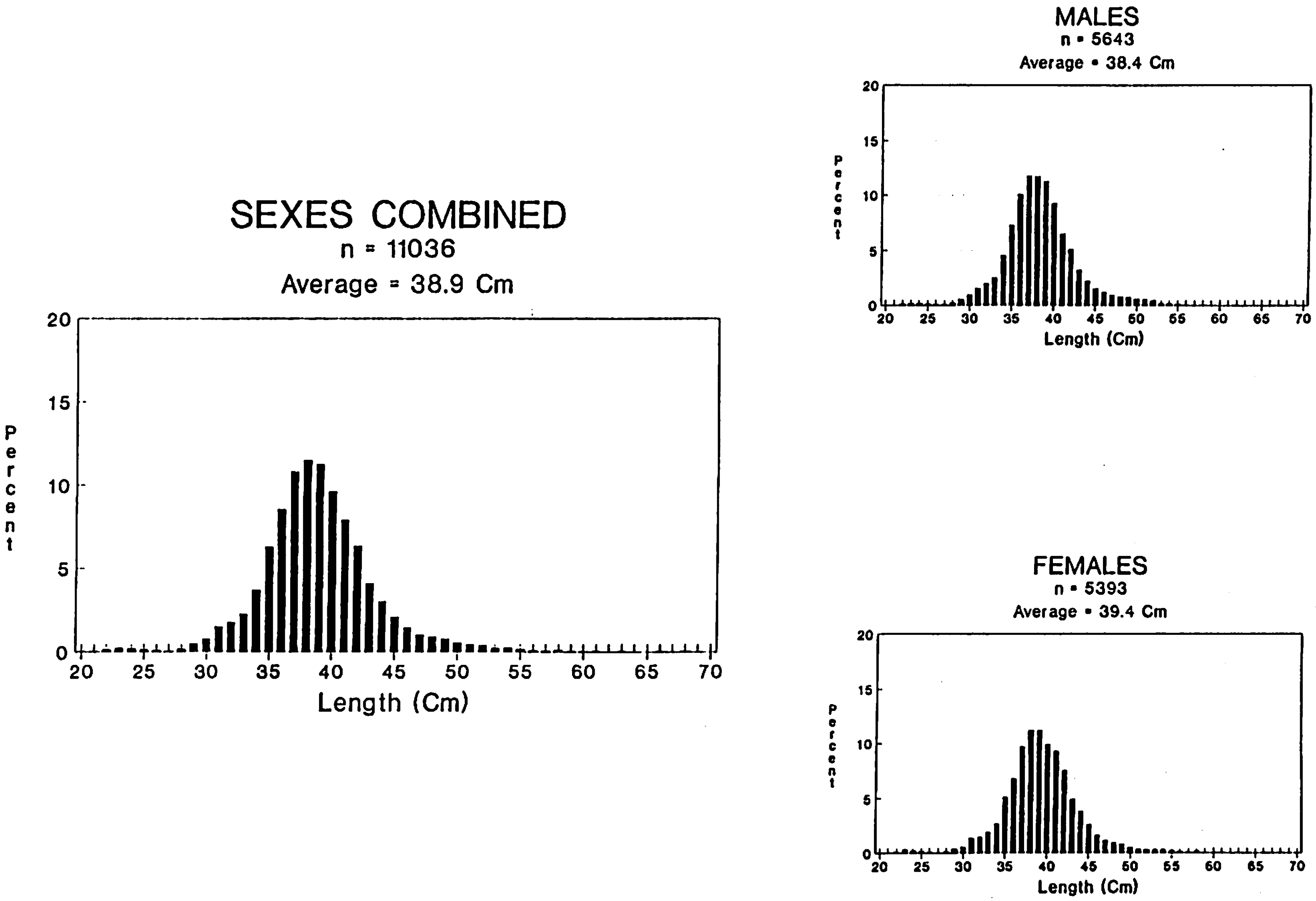


Figure 4.-- Length frequency distribution (%) of pollock taken by domestic fisheries during spring 1989, all reporting sub-areas combined.



SEXES COMBINED
n = 11036
Average = 38.9 Cm

MALES
n = 5643
Average = 38.4 Cm

FEMALES
n = 5393
Average = 39.4 Cm

Figure 5.-- Length frequency distribution (%) of pollock taken by domestic fisheries during spring 1989, Shelikof reporting sub-area.

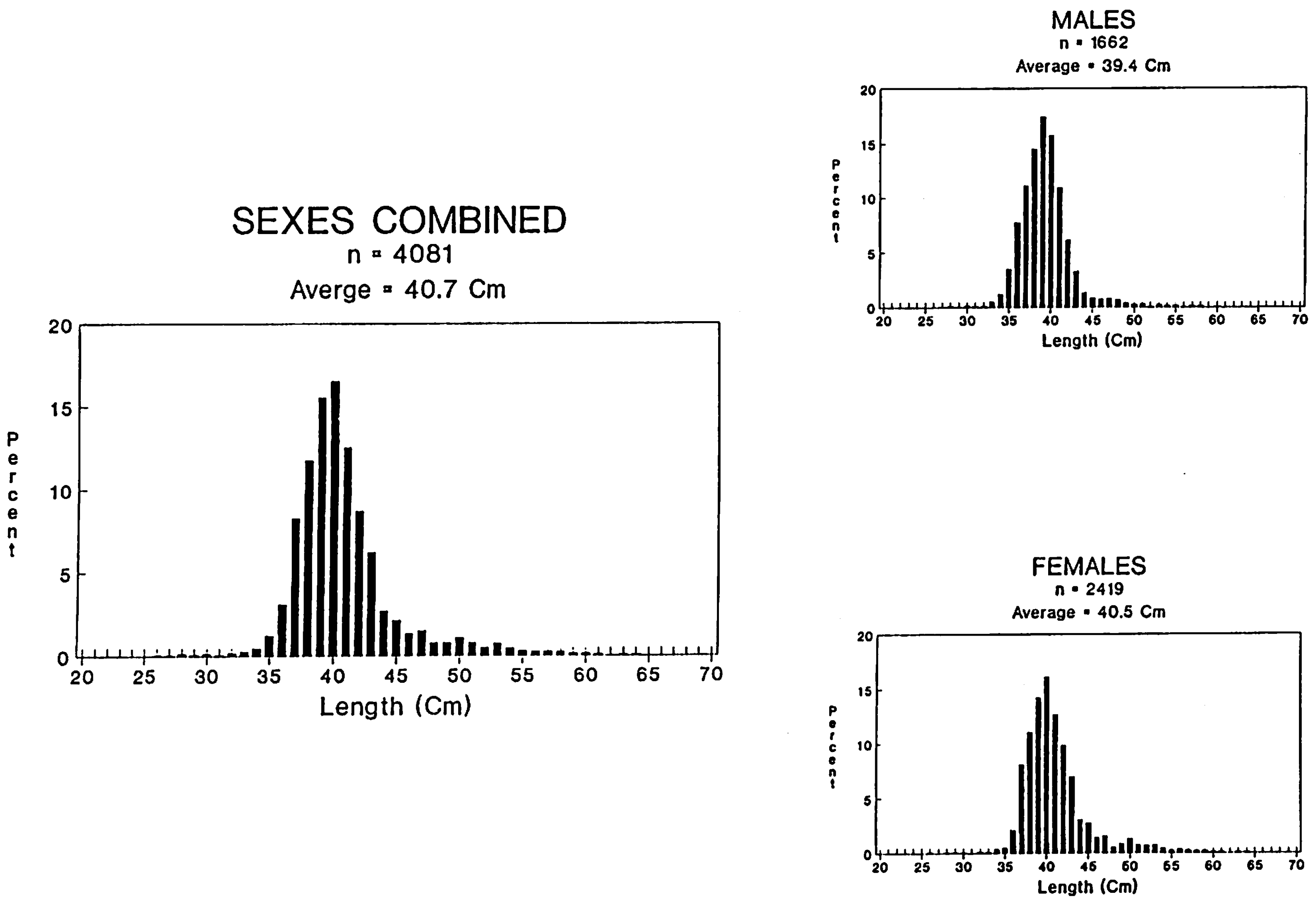


Figure 6.-- Length frequency distribution (%) of pollock taken by domestic fisheries during spring 1989, Chiniak reporting sub-area.

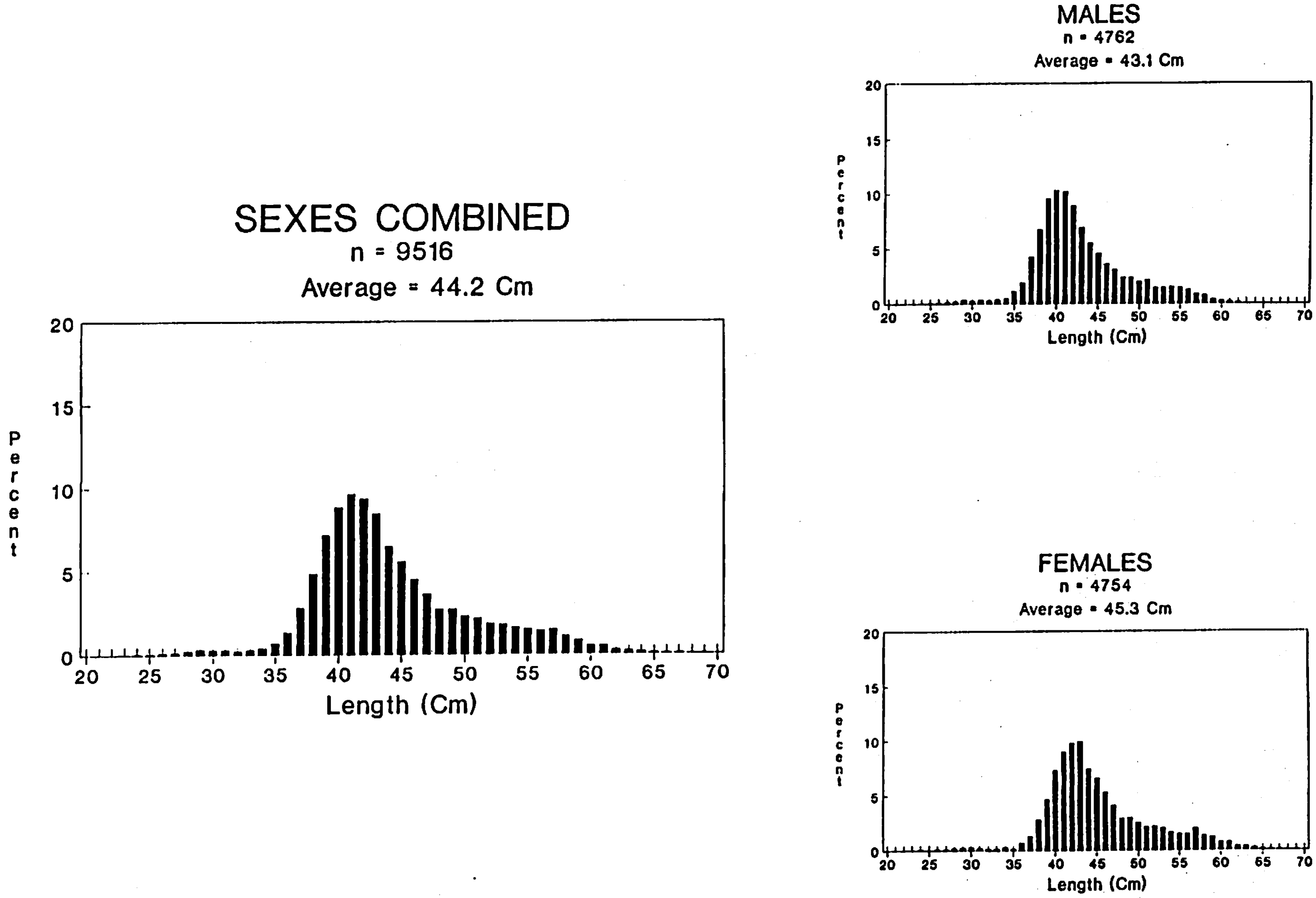


Figure 7.-- Length frequency distribution (%) of pollock taken by domestic fisheries during spring 1989, Marmot reporting sub-area.

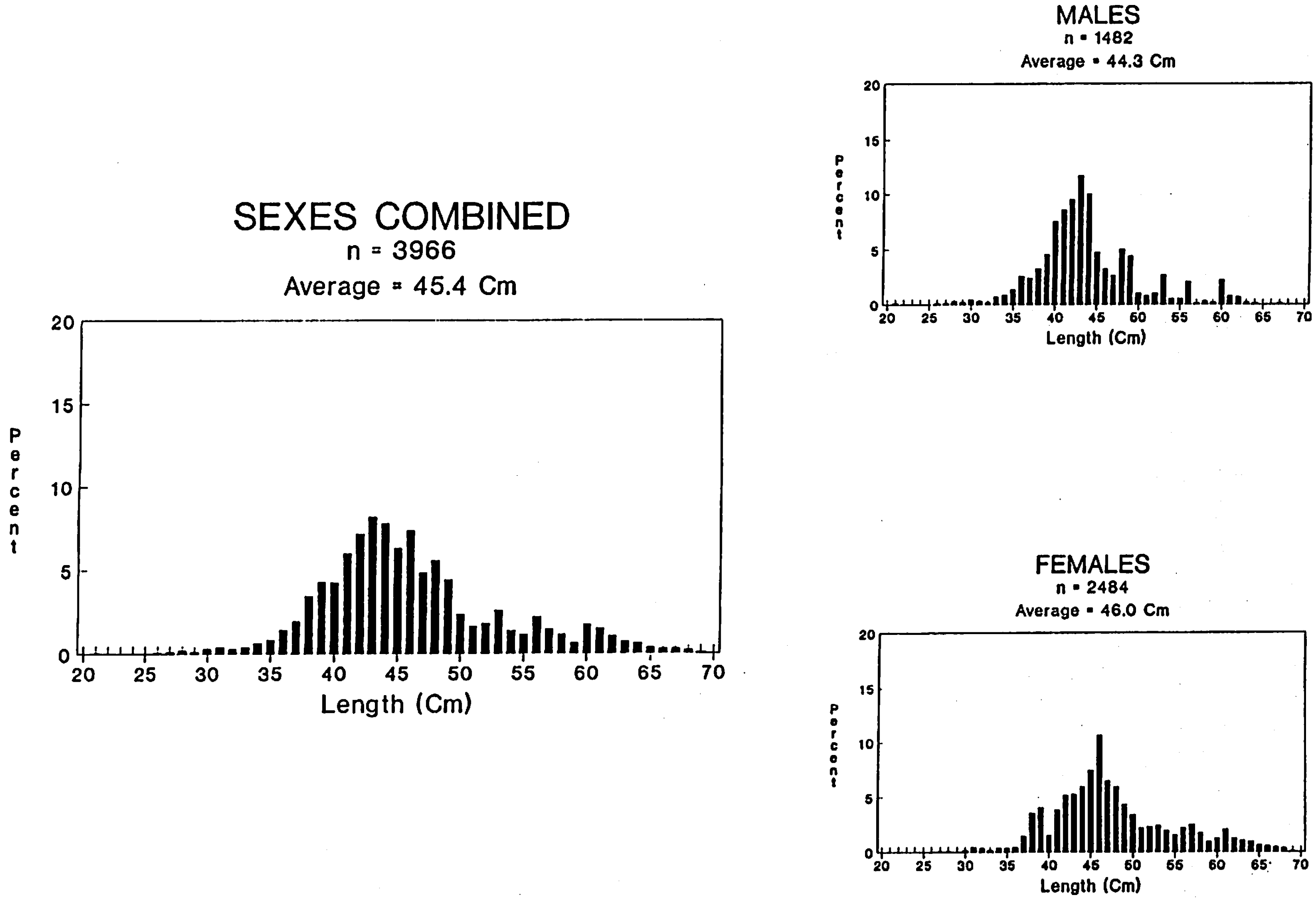


Figure 8.-- Length frequency distribution (%) of pollock taken by domestic fisheries during spring 1989, Barnabas reporting sub-area.

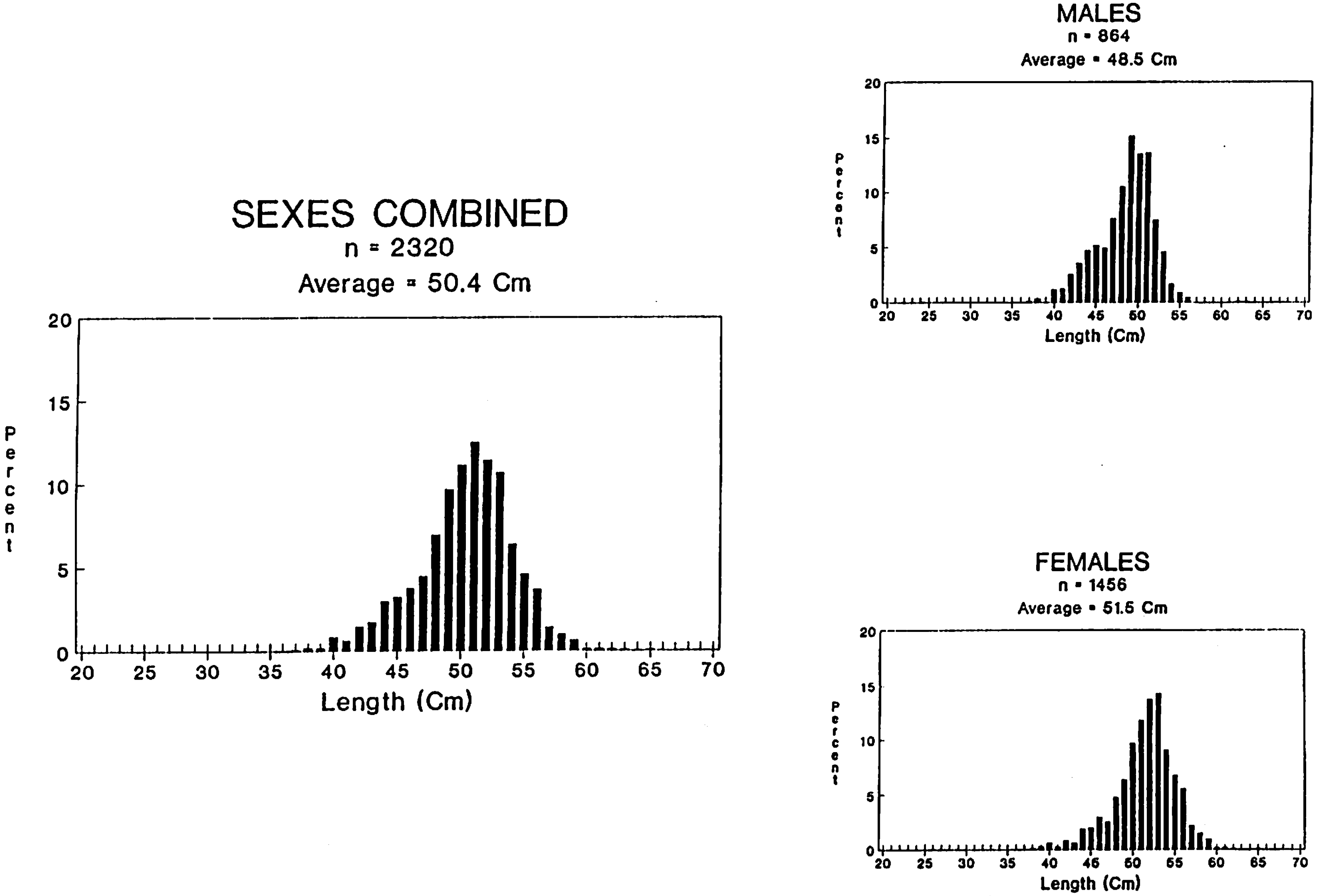


Figure 9.-- Length frequency distribution (%) of pollock taken by domestic fisheries during spring 1989, Chirikof reporting sub-area.

