

Meeting of the Science Group
of the
Scientific and Technical Committee
for the
Convention on the Conservation and Management
of Pollock Resources in the Central Bering Sea

September 3-5, 1997
Gdynia, Poland

Held at
The Sea Fisheries Institute
Gdynia, Poland

Introduction, Agenda, and Participant list ..., 8p.

Attachments

- 1 Fishing trial operations, Poland ..., 3p.
- 2 Trial fishing F/V Vigo, Russia ..., 2p.
- 3 Stock assessment documents, U.S. ..., 139p.
- 4 Biological characteristics, China ..., 13p.
- 5 Mid-water trawl survey results, Japan ..., 2p.
- 6 Kaiyo Maru survey cruise, Japan ..., 7p.
- 7 R/V Pusan 851 trawl survey, Korea ..., 21p.
- 8 Age-1 false ring observation, Japan ..., 4p.
- 9 Trawl survey cruise plan, Japan ..., 2p.

**Meeting of the Science Group of the Scientific and Technical Committee for the
Convention on the Conservation and Management of Pollock Resources in the Central
Bering Sea**

September 3-5, 1997
Gdynia, Poland

Delegations from the People's Republic of China, Japan, the Republic of Korea, the Republic of Poland, and the United States participated in an intersessional meeting of the Parties to the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea, Scientific and Technical Committee's Science Group. The Russian Federation did not participate in the meeting.

1. Welcome Address

2. Election of Chairman and Rapporteur

The group elected Dr. Richard Marasco (USA) as chairman of the meeting. Messrs. Stetson Tinkham and Bill Hines (USA) were appointed as rapporteurs.

3. Adoption of Agenda

Attached to this report are: (1) the revised agenda of the meeting; (2) a list of participants; and (3) a list of reports distributed at the meeting.

4. Opening Statements

5. Pollock Stock Assessment

5.1 Update catch and effort statistics

The data manager (Dr. Wespestad) provided a list and disk file of all the data submitted to him by the Parties. The Parties are asked to review them and submit corrections directly to him.

5.2 Present Results of Trial Fishing

Poland presented their trial fishing results which took place during September 1-11, 1996 in the central Bering Sea (Attachment 1). Pollock was caught only in the northeastern and eastern part of the donut hole. During the cruise, 11 hauls were made of which only six hauls contained pollock. A total of 184 individual fish were caught during the trial fishing operations of which 116 individual fish were taken in one haul. Older pollock dominated the catch (1978-1980 year classes). 1986 and 1989 year classes were also represented in the sample. During the 1995 trial fishing, no 1986 and 1989 year classes were observed. Ages were determined for 50 individual fish from otoliths.

Korea did not conduct trial fishing during 1996.

The United States did not conduct trial fishing during 1996.

Japan did not conduct trial fishing during 1996.

The Russian Federation sent to the meeting a facsimile describing their trial fishing operation which took place during August 16-19, 1997 (Attachment 2). The report indicated no fish was detected during the operation.

The People's Republic of China presented preliminary 1997 trial fishing results. The results showed that the abundance of pollock in the Central Bering Sea from June to August remained low, with catch per haul ranging from several to 60 individuals. The written report will be provided at the second annual conference.

5.3 Review results of the 1996-1997 research cruises

The United States presented results from the echo integration-trawl survey of pollock in the southeastern Aleutian Basin near Bogoslof Island during February - March 1997 (Attachment 3). The abundance estimate for the entire survey area was 392,000 t. The estimate for the Bogoslof Area specified in the Convention was 342,000 t. The U.S. noted that the biomass estimate for 1997 was the lowest since the surveys were initiated.

The People's Republic of China presented a paper, *Some biological characteristics of walleye pollock in the Bogoslof spawning ground during February-March, 1997* (Attachment 4), based on samples collected from the *Miller Freeman* cruise.

Japan presented results of their research cruises conducted in 1996 and 1997 (Attachments 5 and 6 respectively). The 1996 cruise conducted during November 8-17 in the central Bering Sea indicated no pollock was caught and no significant echo signs of adult pollock was observed. The 1997 cruise conducted during May 19-July 4 focused on larval pollock. The size of the larvae observed during the 1997 cruise exceeded the size of those observed during past surveys which took place during 1993 and 1995. The 1997 report also indicates that water temperatures were higher.

The Republic of Korea presented their May-June 1997 cruise report (Attachment 7). The survey was divided into four areas with corresponding biomass estimates: Bogoslof Island Area - 13,274 t; Area between Bogoslof and the central Bering Sea - 17,795 t; Continental Shelf - 157,098 t; and the Donut Hole - 12,096 t.

5.4 Review and update status of the Aleutian Basin stock

5.4.a. Relative and absolute abundance of pollock resources in the Aleutian Basin.