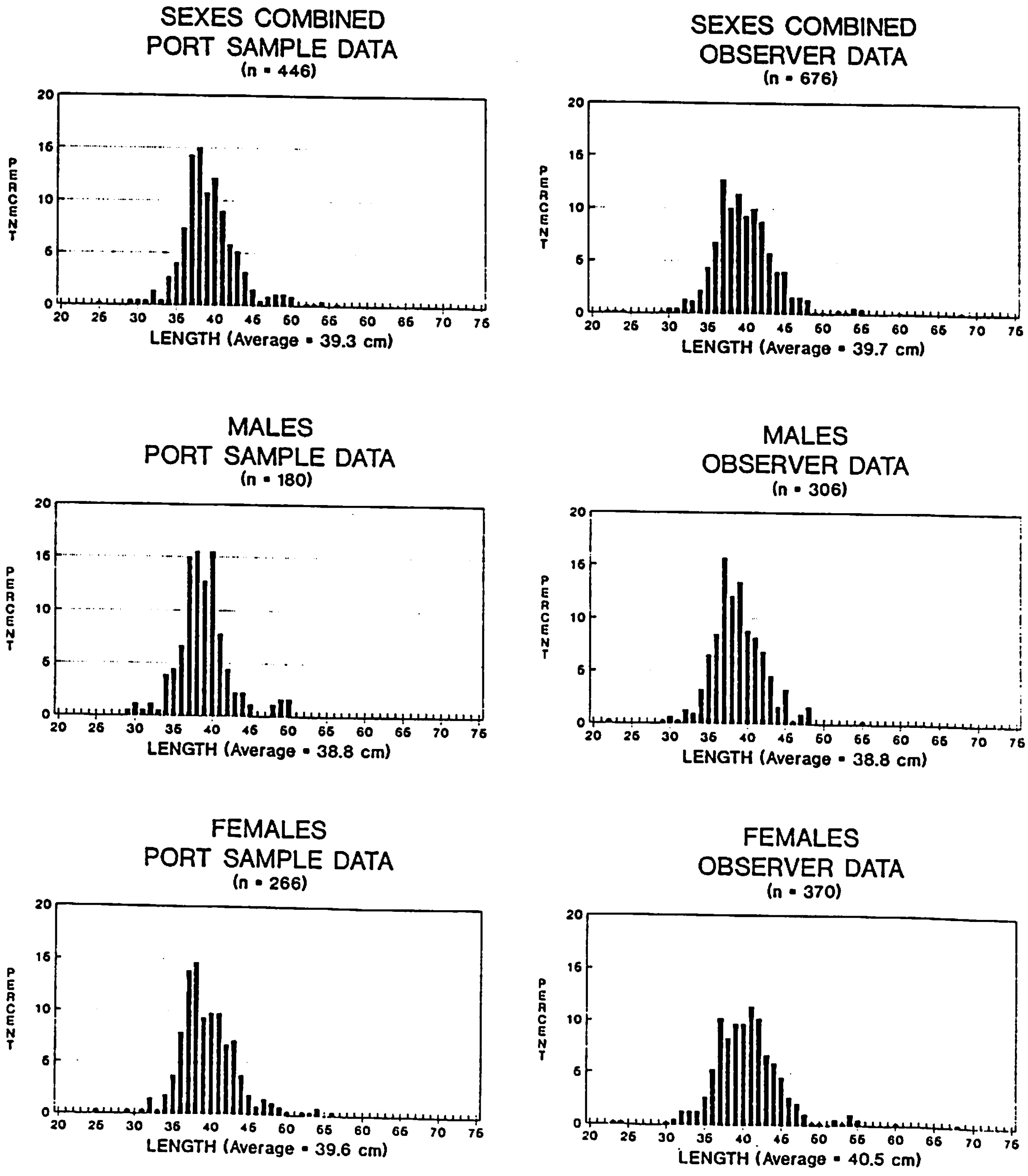


Figure 10.--Comparison of pollock length frequency distributions (%) sampled from the same fishing trip at two different times. Data collected on the fishing grounds by the NPFMC Pilot Domestic Observer Program and during dockside delivery on Kodiak Island by the NMFS Port Sample Data Collection Program during spring 1989, case #1-Shelikof Strait.

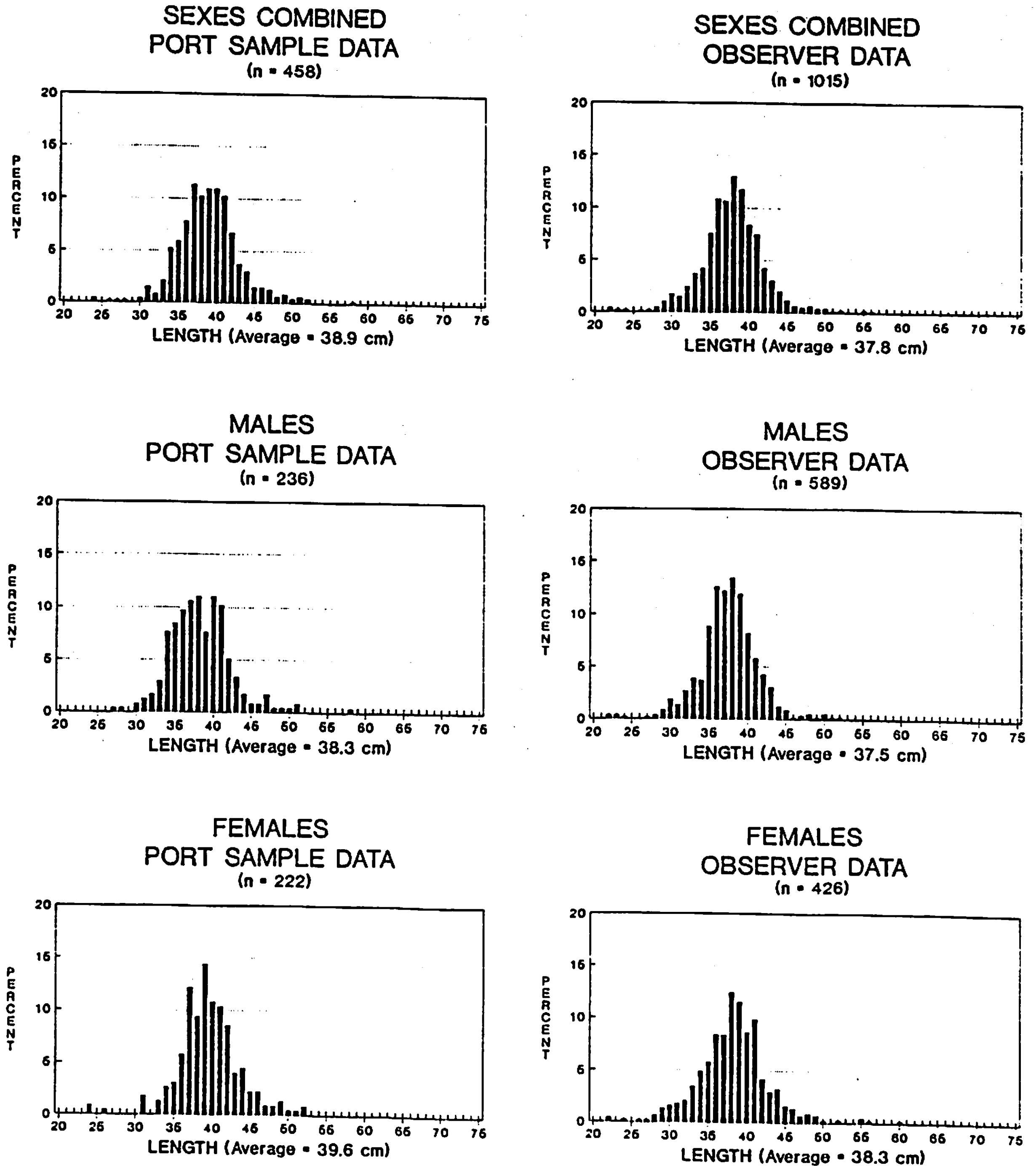


Figure 11.--Comparison of pollock length frequency distributions (%) sampled from the same fishing trip at two different times. Data collected on the fishing grounds by the NPFMC Pilot Domestic Observer Program and during dockside delivery on Kodiak Island by the NMFS Port Sample Data Collection Program during spring 1989, case #2-Shelikof Strait.

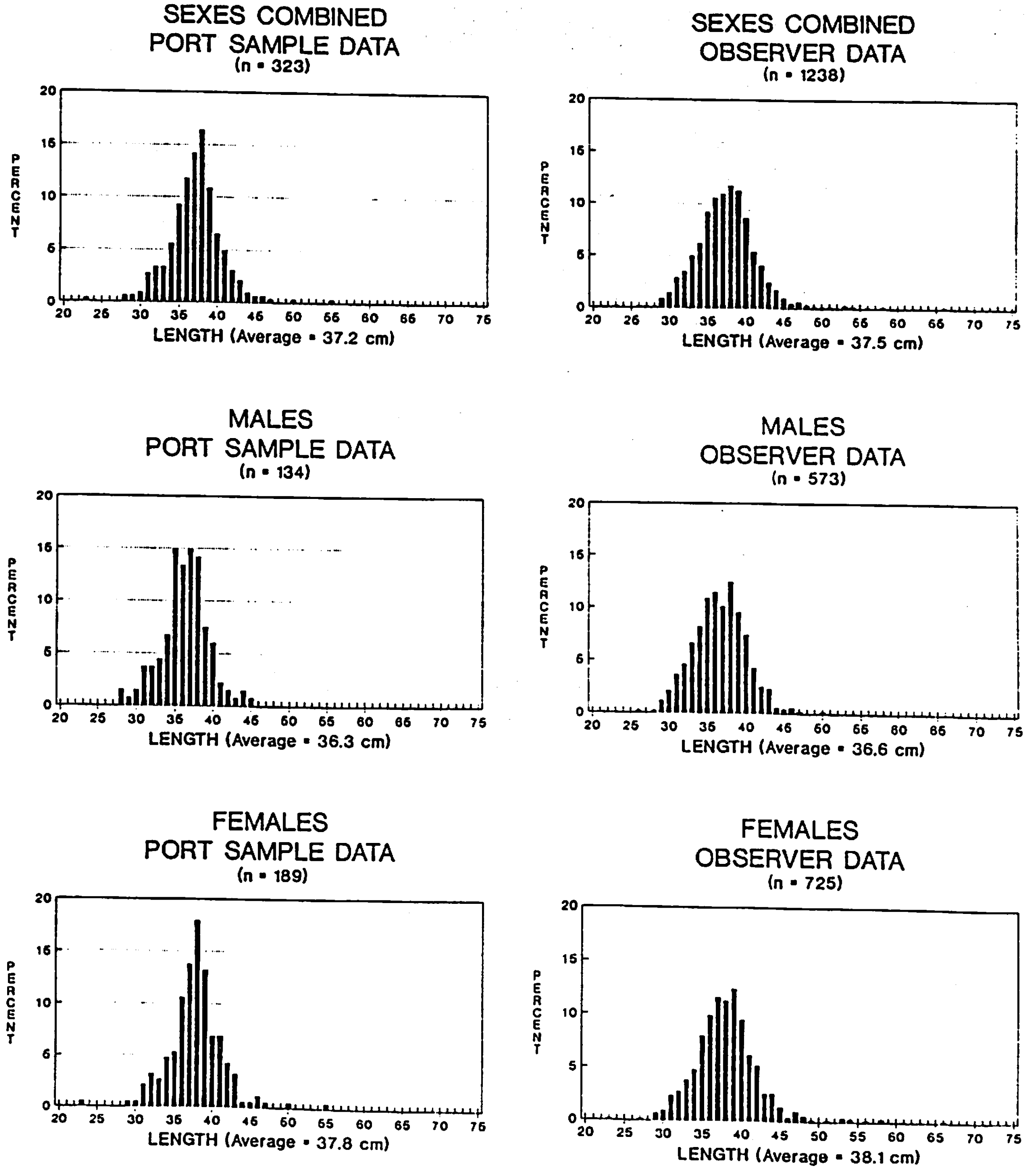


Figure 12.--Comparison of pollock length frequency distributions (%) sampled from the same fishing trip at two different times. Data collected on the fishing grounds by the NPFMC Pilot Domestic Observer Program and during dockside delivery on Kodiak Island by the NMFS Port Sample Data Collection Program during spring 1989, case #3-Shelikof Strait.

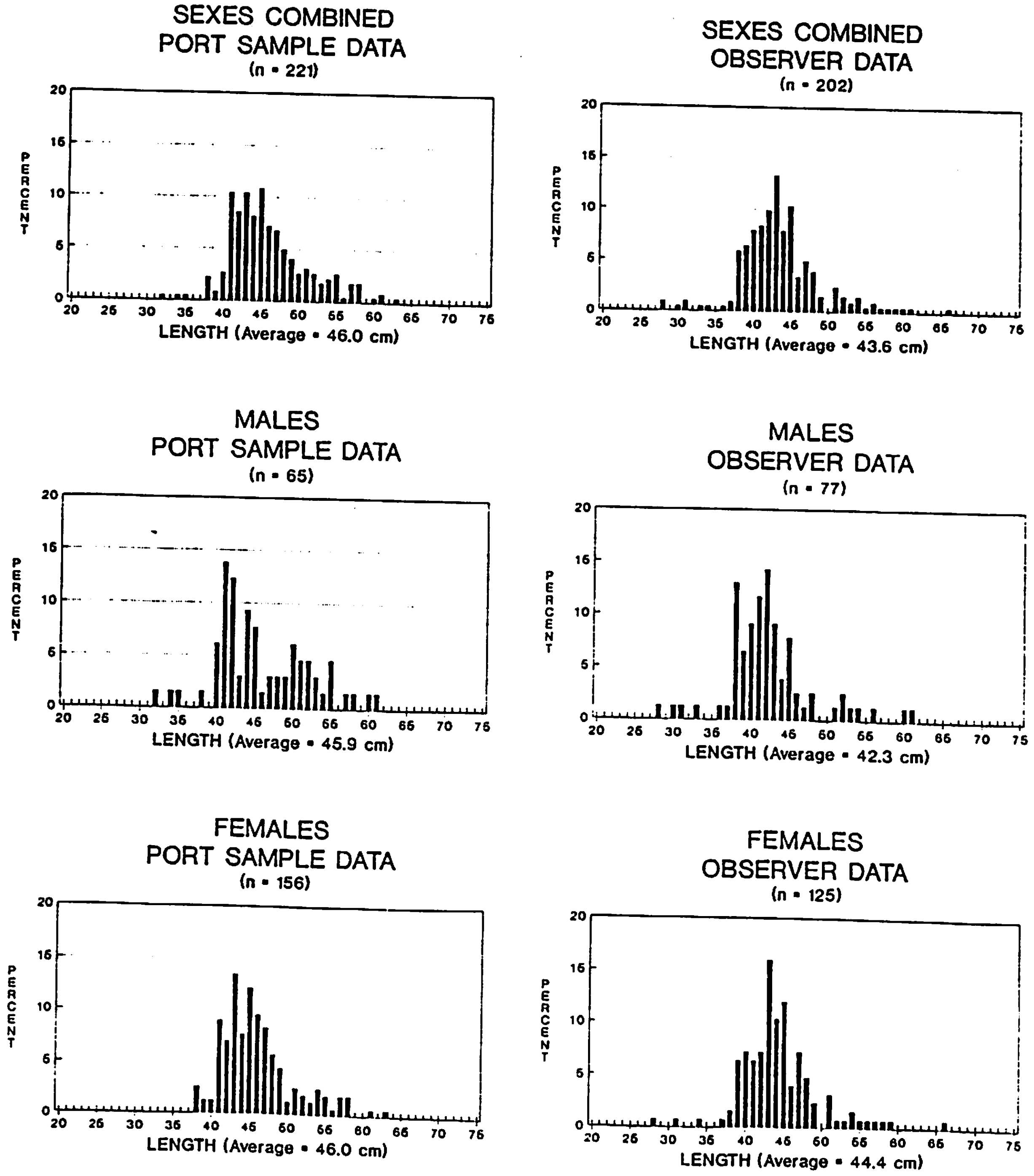


Figure 13. --Comparison of pollock length frequency distributions (% sampled from the same fishing trap at two different times. Data collecte on the fishing grounds by the NPFMC Pilot Domestic Observer Program an during dockside delivery on Kodiak Island by the NMFS Port Sample Dat Collection Program during spring 1989, Case #4-Barnabas.

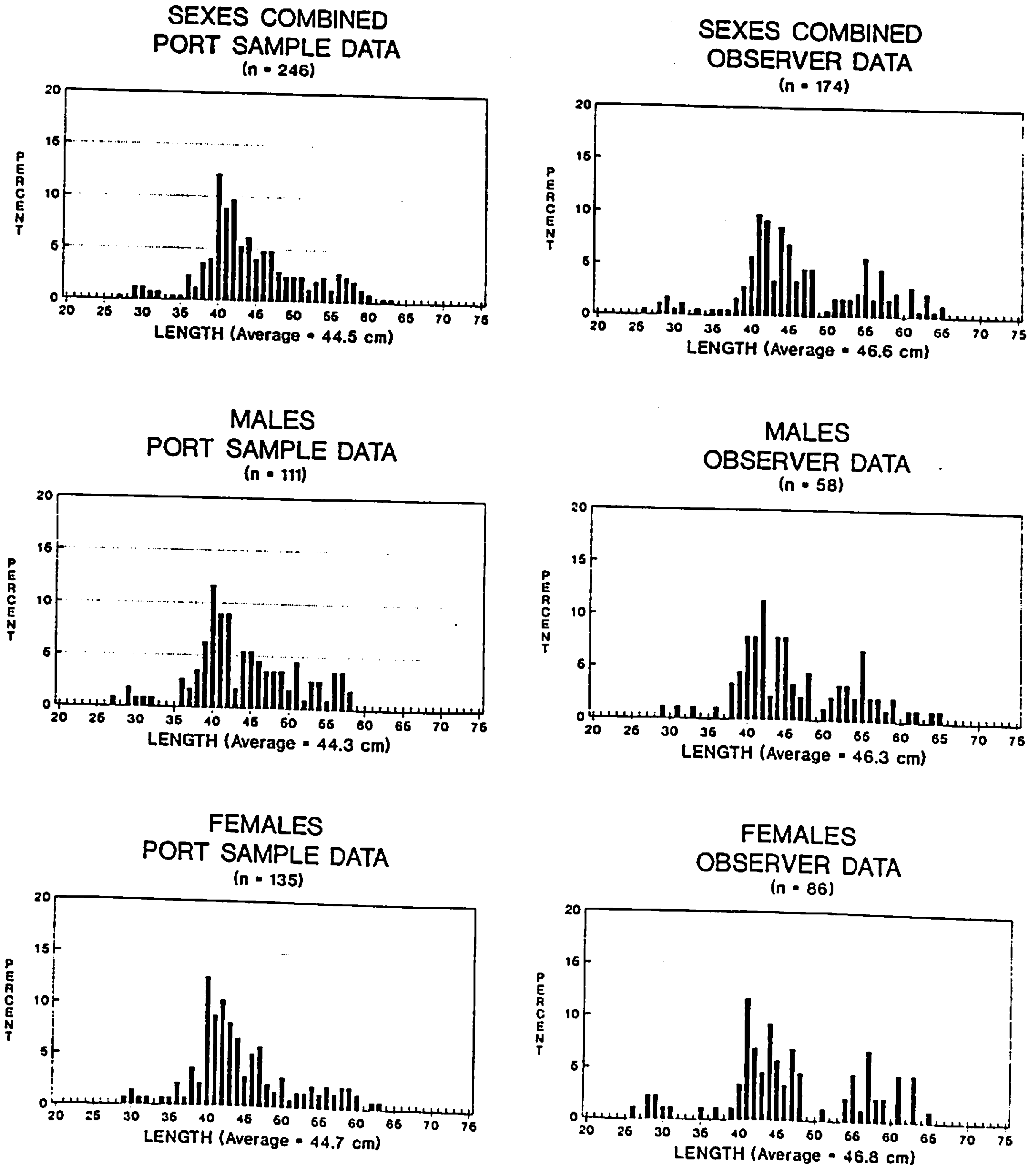


Figure 14. --Comparison of pollock length frequency distributions (% sampled from the same fishing trap at two different times. Data collecte on the fishing grounds by the NPFMC Pilot Domestic Observer Program an during dockside delivery on Kodiak Island by the NMFS Port Sample Dat Collection Program during spring 1989, Case #5-Marmot Gully.

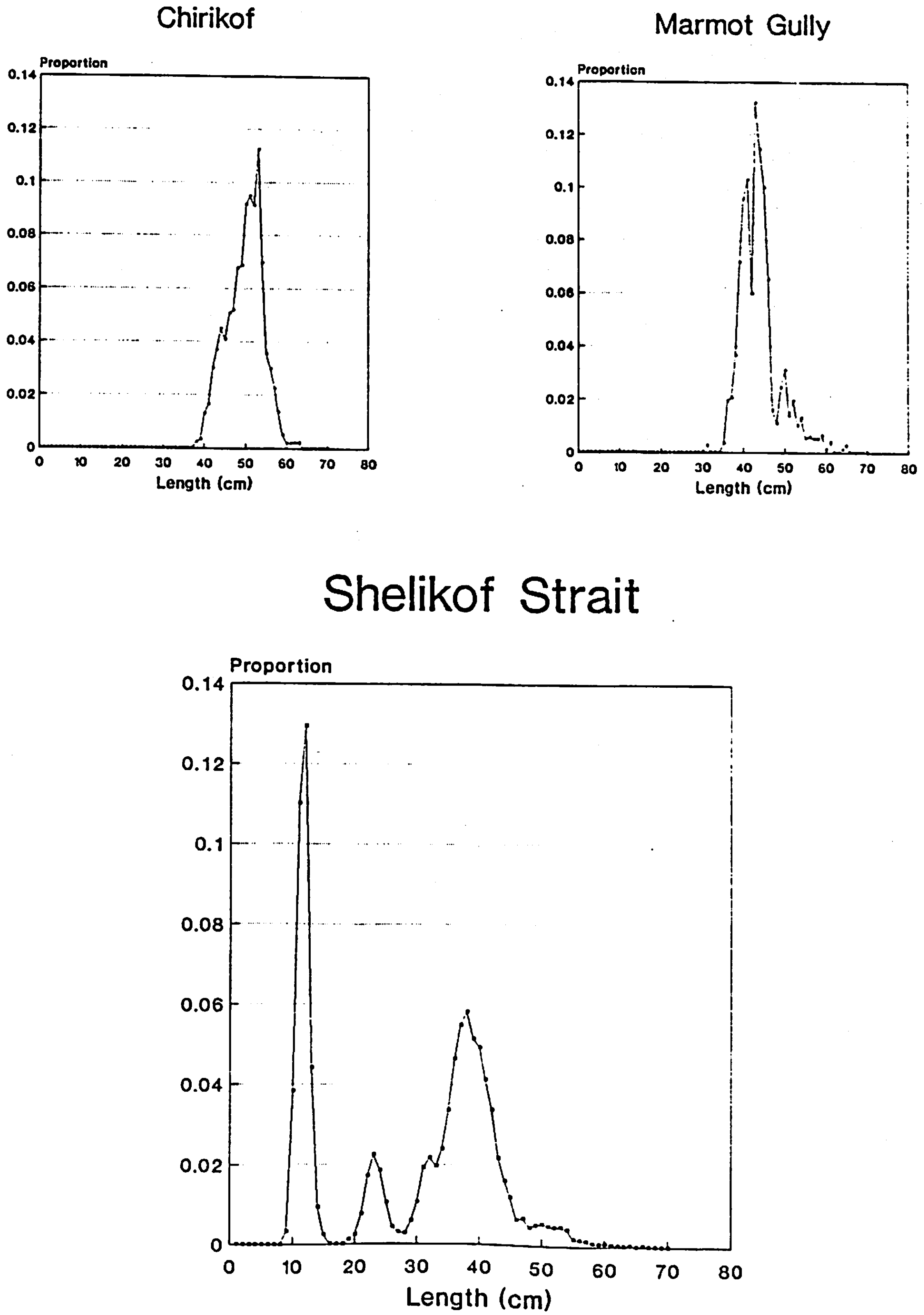


Figure 15.--Comparison of length frequency distributions (%) of pollock taken from the Chrikof, Marmot Gully, and Shelikof Strait reporting sub-areas by domestic fisheries during spring 1989 and from Shelikof Strait by the spring 1989 hydroacoustic survey.

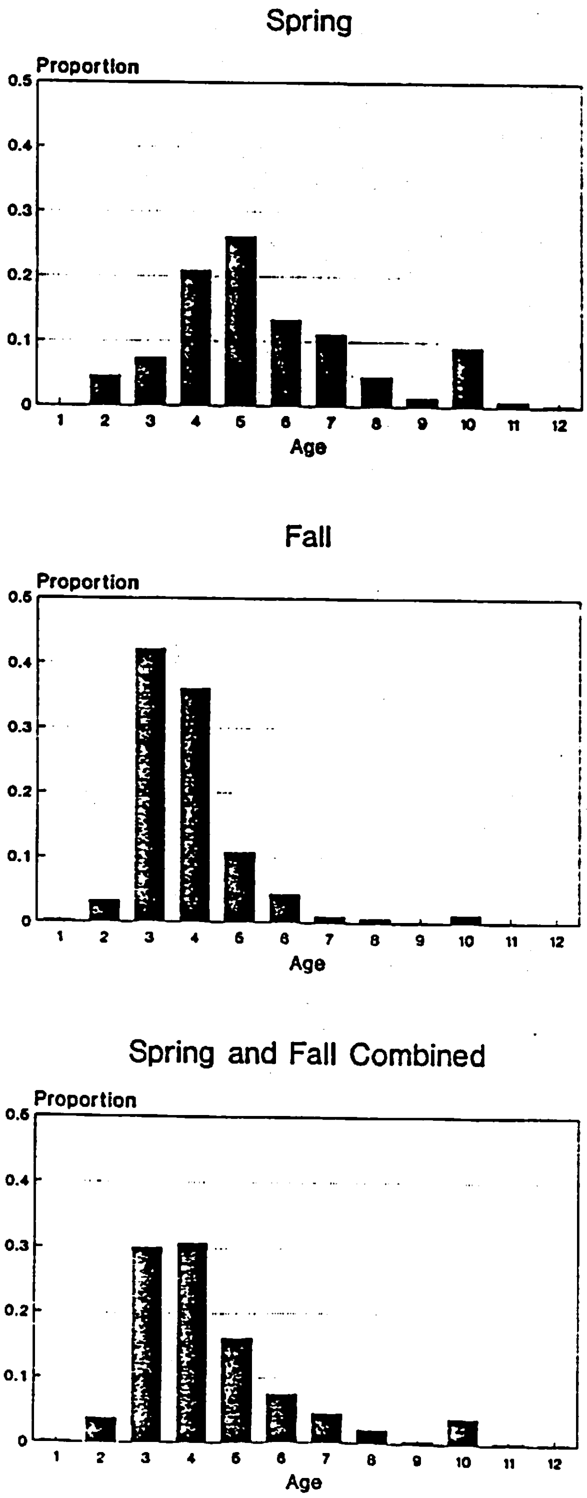


Figure 16.--Age composition estimates of pollock taken in the spring and fall commercial fisheries from the Gulf of Alaska, 1988.

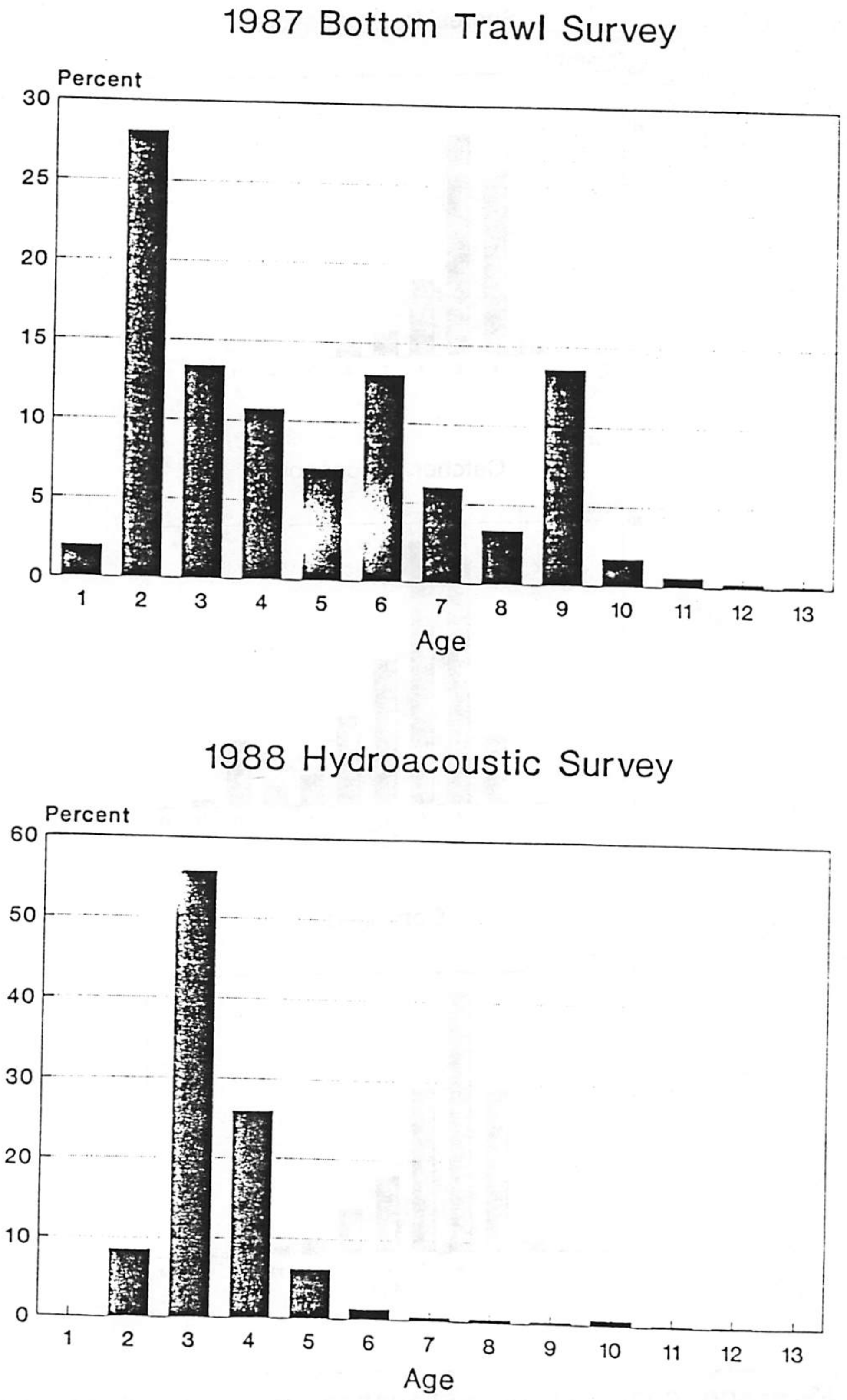
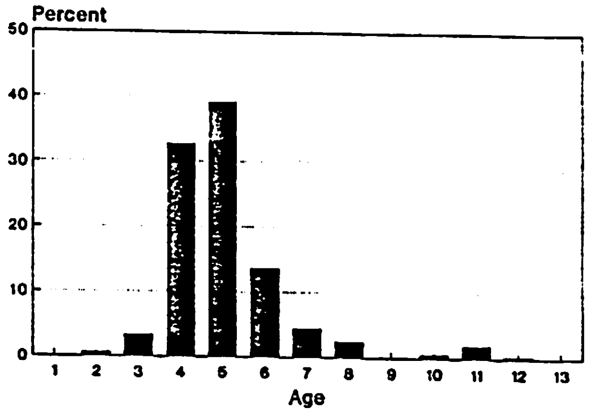
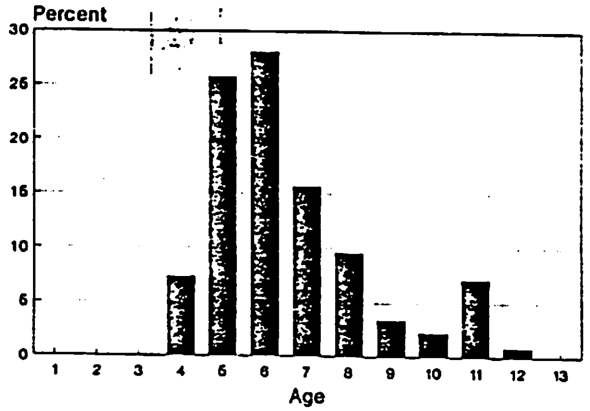


Figure 17.--Age composition estimates of pollock from the 1987 bottom trawl survey and the 1988 spring hydroacoustic survey.

Shoreside Processors



Catcher Processors



Combined

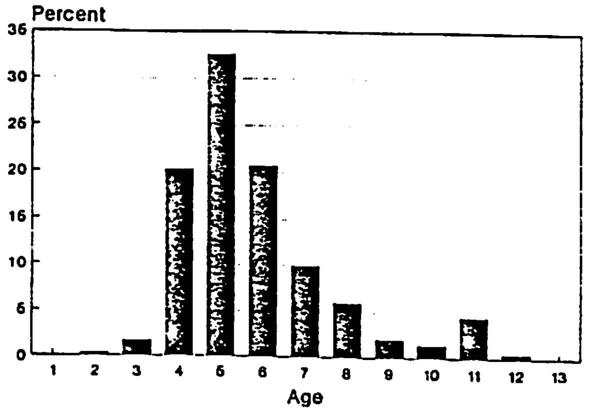


Figure 18.--Age composition estimates of Gulf of Alaska pollock taken in the 1989 spring commercial fisheries by shoreside processors, catcher processors and processors combined.

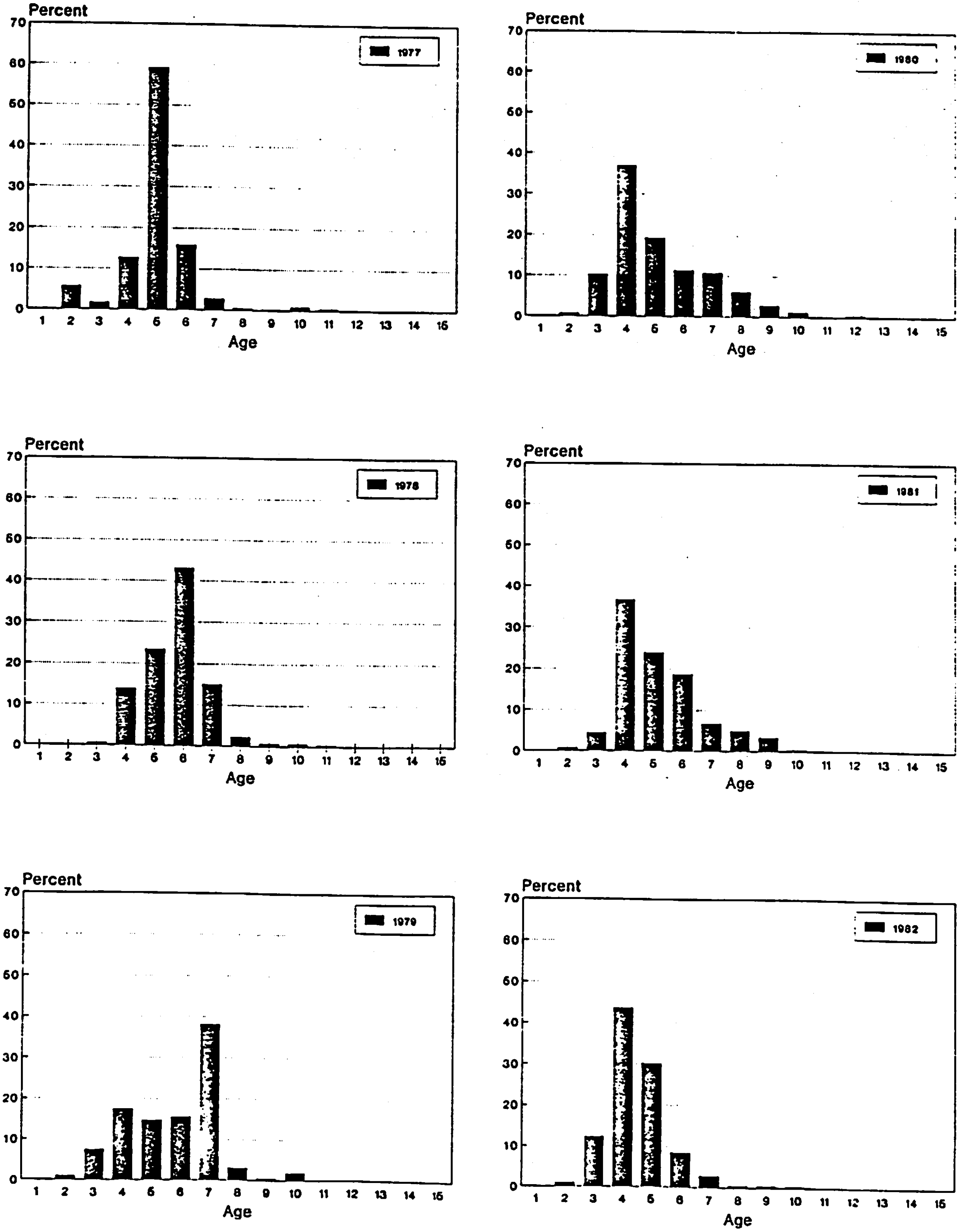


Figure 19.--Age composition estimates of male pollock taken in by the commercial fisheries from the Shumagin INPFC area, May-August 1977-82.

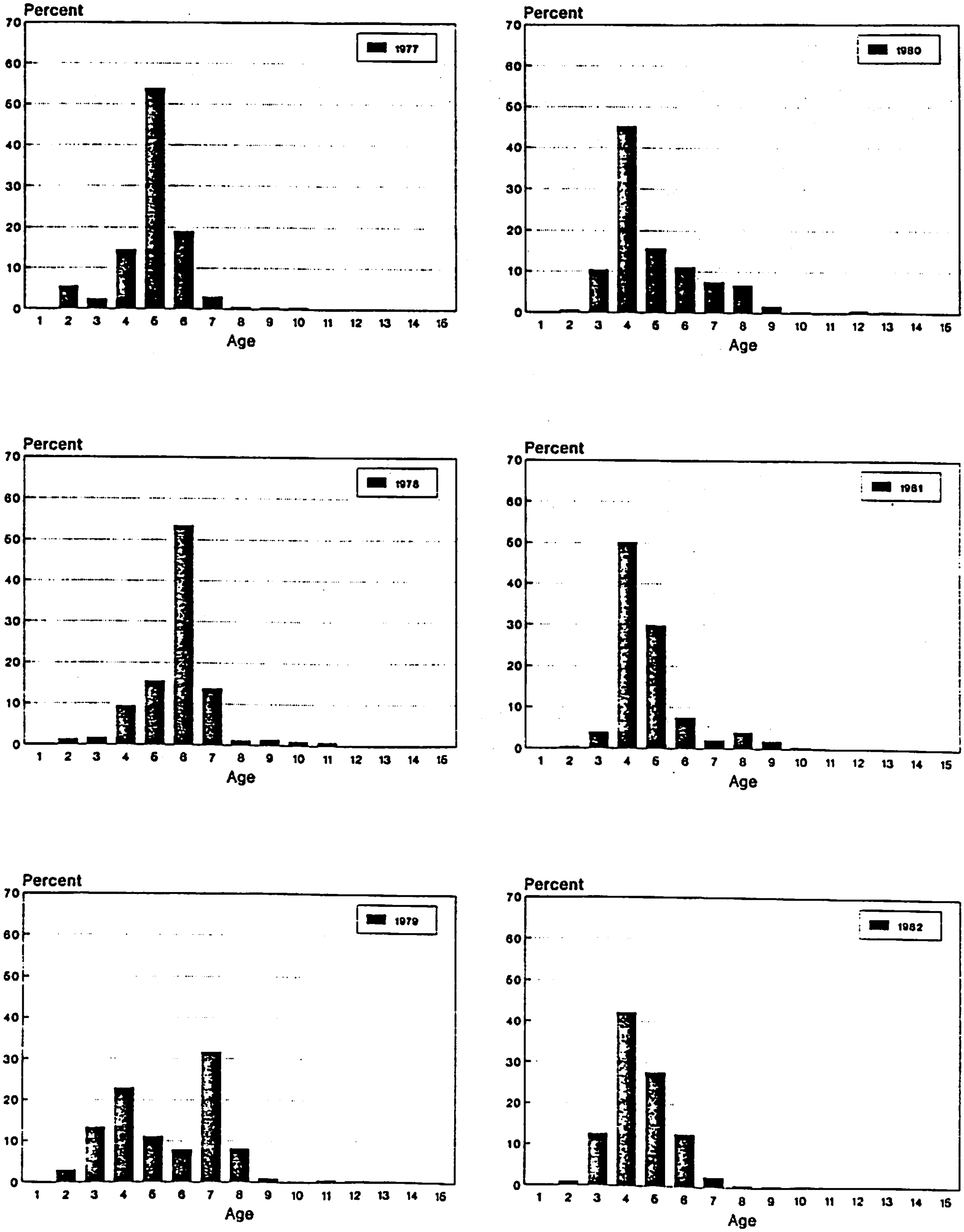


Figure 20.--Age composition estimates of female pollock taken in by the commercial fisheries from the Shumagin INPFC area, May-August 1977-82.