There is insufficient information to estimate the absolute biomass of the pollock resource in the Aleutian Basin directly (Table 1).

However, information from scientific surveys and trial fishing experiments conducted by the Parties indicate that relative abundance of pollock in the Aleutian Basin remains low.

Based on survey information by the Korean R/V *Pusan 851*, a partial estimate of absolute biomass was made for the Donut Hole area. An estimate of 12,096 t (Area D) was made between 17 May and June 12. A research survey conducted by the Japanese stern trawler *Meisho Maru* during November 8-17, 1996 in the Donut Hole area indicated that "no significant echo sign of adult walleye pollock was observed in the international waters"and....there was no pollock catch".

The Polish stern trawler *Acamar* conducted trial fishing during September 1-11, 1996 and indicated that "...pollock was caught only in the north-eastern and eastern part of the Donut Hole.

During the cruise 11 hauls were made of which 6 hauls pollock appeared. All together 184 individuals of pollock were caught". The Russian F/V *Vigo* conducted trial fishing in the Donut Hole area in 1997 (from August 16-19) and indicated that "no fish ...was..detected in the layer from 0 to 500 meters". China also conducted trial fishing in 1997 and will report its final results at the next meeting. The group agreed that more information should be obtained about pollock abundance in the Aleutian Basin.

5.4.b Biomass in the area identified in Annex 1(b).

Only two estimates of absolute abundance of pollock in the Annex 1(b) area were made in 1997 (Table 2). These direct estimates were made from data collected during echo integration-trawl surveys in the Bogoslof Island area by the U.S. and the Republic of Korea. The ROK estimate was for an area slightly larger than that defined in Annex 1(b). Documents presented by the delegations with details on results and methodology are attached to this report.

Table 1. Aleutian Basin pollock biomass estimates

Absolute Abundance estimates: insufficient information to estimate biomass directly
Relative Abundance estimates: Bogoslof survey series (U.S. in 1997) -- low abundance
 Aleutian Basin survey series (Korea in 1997) -- low abundance in eastern and central part of the Aleutian Basin
 Donut Hole survey (Japan in 1996) -- low abundance
 Donut Hole trial fishing (Poland in 1996) -- low abundance
 Donut Hole trial fishing (Russia in 1997) -- low abundance

Table 2. Annex 1(b) Area pollock biomass estimates

<u>Estimate</u>	<u>Dates</u>	<u>Description</u>	<u>Estimate</u>
by U.S.	Mar 1-Mar 10, 1997	spawning	342,000 t
by ROK	May 17 - June 12, 1997	after spawning	13,274 t (for area larger than Annex 1(b) area)

5.4.c. The status of pollock stocks forming foraging accumulations in the central Bering Sea and fishery prospects.

This agenda item was proposed by the Russian delegation. Discussion was deferred.

5.4.d. Coordination of age determination methods for pollock

The Japanese delegation submitted a paper, *False ring observed in the otolith of age 1 walleye pollock collected in the Bering Sea* (Attachment 8), which highlighted the possibility for misinterpreting the first annual ring in relation to false ring formation and suggested a way of avoiding the problem.

Consensus was reached supporting the principle of standardizing age determination using otoliths. A recommendation will be made to the S&T to consider organizing a workshop in 1998 for this purpose. The U.S. has proposed to host a workshop to standardize aging techniques at the Alaska Fisheries Science Center as well as develop a tentative agenda prior to the Second Annual Conference.

6. Review Cooperative Research plans

The United States informed the other parties that surveys in the Bogoslof Area by U.S. vessels on an annual basis may not be possible due to budgetary, manpower and scheduling constraints. The U.S. inquired whether other parties plan on conducting a Bogoslof survey in 1998. All parties, with the possible exception of the Republic of Korea and the Russian Federation (not present), indicated they do not have plans to survey the Area. As an alternative, the U.S. submitted a paper, *Proposed Assessment Procedures for Aleutian Basin Pollock Utilizing Biennial Surveys in the Bogoslof Island Area* (contained in Attachment 3), for the other parties to consider and discuss at the S&T meeting prior to the Second Annual Conference. The paper proposes alternative methods to determine biomass estimates if the U.S. or any other party cannot conduct the Bogoslof survey.

The Republic of Korea stated that they have not determined their research cruise schedule for 1998.

Japan indicated they will not conduct research cruises in the Bogoslof Area in 1998, but consideration is being given to conducting a Bogoslof research cruise in 1999. The Japanese delegation also presented their intention to conduct research in the central Bering Sea during November 1997 (Attachment 9).

The People's Republic of China indicated no research cruises are planned for 1998 as their scientists will be dedicated to supporting trial fishing operations. Beyond 1998, China will contemplate cooperative research cruises pending funding considerations.