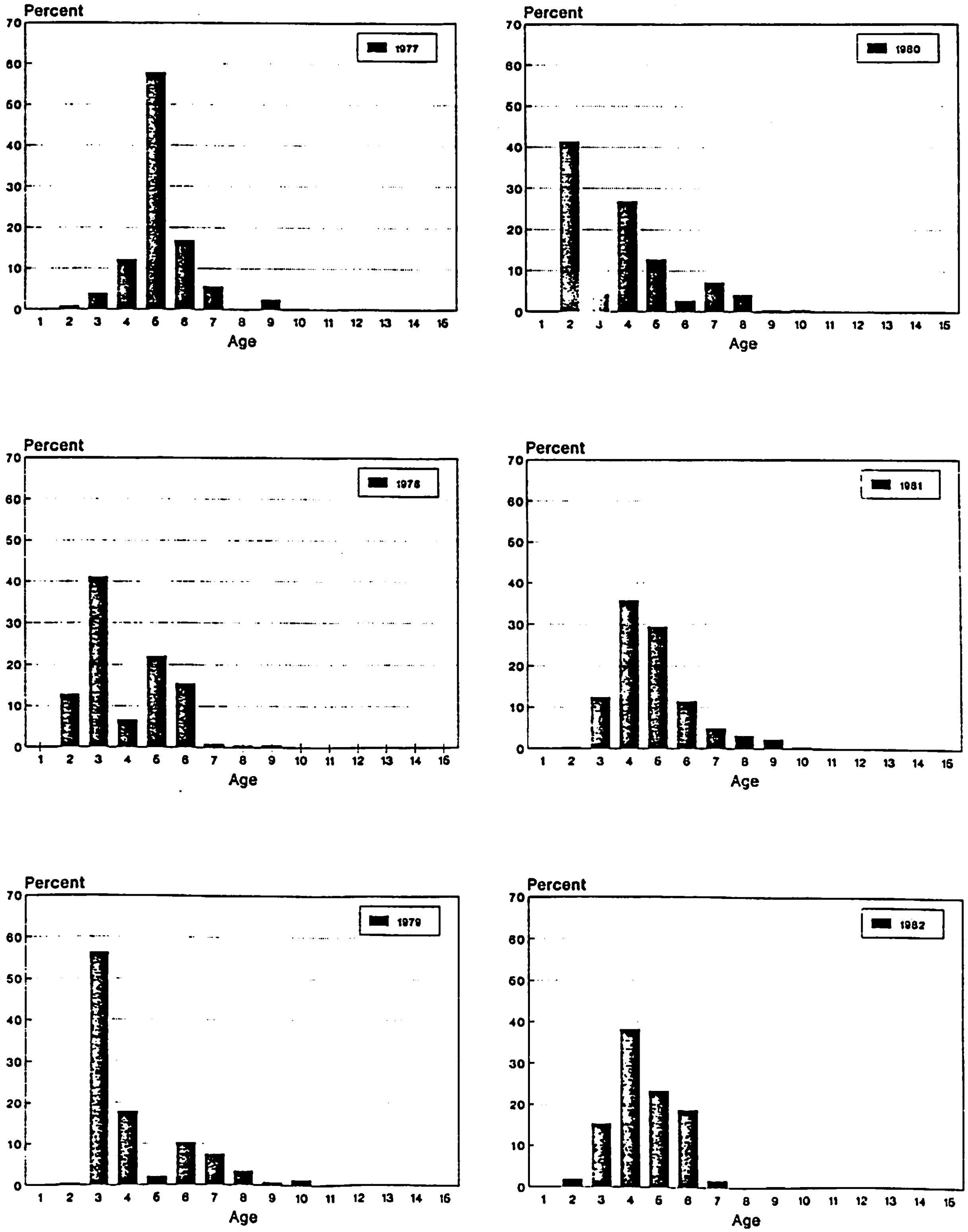


Figure 21.--Age composition estimates of male pollock taken in by the commercial fisheries from the Chirikof INPFC area, May-August 1977-82.

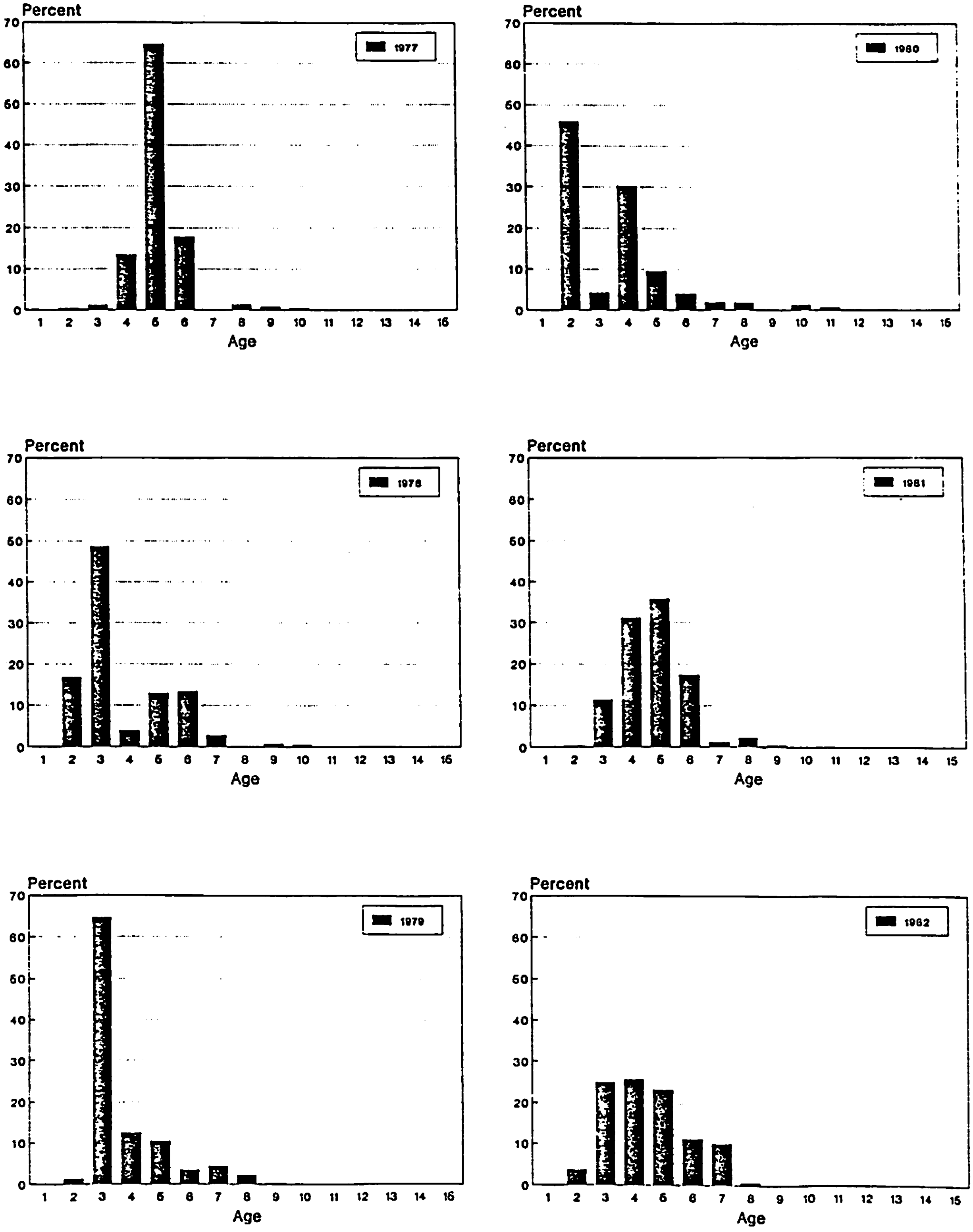


Figure 22.--Age composition estimates of female pollock taken in by the commercial fisheries from the Chirikof INPFC area, May-August 1977-82.

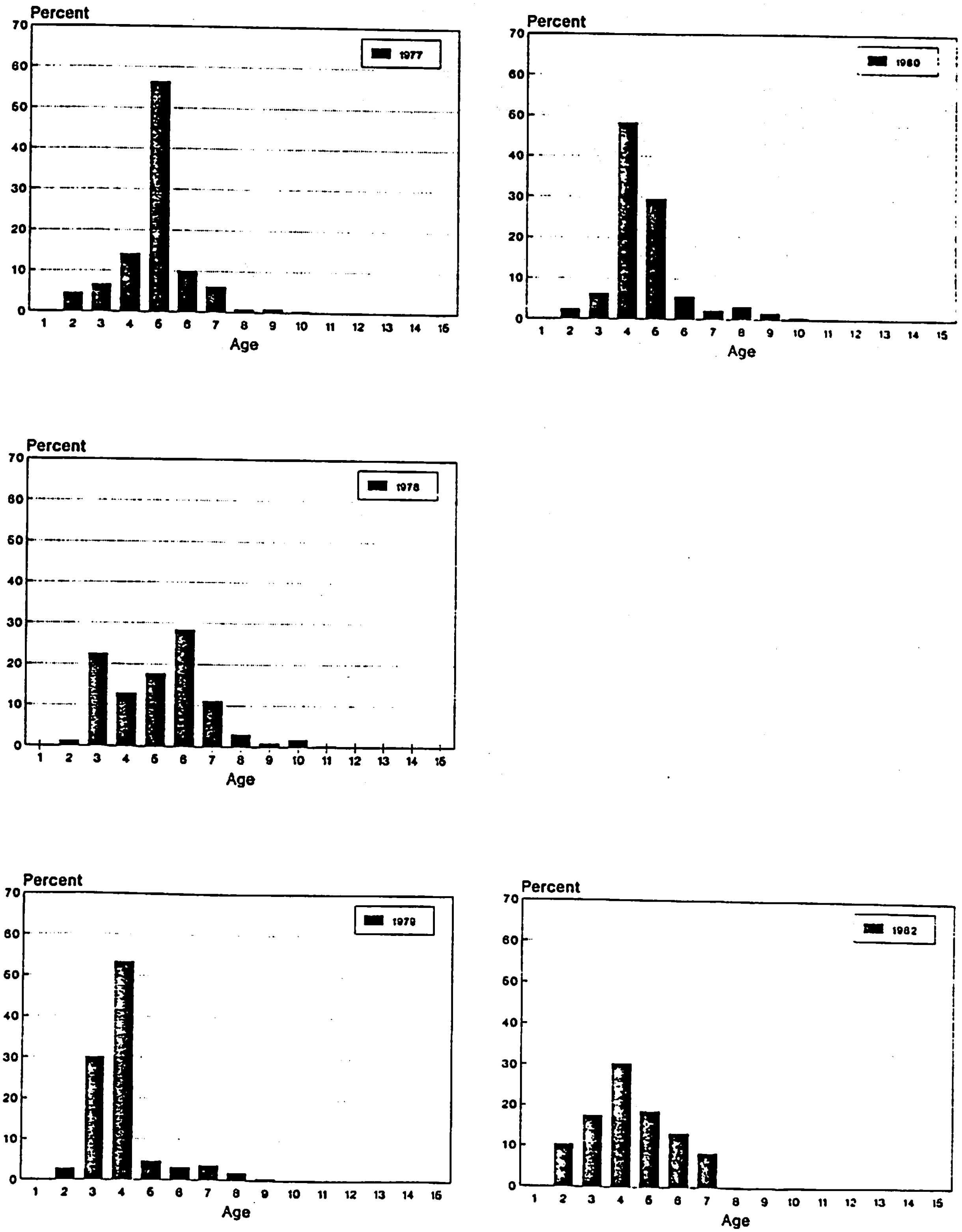


Figure 23.--Age composition estimates of male pollock taken in by the commercial fisheries from the Kodiak INPFC area, May-August 1977-82.

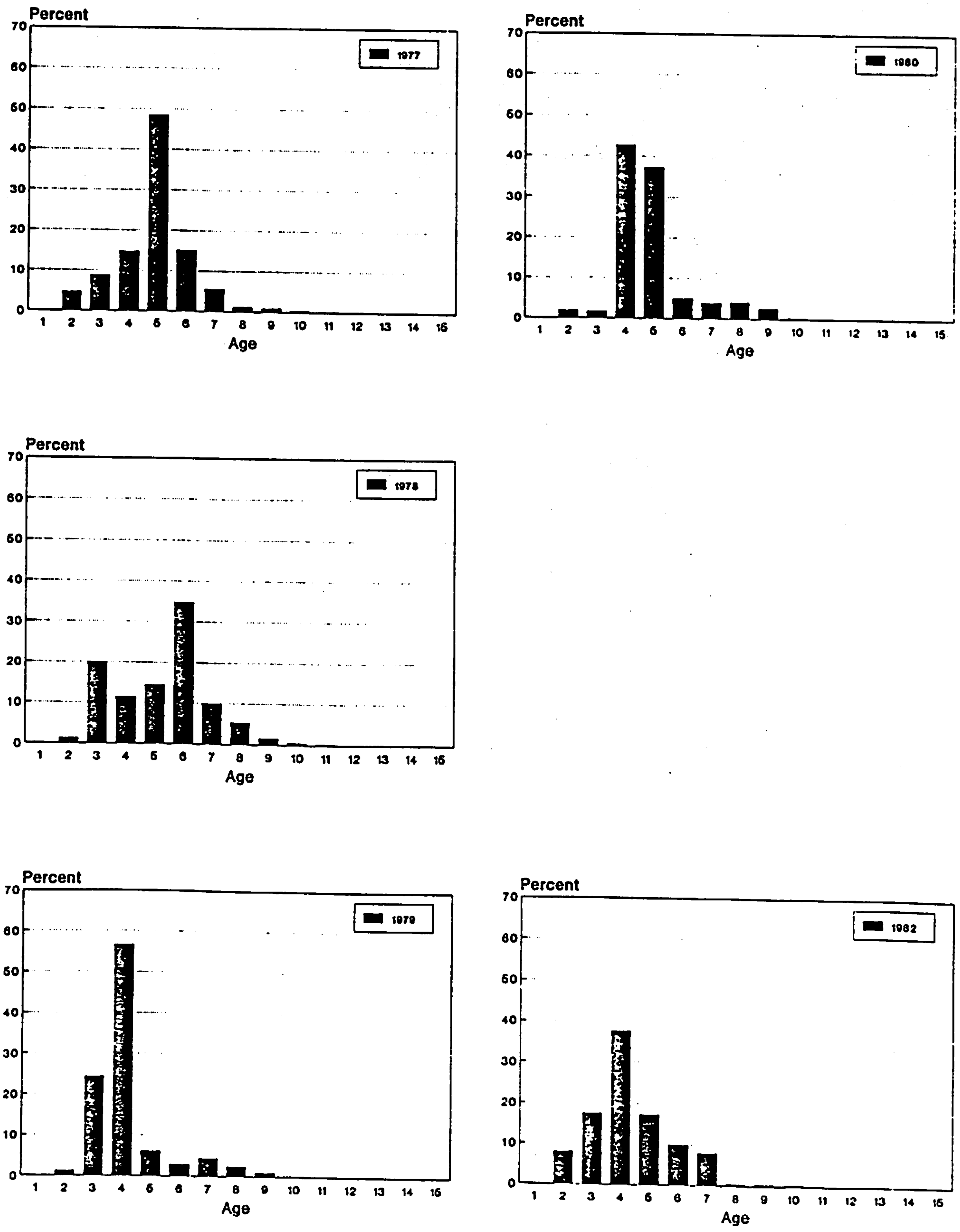


Figure 24.--Age composition estimates of female pollock taken by the commercial fisheries from the Kodiak INPFC area, May-August in 1977-82.

Data Sources	CAGEAN	Synthesis
1. Catch-at-age (CAA)	Yes	Yes
2. Catch Biomass	No	Yes
3. Survey Biomass	Indirectly	Yes
4. Survey CAA	No	Yes
5. Simultaneous application of Bottom Trawl and Hydroacoustic data	No	Yes
6. Separate weight vector for catch and population.	No	Yes
7. Utilizes catch at age 2.	No	Yes

Figure 25.--Data sources available for stock assessment analysis and the use of this data by two stock assessment approaches.

Features	CAGEAN	Synthesis
1. Selectivity for each fishery.	Yes	Yes
2. Selectivity for each survey.	No	Yes
3. Age specific M	Yes	Yes
4. Abundance at beginning of year.	Yes	Yes
5. Biomass at beginning of year.	No	Yes
6. Mean biomass for the year.	No	Yes
7. Spawner-Recruit relationships.	Yes	Yes

Figure 26.--Features of the CAGEAN and Stock Synthesis stock assessment approaches.

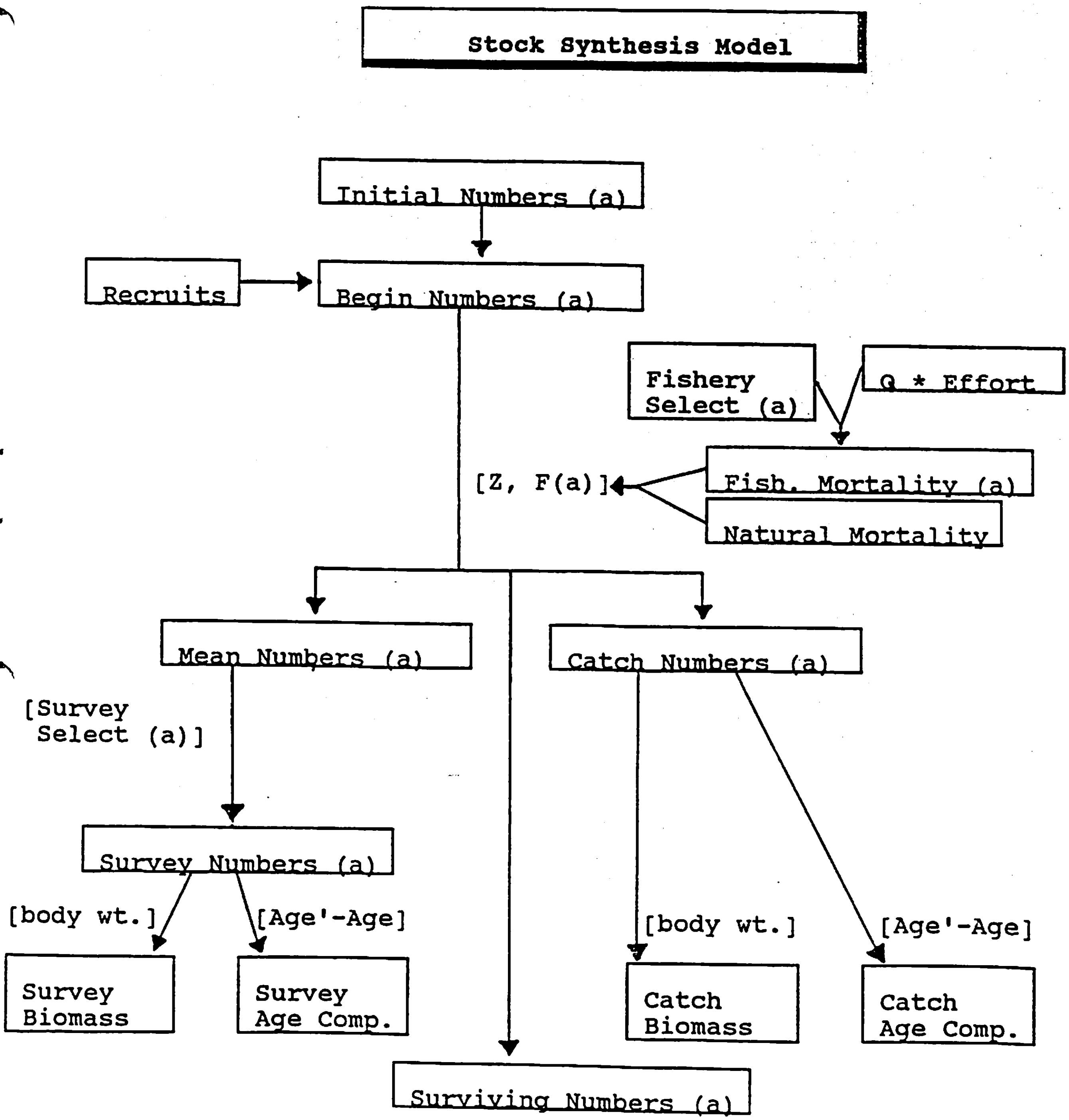


Figure 27.--Flow diagram of the Stock Synthesis stock assessment approach.

HYDROACOUSTIC BIOMASS

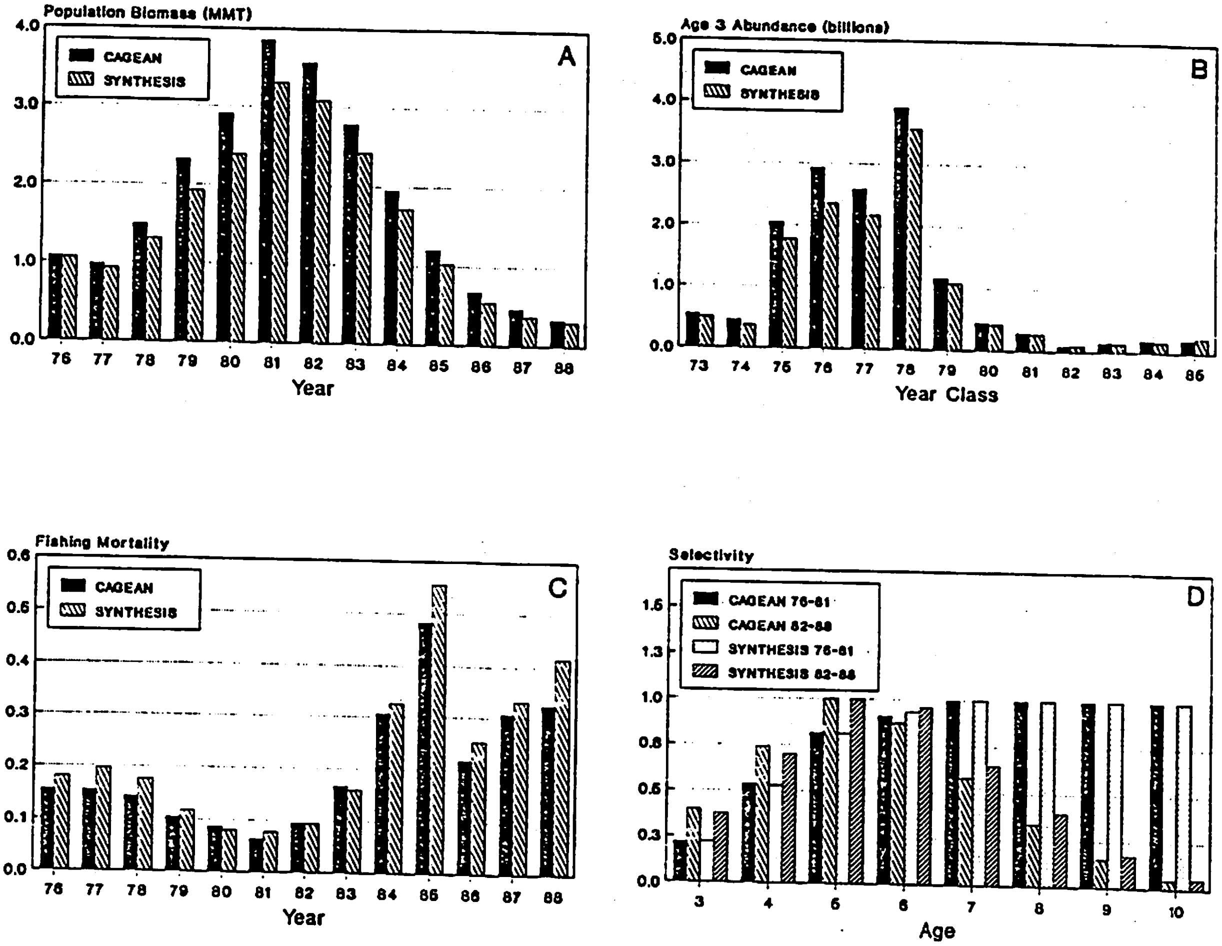


Figure 28.--Comparison of population biomass (panel A), age 3 abundance (panel B), annual fishing mortality rates (panel C) and age-specific selectivity (panel D) estimates from application of the CAGEAN and Stock Synthesis stock assessment approaches to the Gulf of Alaska pollock data. Only catch-at-age and hydroacoustic survey biomass estimates submitted to the model as data.

BOTTOM TRAWL NUMBERS

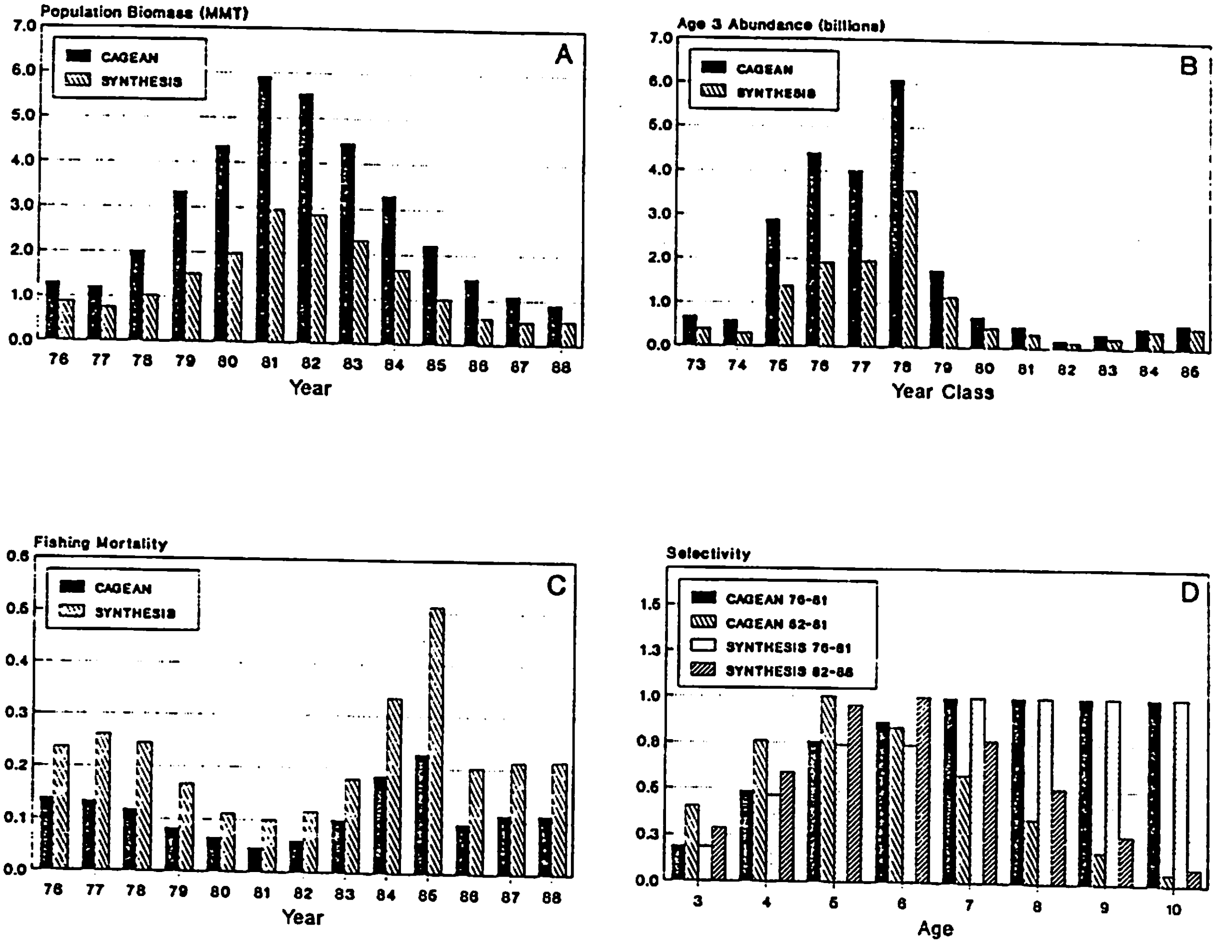


Figure 29.--Comparison of population biomass (panel A), age 3 abundance (Panel B), annual fishing mortality rates (panel C) and age-specific selectivity (panel D) estimates from application of the CAGEAN and Stock Synthesis stock assessment approaches to the Gulf of Alaska pollock data. Only catch-at-age and bottom trawl survey abundance estimates submitted to the models as data. Emphasis of 1.0 placed on the bottom trawl data in the Synthesis application (see text).

BOTTOM TRAWL NUMBERS

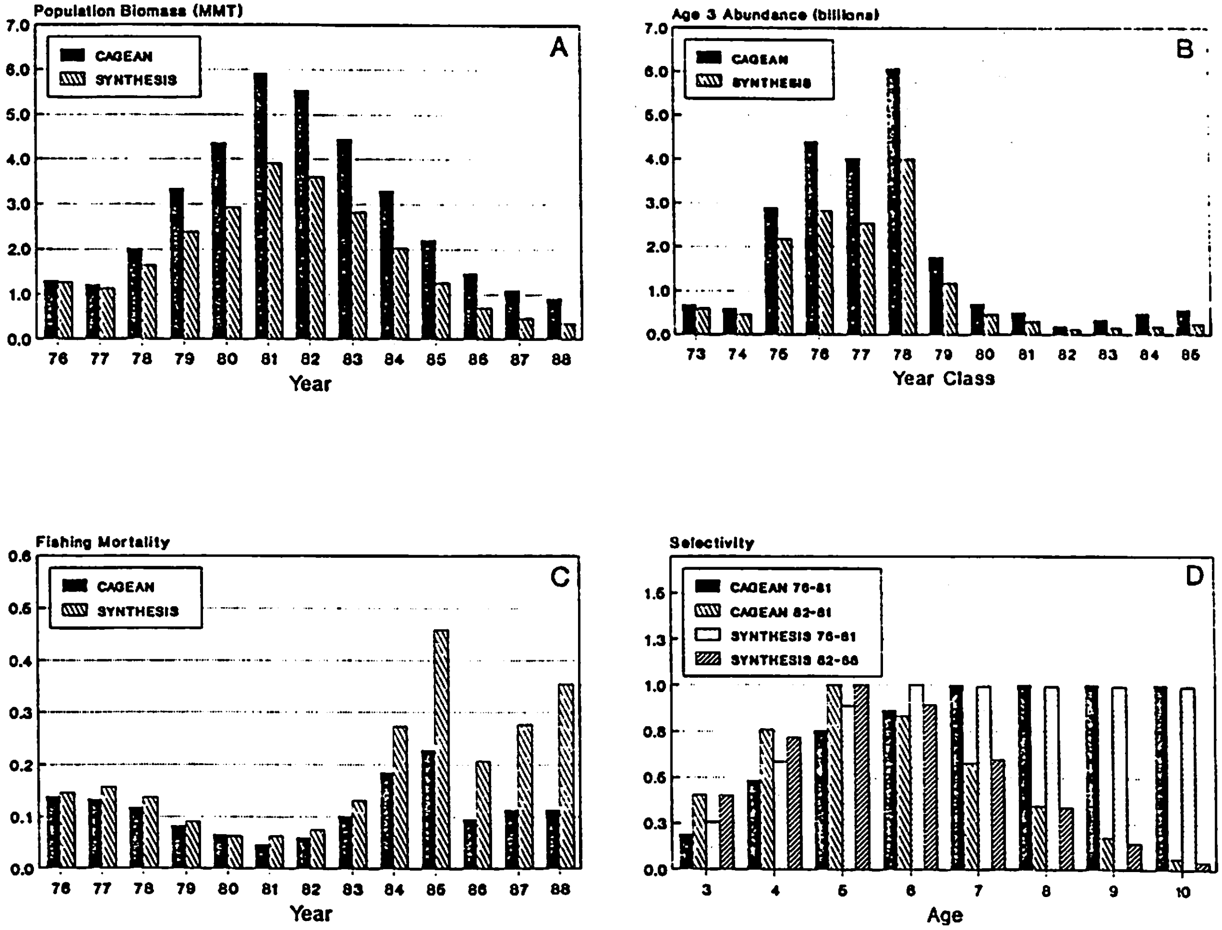


Figure 30.--Comparison of population biomass (panel A), age 3 abundance (Panel B), annual fishing mortality rates (panel C) and age-specific selectivity (panel D) estimates from application of the CAGEAN and Stock Synthesis stock assessment approaches to the Gulf of Alaska pollock data. Only catch-at-age and bottom trawl survey abundance estimates submitted to the models as data. Emphasis of 10.0 placed on the bottom trawl data in the Synthesis application (see text).

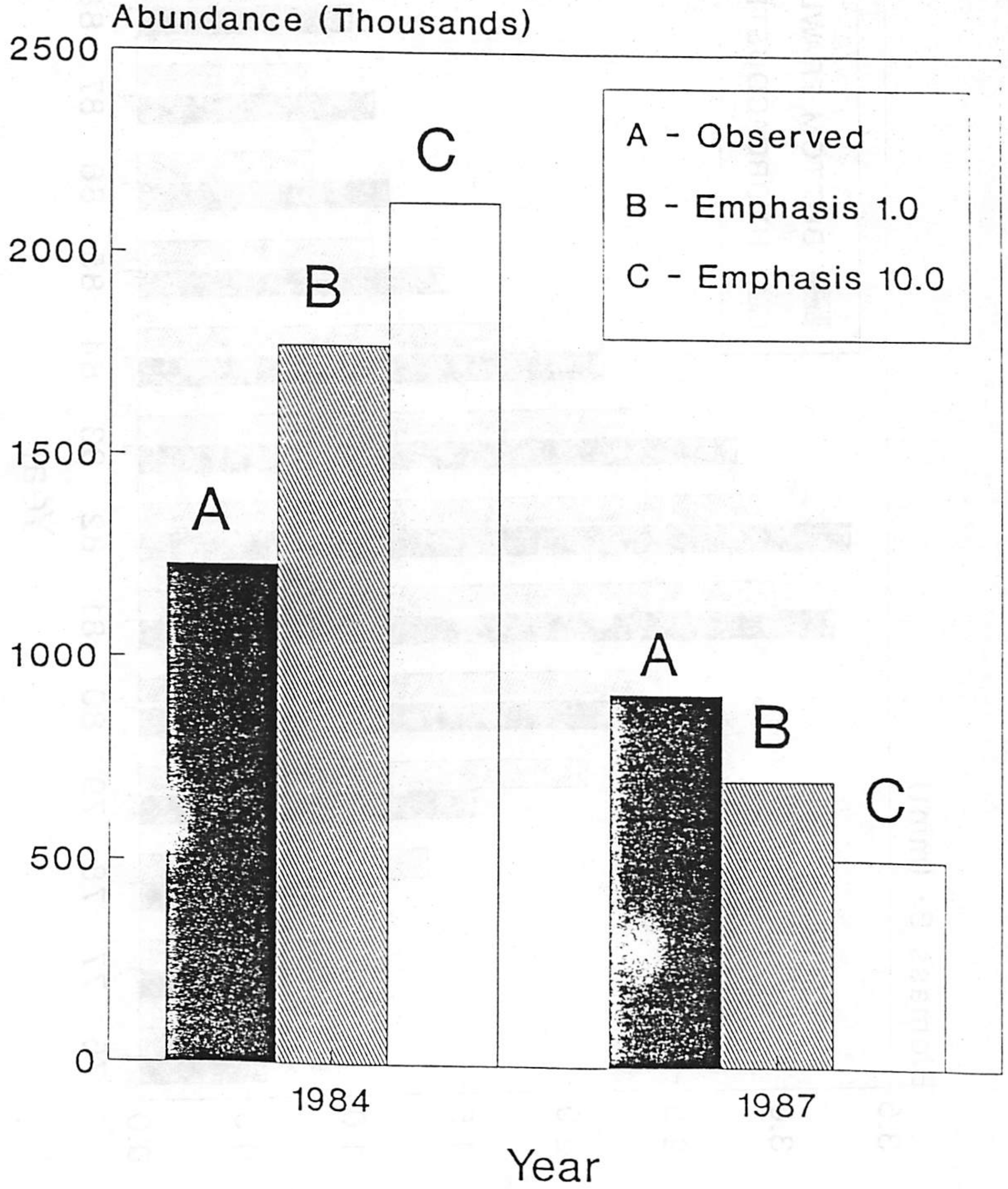


Figure 31.--Bottom trawl abundance estimates as observed from the 1984 and 1987 bottom trawl survey (A) and estimated from application of the Synthesis stock assessment approach to Gulf of Alaska pollock data using two different emphasis values placed on the bottom trawl data (B and C).

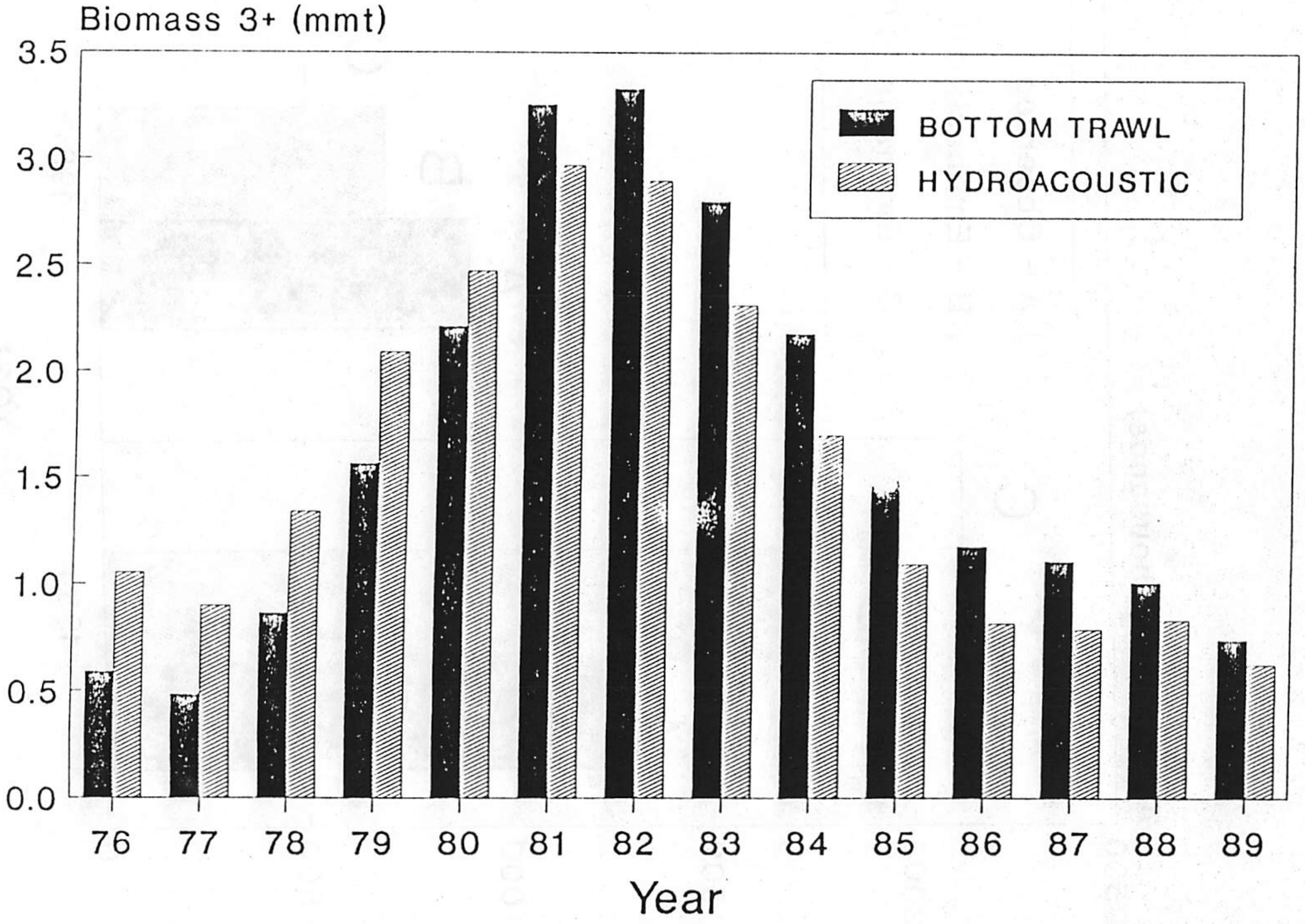


Figure 32.--Comparison of trends in biomass (ages 3-and-older) estimated from applications of the Synthesis stock assessment approach to the Gulf of Alaska pollock data when only catch-at-age and one type of survey abundance and age composition data were submitted to the model.

Figure 33--Trend in natural mortality with age estimated from an application of the Synthesis stock assessment approach to the Gulf of Alaska pollock data under the assumption that all age groups are fully recruited to the survey gear.

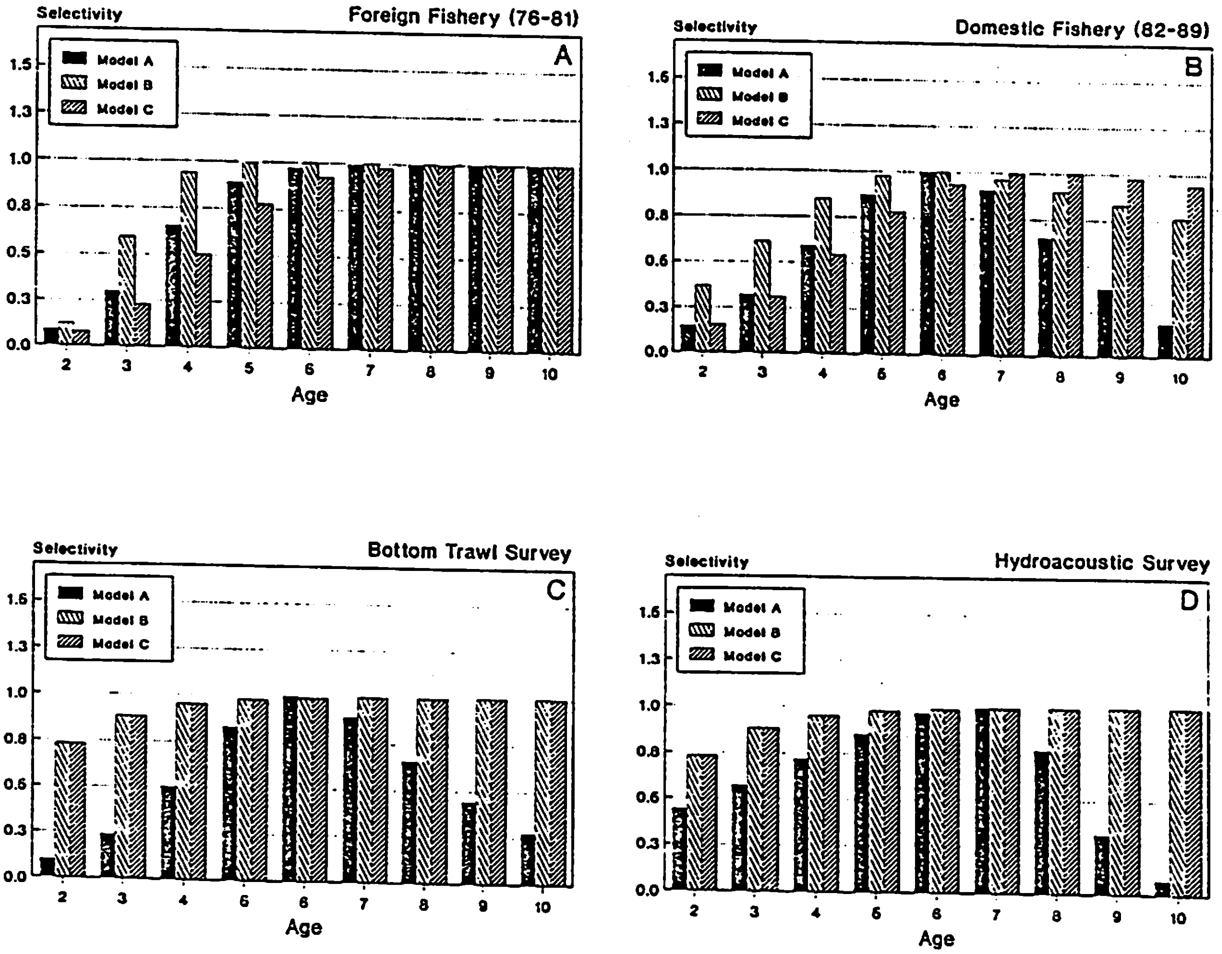


Figure 34.--Comparison of trends in age-specific selectivity estimated from three different configurations of the Synthesis stock assessment approach (see text for explanations of Models A B and C) to the Gulf of Alaska pollock data. Presented are the estimated selectivities from the Foreign Fishery 1976-81 (panel A), Domestic Fishery 1982-1989 (panel B), Bottom Trawl Survey 1984 and 1987 (panel C), and Hydroacoustic Survey 1981, 1982-1989 (panel D).