There was consensus that cooperative research planning is necessary to maximize all resources. The Scientific and Technical Committee will address this issue prior to the Second Annual Conference.

7. Review Trial Fishing Plans

The Republic of Poland indicated they will conduct trial fishing operations with one vessel during mid-September of 1997; as well as tentative plans to conduct trial fishing in 1998.

The Republic of Korea will advise the other parties of their intentions to conduct trial fishing during the Second Annual Conference.

Japan indicated they will not conduct trial fishing in 1997 and 1998.

The People's Republic of China will conduct trial fishing in 1998 utilizing two vessels. The intended timing of the trial fishing operations will be during June-August.

The United States indicated it will not conduct trial fishing and suggested that all parties submit their written trial fishing plans at the Second Annual Conference.

8. Observer Plans

All parties participated in an Observer Training Program hosted by the U.S. during March 24-29, 1997.

9. Other Business

Deferred discussion of the Russian Federation proposal to host a Pollock Symposium in Magadan during February 1998.

The United States informed all parties that logistical information regarding the Second Annual Conference is available.

The issue of future meetings of the Science Group was discussed. Each Party was asked to consider the issue before the Second Annual Conference. The issue will be referred to the S & T Meeting for decision.

Agenda

1. Welcome address
2. Election of chairperson and rapporteur
3. Adoption of agenda
4. Opening statements
5. Pollock stock assessments
 - 5.1. Update catch and effort statistics
 - 5.2. Present results of trial fishing
 - 5.3. Review results of 1996/1997 research cruises
 - 5.4. Review and update status of pollock stocks
 - a. Relative and absolute abundance of pollock resources in the Aleutian Basin
 - b. Biomass of pollock in the area identified in Annex Part 1(b)
 - c. The status of pollock stocks forming foraging accumulations in the central Bering Sea and fishery prospects
 - d. Coordination of age determination methods for pollock
6. Review cooperative research plans
7. Review trial fishing plans
8. Observer plans
9. Other business
10. Review of reports to the annual conference
11. Closing statements

LIST of PARTICIPANTS

China

Xin Deli Bureau of Fisheries, Ministry of Agriculture, Beijing
Gu Dingfang Shanghai Deep Sea Fisheries Co., Shanghai
Zhao Xianyong Yellow Sea Fisheries Research Institute, Qingdao

Japan

Kiyoshi Wakabayashi National Research Institute of Far Seas Fisheries
Akira Nishimura National Research Institute of Far Seas Fisheries
Yoshitsugu Shikada Marine Resources Division, Fishery Agency of Japan

Poland

Andrzej Kiedrzyń Ministry of Transport and Maritime Economy, Warsaw
Jerzy Janusz Sea Fisheries Institute, Gdynia
Ireneusz Wojcik 'DALMOR' S.A., Deep Sea Fishing Co., Gdynia
Stanislaw Kasperak 'GRYF' Deep Sea Fishing Co., Szczecin
Jan Horbowy Sea Fisheries Institute, Gdynia
Ryszard Smolik 'ODRA' Deep Sea Fishing Co., Swinoujscie

Republic of Korea

Yang, Won Seok National Fisheries Research & Development Institute
Choi, Seok Gwan National Fisheries Research & Development Institute

United States

Loh-Lee Low Alaska Fisheries Science Center, National Marine Fisheries Service
Stetson Tinkham Department of State
William Hines National Marine Fisheries Service, Alaska Region
Jimmie Traynor Alaska Fisheries Science Center, National Marine Fisheries Service
Vidar Weststad Alaska Fisheries Science Center, National Marine Fisheries Service
Doug Eggers Alaska Department of Fish and Game
Richard Marasco Alaska Fisheries Science Center, National Marine Fisheries Service

List of Attachments

1. Report on Polish fishing trial operations on pollock in the international waters of the Bering Sea in 1996. (Jerzy Janusz, Poland).
2. Results of trial fishing by the Russian *F/V Vigo*. (Unofficial translation of Russian fax submitted from the Russian Federation to the Science Group meeting).
3. Pollock stock assessment documents submitted by the United States Party. (contains 5 documents).
 - i. Preliminary Bering Sea-Aleutian Islands walleye pollock assessment for 1998.
 - ii. Bering Sea-Aleutian Islands walleye pollock assessment for 1997.
 - iii. Gulf of Alaska walleye pollock assessment for 1997.
 - iv. Walleye pollock abundance in the southeastern Aleutian Basin near Bogoslof Island during February-March, 1997
 - v. Proposed assessment procedures for Aleutian Basin pollock utilizing biennial surveys in the Bogoslof Island Area.
4. Some biological characteristics of walleye pollock in the Bogoslof spawning ground during February-March, 1997. (Xianyong Zhao, China)
5. Cruise results of mid-water trawl survey on pelagic pollock in the international waters of the Bering Sea, 1996. (FAJ, Japan)
6. Outline of the *Kaiyo Maru* survey cruise in 1997 (May 19, 1997-July 4, 1997). (Akira Nishimura, Japan).
7. Results from the 1997 echo integration and midwater trawl survey for the Bering Sea walleye pollock by the R/V *Pusan 851* (NFRDI, Korea).
8. False ring observed in the otolith of age 1 walleye pollock collected in the Bering Sea. (Akira Nishimura, Japan).
9. Cruise Plan for Mid-water Trawl Survey on Pelagic Pollock in the International Waters of the Bering Sea, 1997. (FAJ, Japan).