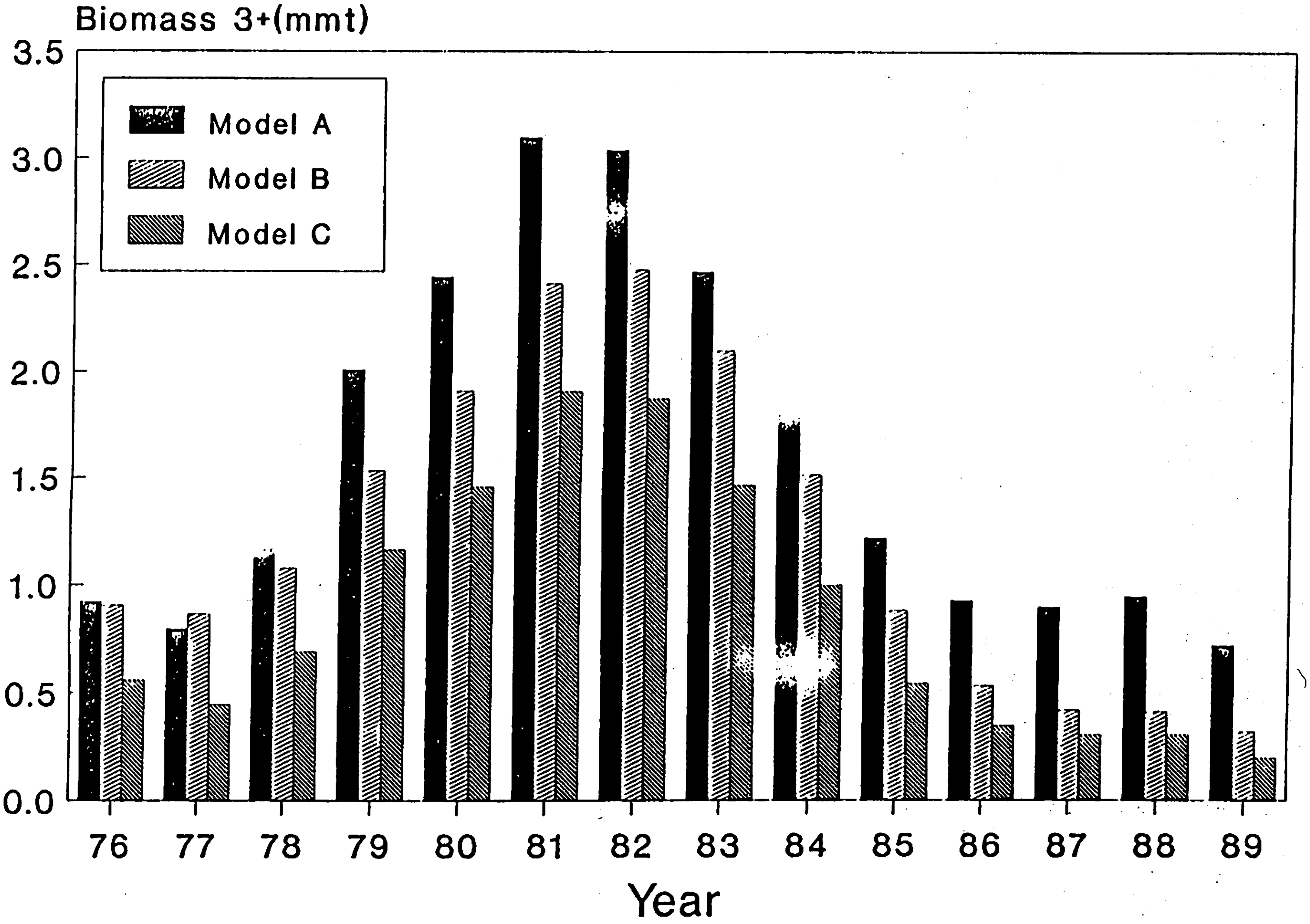


Figure 35.--Comparison of trends in biomass (ages 3-and-older) estimated from three different configurations of the Synthesis stock assessment approach (see text for explanations of Models A B and C) to the Gulf of Alaska pollock data.

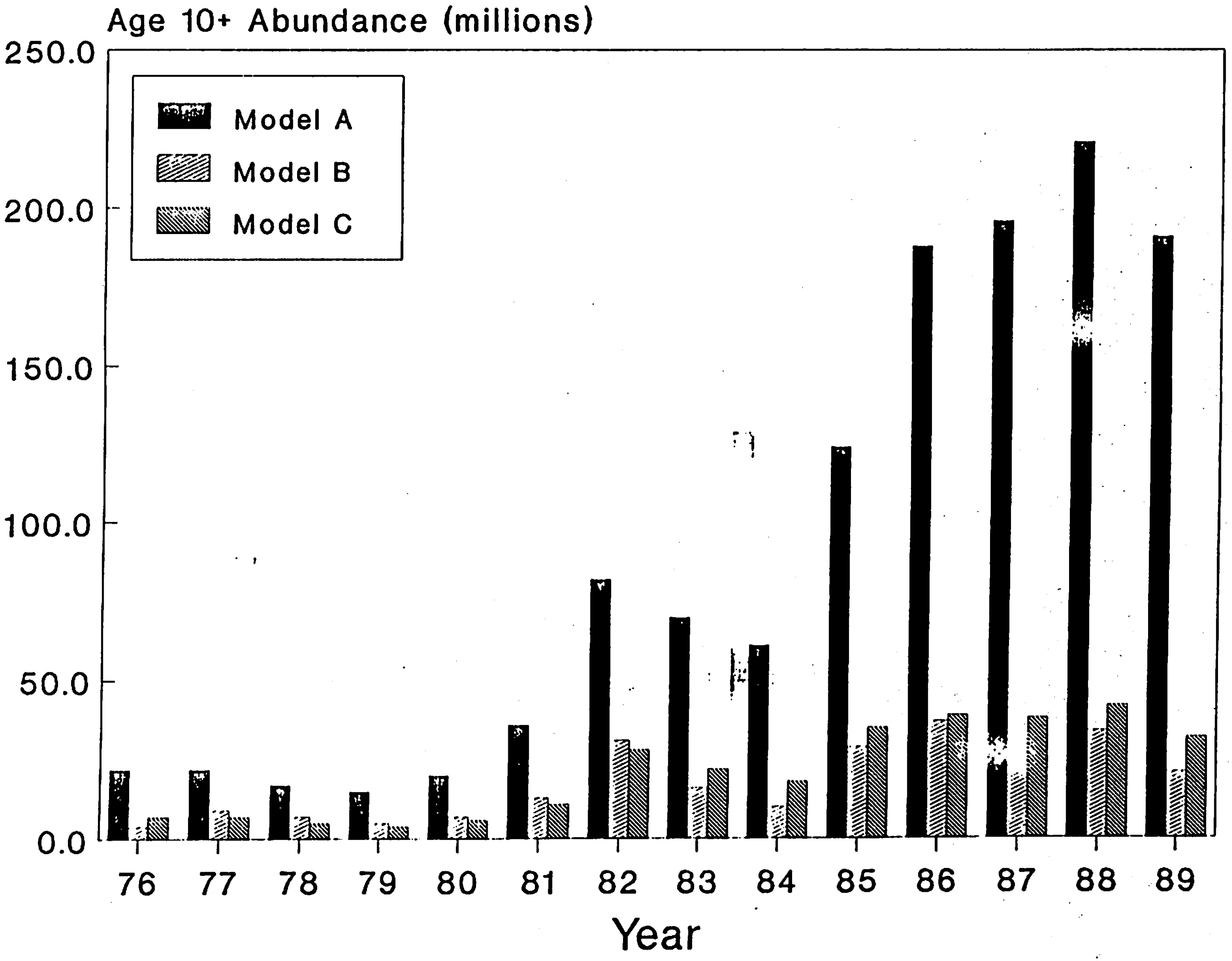


Figure 36.--Comparison of trends in age 10-and-older abundance estimated from three different configurations of the Synthesis stock assessment approach (see text for explanations of Models A B and C) to the Gulf of Alaska stock data.

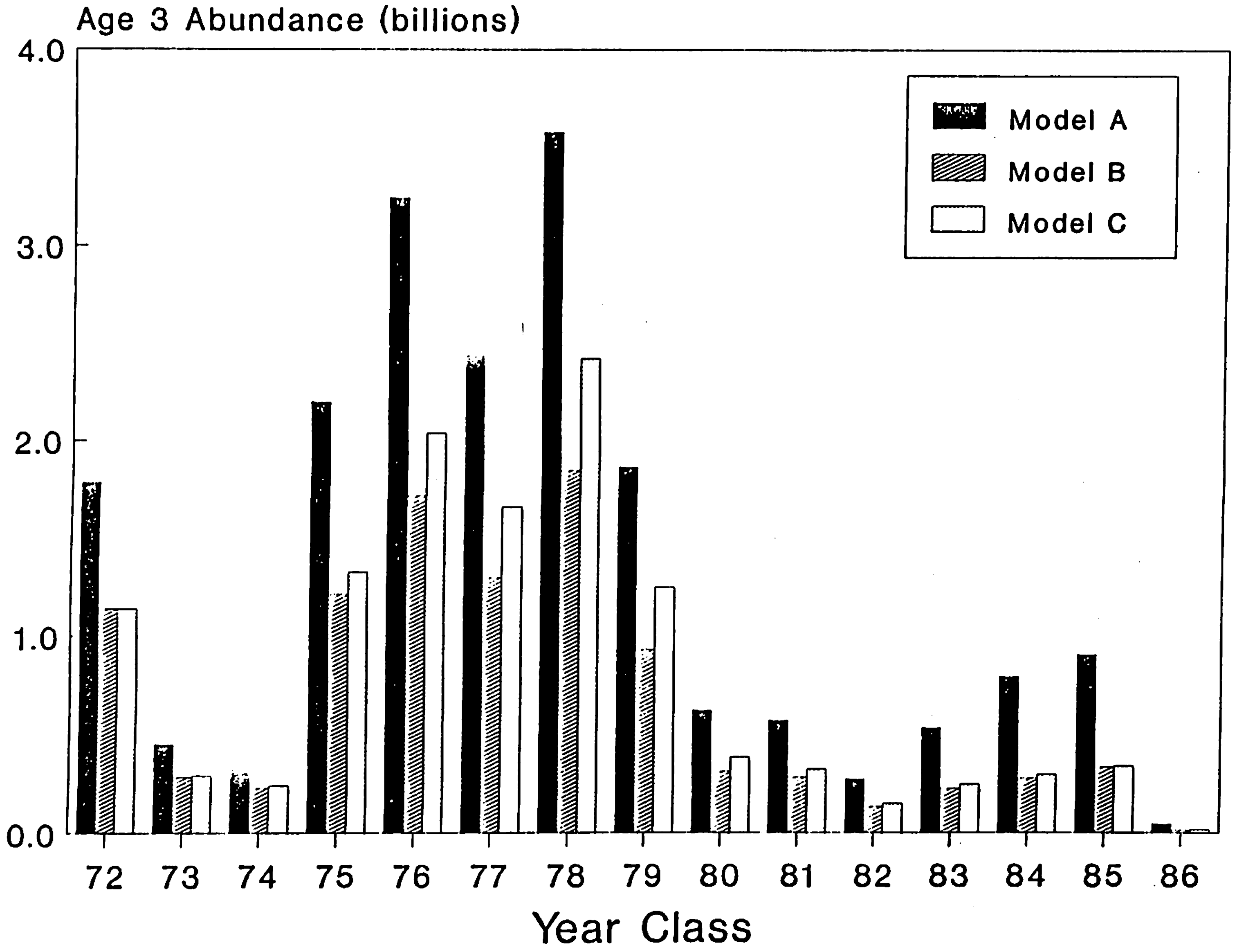


Figure 37.--Comparison of trends in age 3 abundance estimated from three different configurations of the Synthesis stock assessment approach (see text for explanations of Models A B and C) to the Gulf of Alaska pollock data.

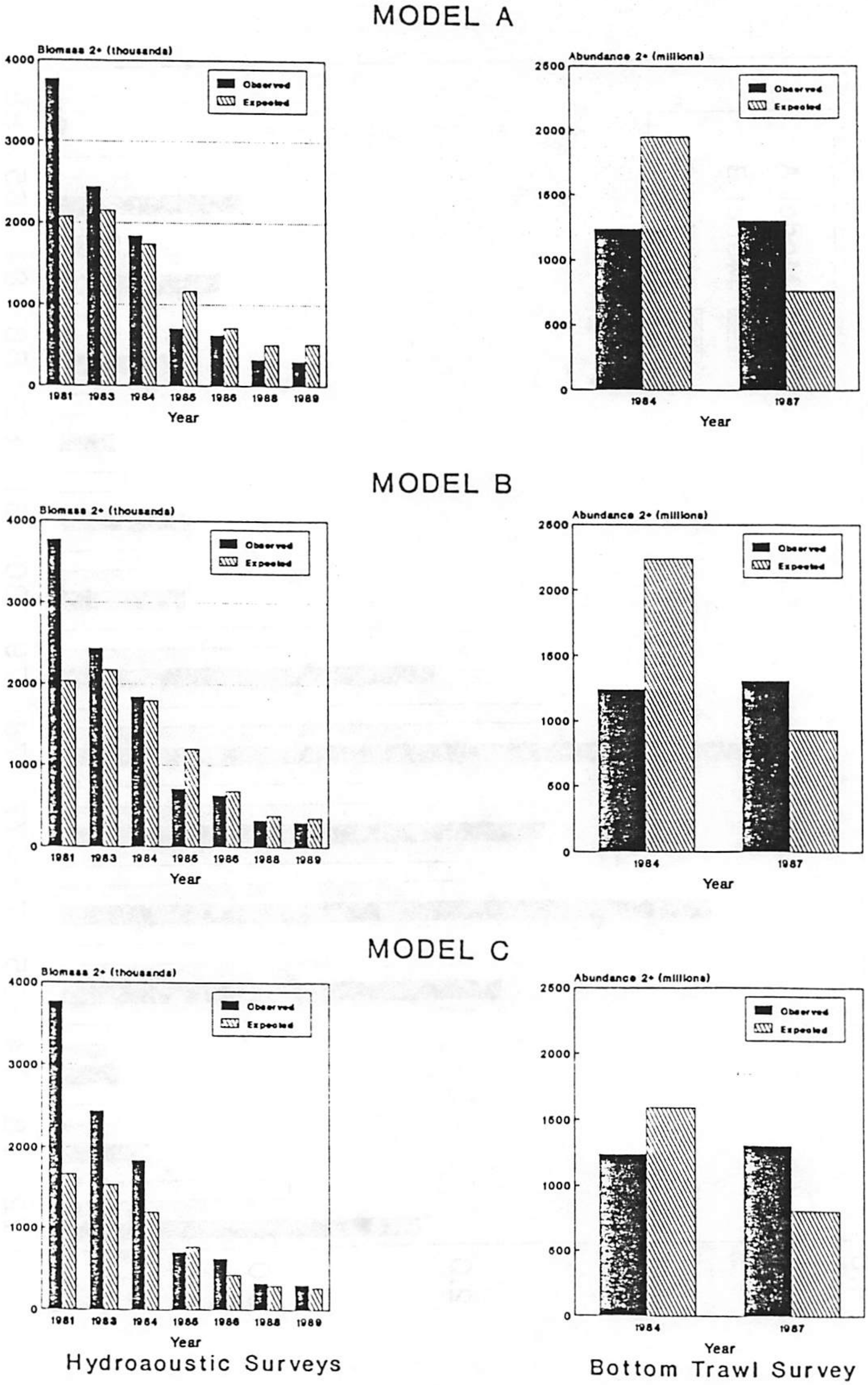


Figure 38.--Bottom trawl and hydroacoustic survey biomass estimates (ages 2-and-older) as observed from the surveys and estimated from application of the Synthesis stock assessment approach to Gulf of Alaska pollock data using three different configurations (see text for explanations of Models A, B and C).

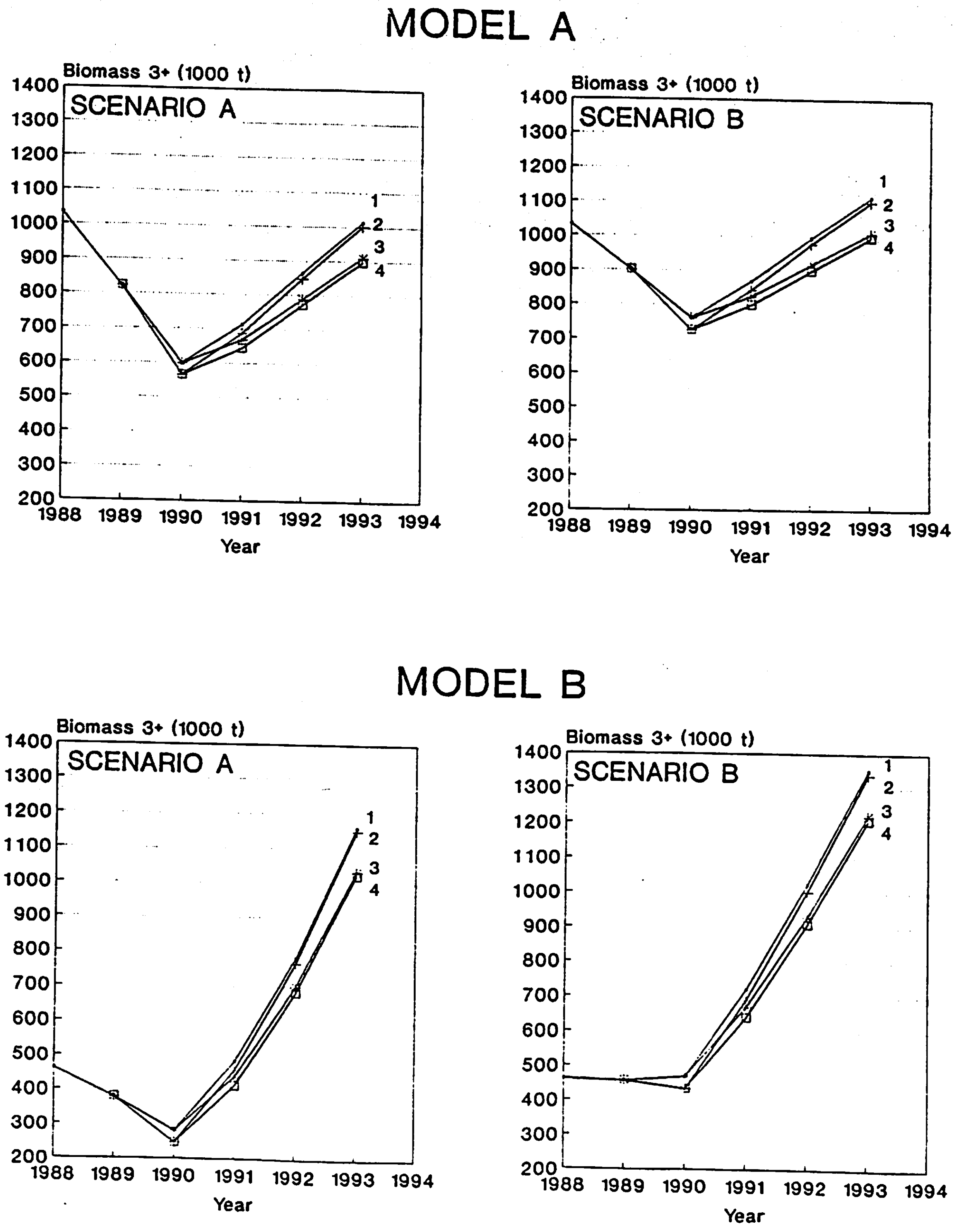


Figure 39.--Forecasts of pollock biomass (ages 3-and-older) in the Gulf of Alaska 1988-93 given two likely recruitment scenarios (A and B) and four catch schedules (see text for description of recruitment and catch schedules). Projections were started with 1988 numerical population estimates derived from an application of the Synthesis stock assessment approach to the Gulf of Alaska pollock data using two configurations (see text for explanations of Models A and B).

Appendix 1

Analysis of Pollock Growth

The purpose of is analysis was threefold. First, if differences in the growth patterns of fish from different geographic areas were detected, then the current assumption of a unit stock would require revision. Second, accurate estimates of mean length and weight-at-age were required for the stock assessment and simulation models used in this analysis. Finally, we plan to apply length frequency distributions from incidental catches of pollock in the 1960's and early 1970's to a general age-length key in an attempt to extend the time series of recruitment indices. This method requires that interannual variability in length-at-age is minimal.

2.2 Analysis of Length

The analysis was initiated by dividing the calendar year into three seasons: January - April, May - August, and September - December. The data was further stratified by INPFC area (Shumagin, Chirikof, Kodiak and Yakutat). The number of length and age samples in each time/area cell for each sex is summarized in Tables 1 and 2.

Kimura (1987) noted that estimates of the proportion of fish at a given length i and age j is biased when length stratified sampling procedures are used in the collection of age structures. Therefore, estimates of mean length-at-age were estimated using the Age Key Growth (AKG) program developed at the Alaska Fisheries Center. The program corrects the length-at-age estimates as follows. In a sample of randomly collected ages, the an estimator of l_j , the mean length-at-age j, is

$$l_j = {}_i [l_i * q_{ij}] \qquad [1]$$

Where l_i is the midpoint of ith length category and q_{ij} is the proportion of the age j fish in length category i. However, when age structures are collected on a length stratified basis, more weight is given to the tails of the distribution of length at age. The unbiased estimator of q_{ij} is

$$q_{ij} = (p_i * q_{ij}) / (p_i * q_{ij}) \qquad [2]$$

Where p_i is the proportion of fish length i in the random length frequency sample, and q_{ij} is the proportion of the ageing sub-sample from the ith length category that is age j.

An analysis of the relative influence of age, sex, year, season and geographic area on length was performed on the estimates of mean length at age using a generalized linear model procedure provided in the SAS statistical package. A minimum of 10 samples was required for the mean length at age to be included in the analysis. The analysis showed age, sex and seasonal effects accounted for the greatest amount of variance in length (Table 3).

Based on the results of the previous section, regional differences were not considered in the estimation of mean length-at-age. Estimates of mean length-at-age were determined by following individual cohorts through the population. This approach eliminated the possibility of confounding the length-at-age data with differences in growth between cohorts. To avoid possible biases caused by aging error, the study was restricted to the six strong year classes (1972, and 1975-1979). Several observations of length-at-age were available for each of these year classes. Observations of mean length-at-age for each cohort from different seasons were included in the fit to the growth model by adjusting the age to reflect the fraction of the year when the sample was taken. Assuming all fish had an arbitrary birthdate in mid-February.

The mean length-at-age data for each sex was fitted to the Von Bertalanffy growth equation using the non-linear least-squares algorithm in the BMDP statistical package. The von Bertalanffy growth equation was re-parameterized to utilize an estimate of length at the beginning of the year L_1 rather than t_0. The revised form of the growth equation was:

$$L_t = L + (L_1 - L) * \exp(-k(1-t)).$$

The advantages of utilizing the revised form of the equation are outlined in Hollowed et al. (1988). The value of L_1 was estimated from observations of length at age 1 from the hydroacoustic survey data. The estimated value of L_1 was 12.63cm for females and 12.83cm for males.

The growth curves for each of the six strong year classes showed some important differences between years (Figures 1 and 2). The cohort spawned in 1972 had the highest asymptotic length for both males and females (Figures 1 and 2). This finding may reflect the source of the data rather than a true difference in growth. The 1972 year class was primarily sampled by the foreign fishing fleet whereas, the 1975-1979 year classes were sampled from both domestic and foreign fleets. The foreign fleet fished with bottom trawl gear and pollock tend to become more demersal as older fish. Therefore, the largest old fish from the 1975-1979 year classes may not have been fully represented in the mid-water data sets.

2.3 Commercial Fishery Weight-at-age

Seasonal estimates of average weight-at-age were determined by calculating the average length-at-age of the six cohorts at the mid-point of each of the four month seasons. Weight-at-age was estimated by applying the length-weight relationship for a given season, sex and year to the average length-at-age estimate for that season and sex. These weight-at-age estimates were then averaged over years and sex to derive the seasonal weight-at-age estimate for males and females combined.

The weight-at-age estimates showed a characteristic step function (Figure 3). This step function was most pronounced for mature fish. The pattern shows a drop in weight during the first season (Jan. - Apr.) followed by steady increase thorough the summer and fall. Estimates of annual weight-at-age for the stock assessment models were estimated by summing the product of the weight-at-age for a given season and the proportion of the total catch that occurred in each season (Table 4, Table 5)

2.4 Survey Length-at-age

Estimates of mean length-at-age for the hydroacoustic data were calculated using the procedure described for the commercial catch data. In the case of the hydroacoustic data, three strong year classes were studied (1977, 1978, and 1979). Independent growth curves were estimated for each sex.

The growth curves resulting from the non-linear fit show little interannual variability in length at age (Figure 4 a and b). Comparison of the hydroacoustic and fishery mean length-at-age estimates showed the fishery tended to capture slightly larger fish at younger ages and smaller fish at older ages (Figure 5).

2.5 Survey Weight-at-age

Estimates of weight-at-age were calculated for the survey data by applying the annual length-weight relationships for each sex to the estimated mean length-at-age derived from the 1977-1979 year classes. A mean weight-at-age value was calculated for each sex as the average the annual weight-at-age values (Table 6 main text).

Comparison of the weight-at-age estimates derived from the hydroacoustic data and the spring commercial fisheries data showed the fisheries estimate of the weight of older fish was substantially lower than the hydroacoustic estimate (Figure 6, Tables 6 main text).

Table 1. Number of Fish Aged and Lengths Measured for Male Pollock in the Gulf of Alaska

YEAR	SEASON	SHUMAGIN # LEN	SHUMAGIN # AGED	CHIRIKOF # LEN	CHIRIKOF # AGED	KODIAK # LEN	KODIAK # AGED	YAKUTAT # LEN	YAKUTAT # AGED	TOTAL # AGED	TOTAL # LEN
1976	1	-	-	-	-	-	-	-	-	0	0
	2	-	-	-	-	623	217	-	-	217	623
	3	-	-	173	55	-	-	-	-	55	173
1977	1	-	-	-	-	-	-	-	-	0	0
	2	1844	144	1093	108	5602	436	58	5	693	8597
	3	1416	49	1905	58	1133	49	-	-	156	4454
1978	1	145	18	1766	135	-	-	457	129	282	2368
	2	2790	139	4410	371	6329	468	678	122	1100	14207
	3	4597	201	-	-	5203	160	1006	42	403	10806
1979	1	-	-	-	-	-	-	-	-	0	0
	2	2449	65	3198	108	11452	429	557	107	709	17656
	3	2668	62	474	2	5694	180	2261	174	418	11097
1980	1	1761	154	614	85	-	-	-	-	239	2375
	2	5181	192	1751	121	3824	297	613	8	618	11369
	3	3731	175	3269	163	1890	106	778	69	513	9668
1981	1	1876	84	2767	165	-	-	-	-	249	4643
	2	3852	238	2517	148	396	20	44	6	412	6809
	3	6282	174	7257	385	1322	103	244	47	709	15105
1982	1	-	-	18965	483	-	-	-	-	483	18965
	2	24599	534	3418	86	6577	189	-	-	809	34594
	3	12263	171	27386	273	10662	94	-	-	538	50311
1983	1	-	-	36174	717	680	10	-	-	727	36854
	2	20228	254	1917	67	12157	36	-	-	357	34302
	3	11740	137	21780	323	7636	195	-	-	655	41156
1984	1	-	-	68907	374	-	-	-	-	374	68907
	2	-	-	8888	89	9508	132	-	-	221	18396
	3	21470	238	22334	220	29467	311	-	-	769	73271
1985	1	-	-	102827	1001	4149	56	-	-	1057	106976
	2	-	-	-	-	-	-	-	-	0	0
	3	20710	191	-	-	14837	160	-	-	351	35547
1986	1	-	-	21693	188	8153	85	-	-	273	29846
	2	-	-	-	-	-	-	-	-	0	0
	3	7452	42	-	-	2491	188	-	-	230	9943
1987	1	-	-	-	-	-	-	-	-	0	0
	2	-	-	-	-	-	-	-	-	0	0
	3	-	-	-	-	-	-	-	-	0	0
TOTAL		157054	3262	365483	5725	149785	3921	6696	709	13617	679018

Table 2. Number of Fish Aged and Lengths Measured for Female Pollock in the Gulf of Alaska

		SHUMAGIN		CHIRIKOF		KODIAK		YAKUTAT		TOTAL	TOTAL
YEAR	SEASON	# LEN	# AGED	# LEN	# AGED	# LEN	# AGED	# LEN	# AGED	# AGED	# LEN
1976	1	-	-	-	-	-	-	-	-	0	0
	2	-	-	-	-	787	246	-	-	246	787
	3	-	-	145	56	-	-	-	-	56	145
1977	1	-	-	-	-	-	-	-	-	0	0
	2	1793	174	1222	119	7733	530	81	8	831	10829
	3	1494	44	2407	74	1396	70	-	-	188	5297
1978	1	291	44	1818	168	-	-	1128	246	458	3237
	2	4163	193	4608	364	8393	580	730	144	1281	17894
	3	4470	195	690	14	7678	268	1388	38	515	14226
1979	1	-	-	-	-	-	-	-	-	0	0
	2	2148	84	3091	143	16069	491	722	217	935	22030
	3	2144	67	456	6	7294	173	2822	184	430	12716
1980	1	1711	166	531	74	-	-	-	-	240	2242
	2	5211	202	1579	139	5645	379	731	5	725	13166
	3	3142	165	2618	166	2476	140	875	82	553	9111
1981	1	1301	74	1775	174	-	-	-	-	248	3076
	2	4321	284	3118	181	650	26	88	10	501	8177
	3	5149	156	7647	376	1560	125	2989	51	708	17345
1982	1	-	-	10568	496	-	-	-	-	496	10568
	2	26470	566	3312	101	8737	223	-	-	890	38519
	3	13554	180	27815	286	11823	111	-	-	577	53192
1983	1	-	-	22090	628	456	10	-	-	638	22546
	2	25958	358	2339	129	14121	59	-	-	546	42418
	3	10947	119	22452	390	8710	200	-	-	709	42109
1984	1	-	-	61209	307	-	-	-	-	307	61209
	2	-	-	8784	103	13681	158	-	-	261	22465
	3	21462	269	21861	216	37718	370	-	-	855	81041
1985	1	-	-	87590	943	3982	73	-	-	1016	91572
	2	-	-	-	-	-	-	-	-	0	0
	3	21519	214	-	-	15697	177	-	-	391	37216
1986	1	-	-	15236	191	6593	98	-	-	289	21829
	2	-	-	-	-	-	-	-	-	0	0
	3	7603	55	-	-	2806	201	-	-	256	10409
1987	1	-	-	-	-	-	-	-	-	0	0
	2	-	-	-	-	-	-	-	-	0	0
	3	-	-	-	-	-	-	-	-	0	0
TOTAL		164851	3609	314961	5844	184005	4708	11554	985	15146	675371

Appendix 1, Table 3. Summary of generalized linear model of factors influencing length of Gulf of Alaska pollock.

```
                 General Linear Models Procedure

Dependent Variable: Length

Source           DF      Squares        Square     F Value     Pr > F
--------------------------------------------------------------------
Model            25  30960.11497    1238.40460      272.80      0.000

Error           710   3223.06537       4.53953

Corrected Total 735  34193.17934
---------------------------------------------------------------------
R-Square = 0.905712  C.V. = 4.850772  Root MSE = 2.130617
Mean Length = 43.9cm

Source           DF     Type III   Mean Square     F Value      Pr > F
---------------------------------------------------------------------
Year              8    454.91734      56.86467       12.53      0.0001
Season            2   1248.00711     624.00355      137.46      0.0001
Age              12  26965.62143    2247.13512      495.02      0.0000
Sex               1    745.19994     745.19994      164.16      0.0001
Area              2    406.86192     203.43096       44.81      0.0001
```

**** PRELIMINARY REPORT ****
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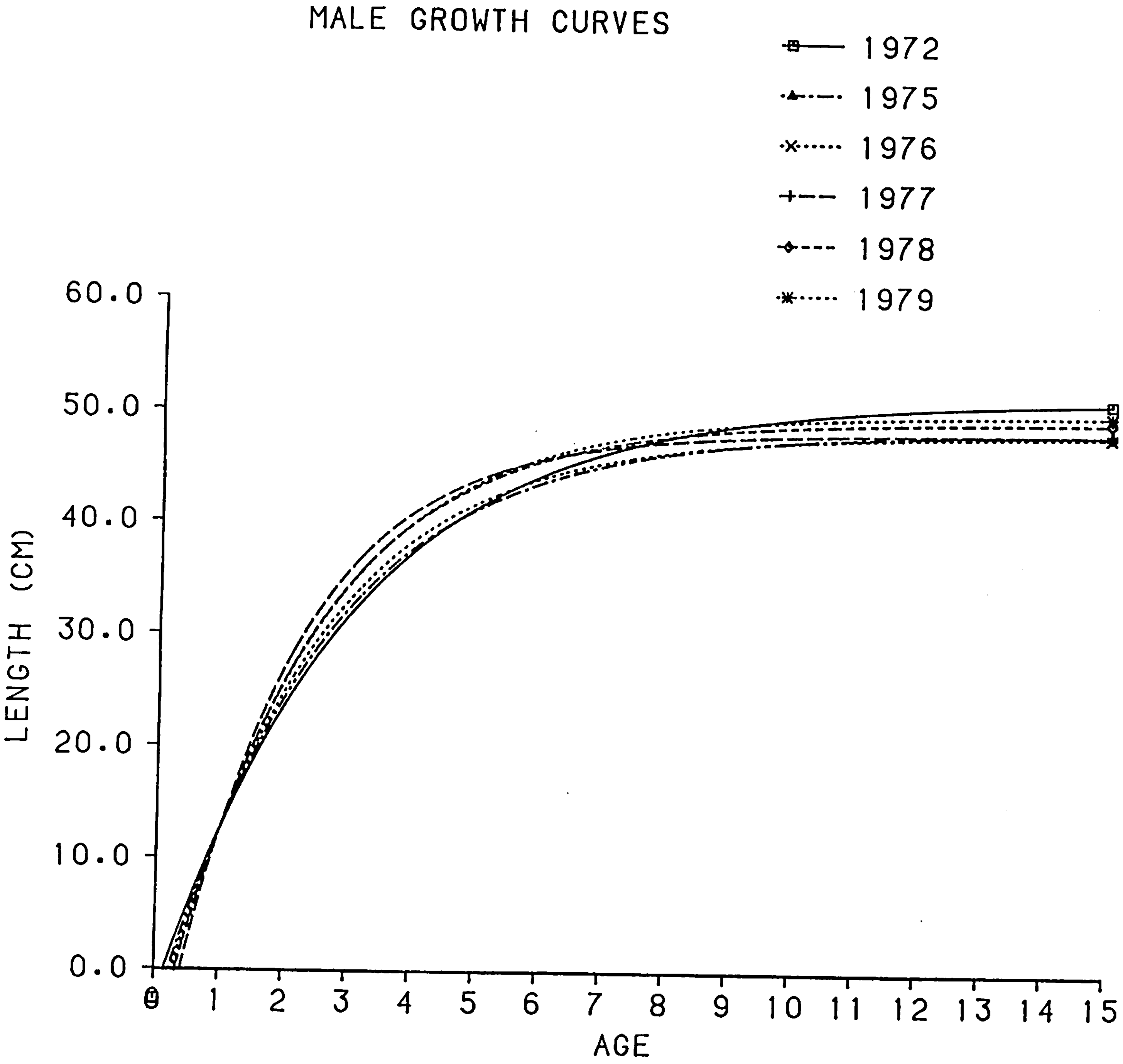
Appendix 1, Table 4. Estimated mean weight-at-age for each season in grams.

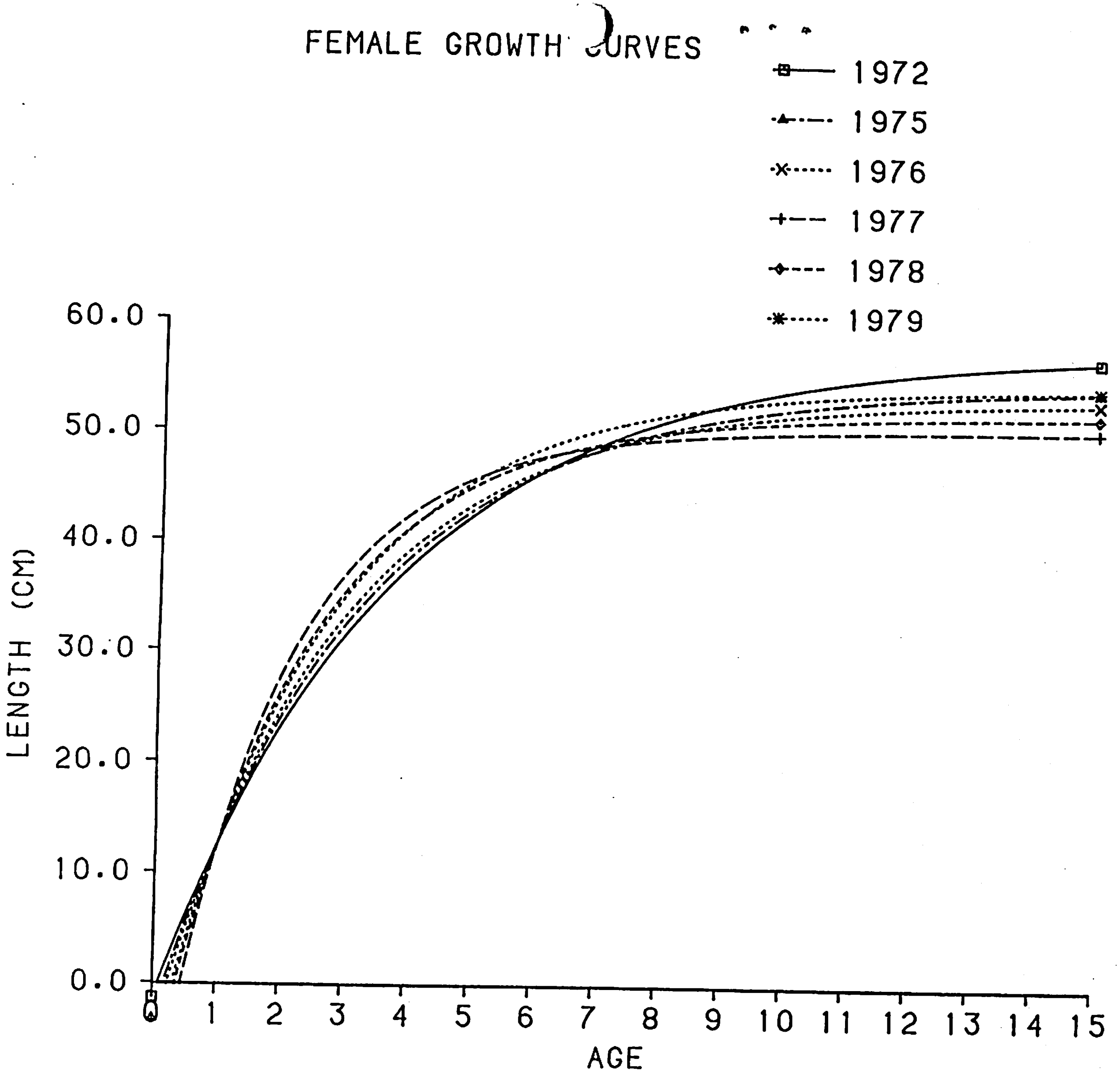
Age	Jan - Apr.	May - Aug	Sep - Dec
1	17.786	60.511	100.660
2	128.439	214.411	273.580
3	294.140	388.487	455.301
4	460.377	542.490	611.960
5	601.550	664.696	734.890
6	711.798	756.406	826.652
7	794.034	823.162	893.276
8	853.805	870.945	940.909
9	896.619	904.842	974.688
10	927.051	928.743	998.558
11	948.670	945.687	1015.407
12	963.859	957.619	1027.308
13	974.661	954.238	1023.769

Appendix 1, Table 5. Annual estimates of weight-at-age derived by applying the relative proportion of the catch that occurred in a given season to the estimated mean weight-at-age for that season.

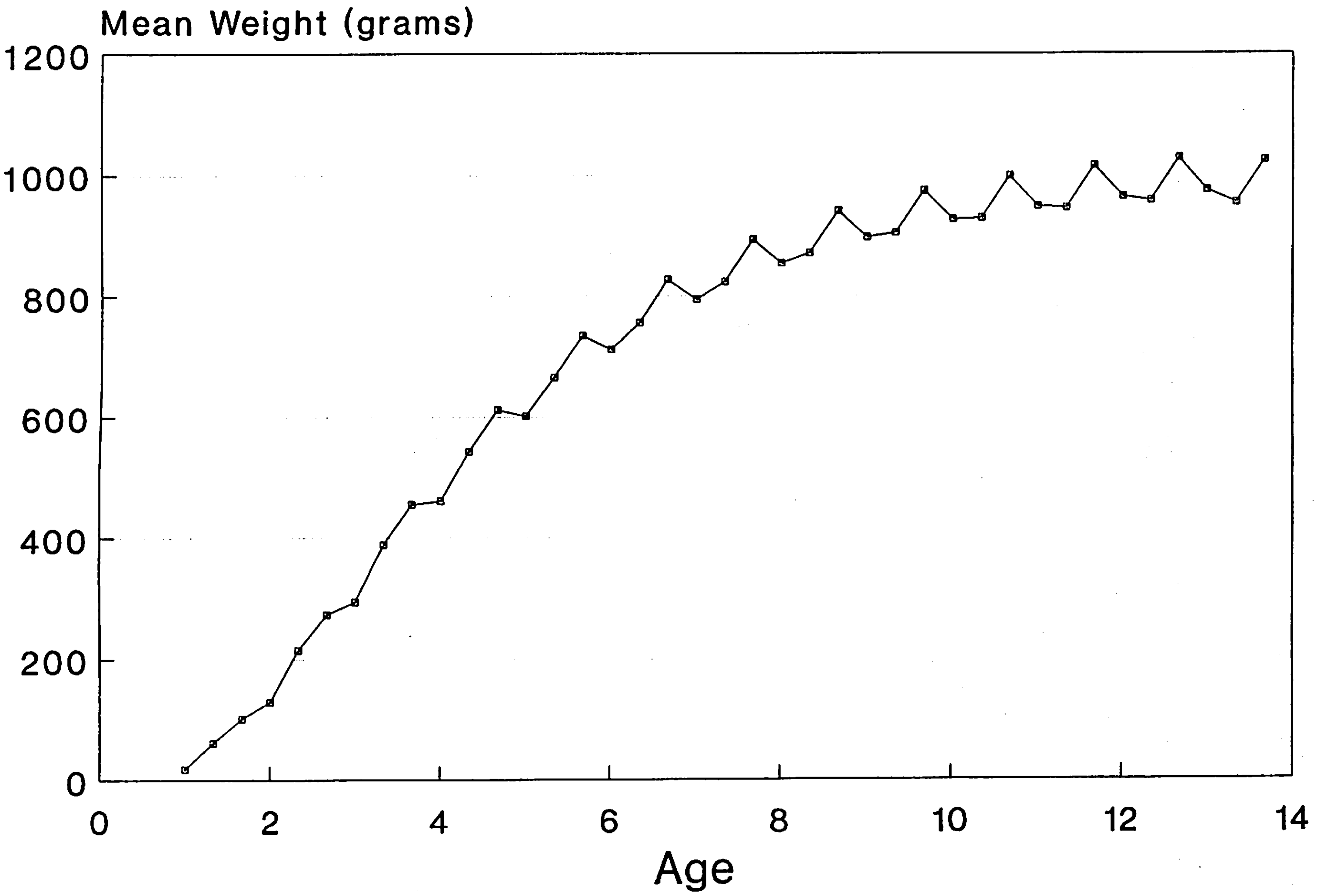
	Year												
Age	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	92.133	62.632	82.884	66.845	69.070	54.081	45.602	48.051	35.959	41.368	87.595	71.476	17.786
2	259.964	211.597	251.641	218.672	221.058	194.412	178.363	182.684	160.287	169.775	251.238	222.755	128.439
3	440.002	386.015	430.563	393.901	396.717	367.154	349.453	354.265	329.501	340.034	430.439	398.837	294.140
4	596.715	544.047	586.374	551.644	555.216	527.620	511.684	516.214	493.624	503.523	588.255	558.682	460.377
5	720.323	671.387	709.200	678.316	682.718	658.738	645.697	649.683	630.778	639.474	713.598	687.790	601.550
6	812.865	767.901	801.093	774.134	779.280	758.945	748.763	752.196	736.955	744.433	807.839	785.831	711.798
7	880.172	838.610	867.889	844.252	850.002	832.738	824.952	827.918	815.754	822.203	876.564	857.762	794.034
8	928.343	889.440	915.672	894.620	900.832	885.955	880.028	882.630	872.852	878.502	925.833	909.522	853.805
9	962.523	925.600	949.564	930.436	936.992	923.893	919.347	921.670	913.677	918.731	960.831	946.373	896.619
10	986.678	951.178	973.498	955.765	962.578	950.771	947.235	949.369	942.664	947.286	985.583	972.473	927.051
11	1003.744	969.297	990.418	973.703	980.692	969.822	967.013	969.004	963.233	967.540	1003.076	990.945	948.670
12	1015.790	982.060	1002.356	986.341	993.456	983.234	980.929	982.821	977.698	981.789	1015.420	1003.963	963.859
13	1012.902	982.290	998.982	986.025	993.684	986.288	986.181	987.181	985.342	988.488	1013.813	1005.300	974.661



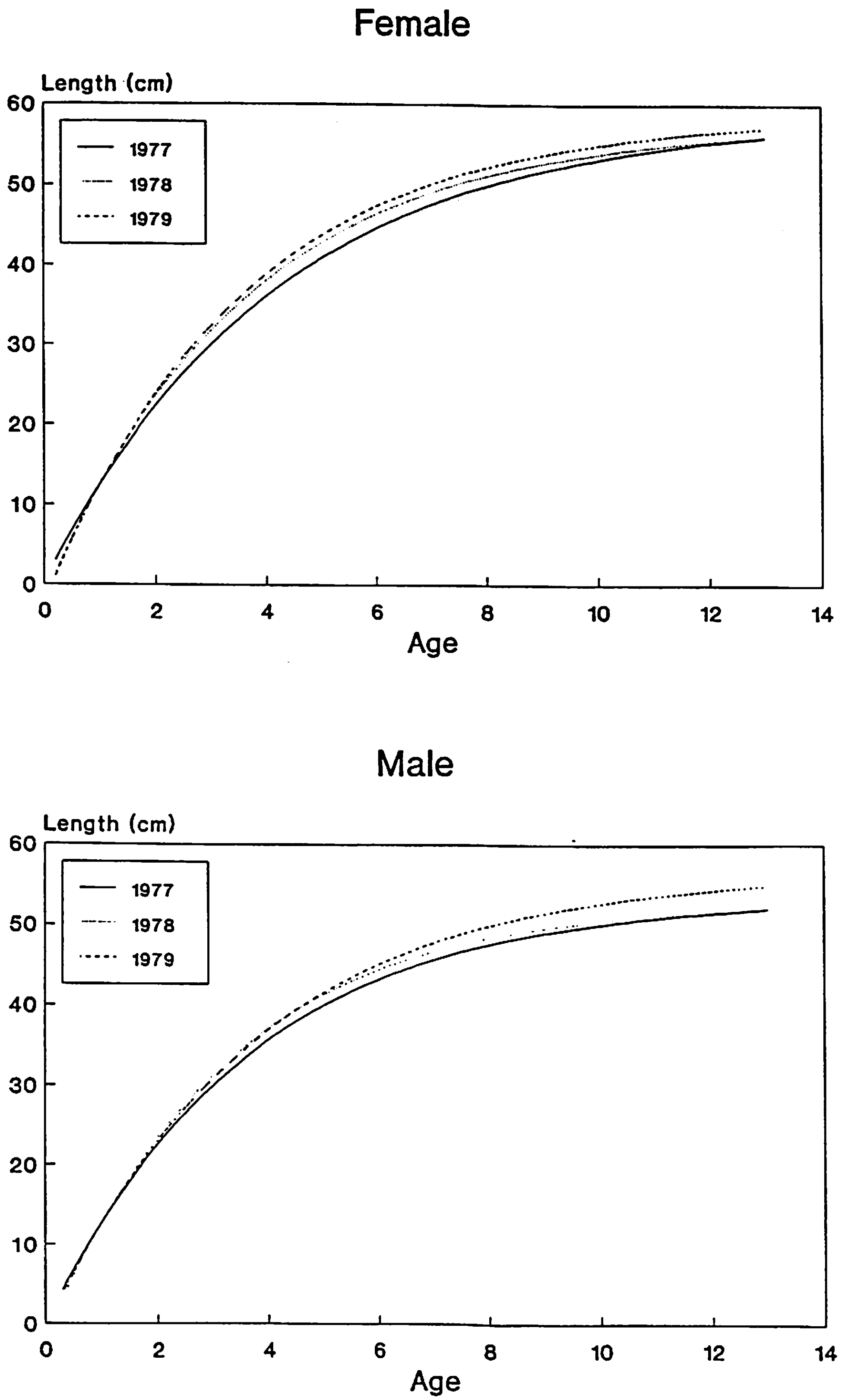
Appendix 1, Figure 1. Estimates of mean length-at-age for males based on commercial fisheries data for the 1972 and 1975-1979 cohorts of walleye pollock in the Gulf of Alaska.



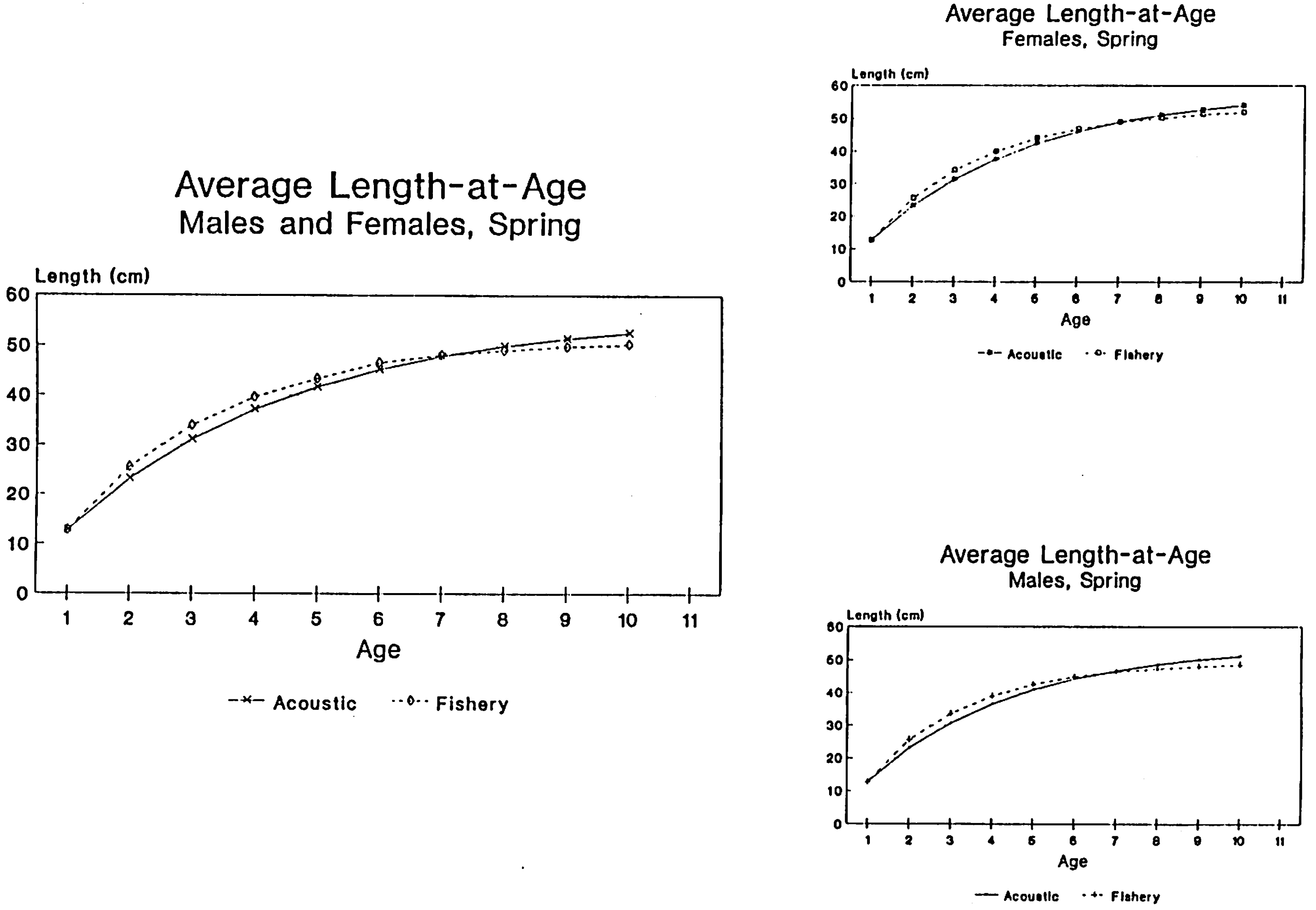
Appendix 1, Figure 2. Estimates of mean length-at-age for females based on commercial fisheries data for the 1972 and 1975-1979 cohorts of walleye pollock in the Gulf of Alaska.



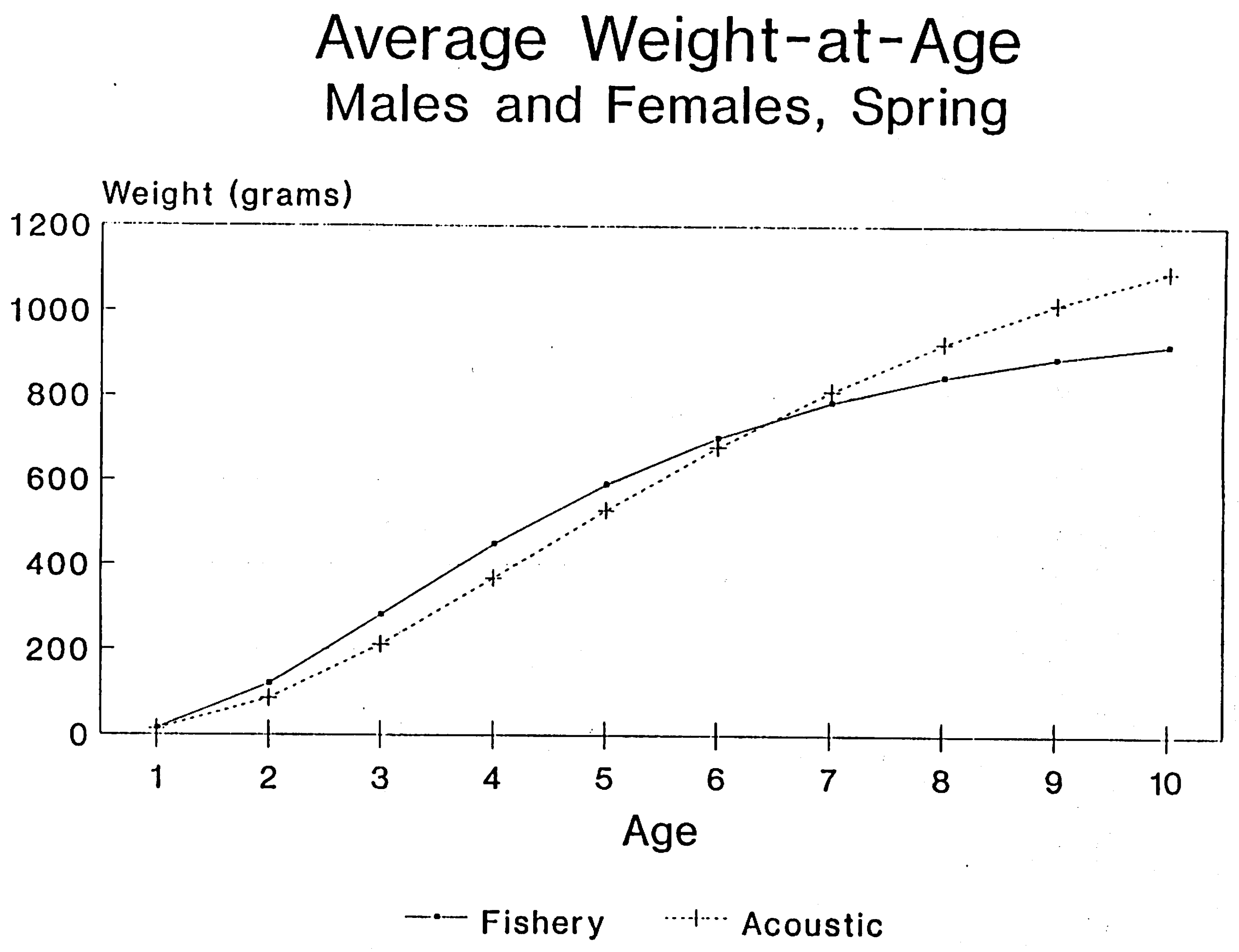
Appendix 1, Figure 3. Seasonal estimates of mean weight-at-age for walleye pollock in the Gulf of Alaska derived by applying observed length-weight relationships to the estimated mean length at age from commercial fisheries statistics.



Appendix 1, Figure 4. Estimates of mean length-at-age for females and males based on hydroacoustic survey data for the 1977-1979 cohorts of walleye pollock in the Gulf of Alaska.



Appendix 1, Figure 5. Comparison of mean length-at-age estimates derived from fisheries and hydroacoustic data.



Appendix 1, Figure 6. Comparison of mean weight-at-age estimates derived from fisheries and hydroacoustic data.

Appendix 2

SYNTHESIS MODEL CALCULATIONS

Recruitment at age 1 is:

$$N_{y1} = R_y$$

where: R is recruitment
N is numbers at age

$$R_y = VR * \frac{SPB / VSPB}{(1 - DD*(1-(SPB/VSPB)))}$$

Numbers at age are:

$$N_{ya} = N_{y-1,a-1} * e^{-Z_{y-1,a-1}}$$

and for the maximum, accumulator age:

$$N_{ya} = N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}$$

where: Z is total mortality

$$Z_{ya} = M_a + \Sigma_t [F_{yat}]$$

where: M is natural mortality
F is fishing mortality

$$F_{yat} = E_{yt} * VA_{at}$$

where: E is the fishing mortality rate for the most available age. E should be proportional to measured fishery effort by a catchability coefficient, Q

$VA_{at} = 1.0$ for at least 1 age, and is ≤ 1.0 in all other ages

Catch at age for the Tth fishery is:

$$C_{yat} = F_{yat} * N_{ya} * (1 - e^{-Z_{ya}}) / Z_{ya}$$
$$= F_{yat} * \bar{N}_{ya}$$

Catch biomass for the Tth fishery is:

$$CB_{yt} = \Sigma_a [C_{yat} * W_{yat}]$$

where: W is body weight

Numbers at age available to the Tth type of survey, conducted near the middle of the year are equal to:

$$S_{yat} = Q_t * VA_{at} * \overline{N}_{ya}$$

where: VA is selectivity at age

Q is a scaling factor (catchability coefficient) defined as the ratio of the sum of the observed survey abundances to the sum of the estimated survey abundances. Q is defined equal to 1.0 for a calibrated survey.

The expected value for the Tth type of survey is:

$$SB_{yt} = Q_t * \Sigma_a [S_{yat} * W_{yat}] \quad \text{if measured in biomass}$$

$$SN_{yt} = Q_t * \Sigma_a [S_{yat}] \quad \text{if measured in numbers}$$

Because of low precision in age determination, C and S are not the best estimates of the expected age composition for the fishery and survey samples. Instead, each must be smeared by the estimated error in age determination:

$$SAMPAGE_{yta's} = \Sigma_a [C_{ytas} * A'@A_{aa's}]$$

Where A'@A is the ageing error matrix.

Likelihoods

For each type of survey abundance we assume a lognormal error, and we approximate the lognormal standard error of each survey estimate by the coefficient of variation calculated for that survey. The lognormal deviation of a given observation is:

$$DEV_{yt} = \log(OSN_{yt}/SN_{yt})$$

The log likelihood of this deviation is (ignoring a constant):

$$L_{yt} = -0.5 * [DEV_{yt} / se_{yt}]^2 - \log[se_{yt}]$$

where: OSN is the observed survey value
se is the survey's coefficient of variation

For survey and fishery age composition, we assume a multinomial error structure:

$$L_{yt} = K * \Sigma_a [p_{yat} * \log(p'_{yat})]$$

where: K is the minimum of 400 and the actual number of fish in the yt sample. This maximum of 400 on K follows Fournier and Archibald (1982) and Methot (1986) and prevents large samples from dominating the result.

p_{yat} is the observed proportion at age in the yt sample

p'_{yat} is the estimated proportion at age in the yt sample. Calculated from the C_{ytas} for fishery samples and the S_{ytas} for survey samples, and the ageing error matrix, A'@A, which defines the distribution of age assignments. It is the SAMPAGE from above converted to proportions.