**REPORT ON POLISH FISHING TRIAL OPERATIONS
ON POLLOCK IN THE INTERNATIONAL WATERS
OF THE BERING SEA IN 1996**

Jerzy Janusz
Sea Fisheries Institute,
Kollataja 1, 81-332 Gdynia, Poland

The trial fishing operations in the international waters of the Bering Sea (Donut hole) were carried out by the Polish fishing trawler m/t ACAMAR in the period from September 1 through September 11, 1996 in accordance with the intention indicated during First Annual Conference (Nov. 13-15, 1996, Moscow). The purpose of the trial cruise of the Polish vessel was to determine the geographical distribution of pollock in the international waters of the Bering Sea and to collect the biological data.

Results

Acoustic observations started in the north part of the Donut hole. The hydroacoustic trackline of the vessel is presented in Fig. 1.

During all the time of research, at the depth of about 250 m., the echograms indicated the presence of a layer of thickness about 60 m. In the control hauls it was observed that the layer consisted mainly of Myctophids and also jellyfish, squids and Pacific lamprey were observed.

Pollock was caught only in the north-eastern and eastern part of the Donut hole. During the cruise 11 hauls were made of which only in 6 hauls pollock appeared. All together 184 individuals of pollock were caught. The sex ratio was nearly 1:1 (93 males and 91 females).

The length of pollock (fork length) ranging from 42 to 62 cm, with the majority between 52-58 cm (Fig.2). The mode for males was 54 cm, and for females 58 cm.

The age of pollock determined on the basis of 68 fish is presented in figure 3. In the samples pollock at age 16-18 years old (1978-1980 year classes) dominated. The younger pollock at age 10 and 7 years old (1986 and 1989 year-classes) was also represented in the sample. In the 1995 trial catches such a young year classes were not observed.

Gonads maturity indicated that majority of pollock (83%) had their gonads in the resting stage (2-nd stage according to the 8-grade Maier scale), 9% in spent stage (8-th stage) and 8% in the developing stage (3-th stage).

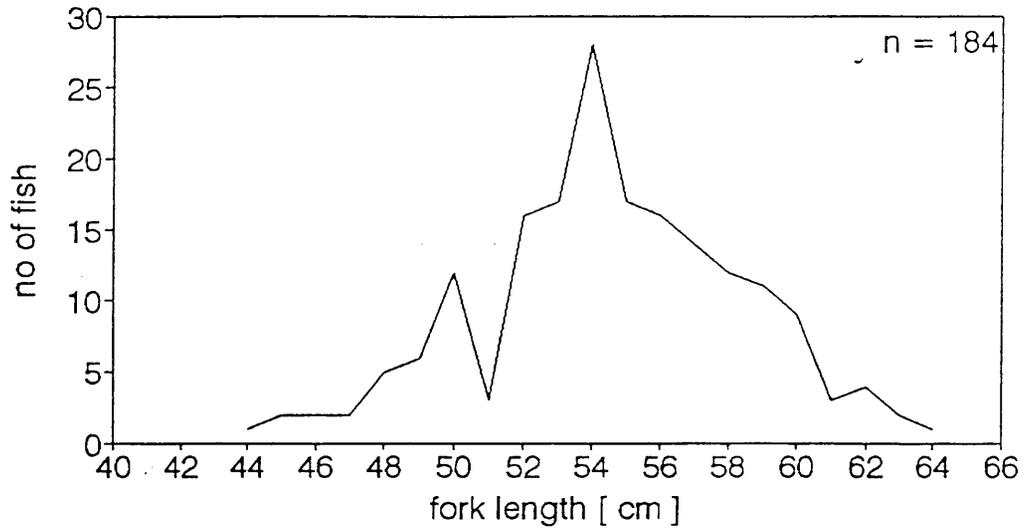


Fig. 2
Length distribution of pollock during Polish trial catches,
(September 1996)

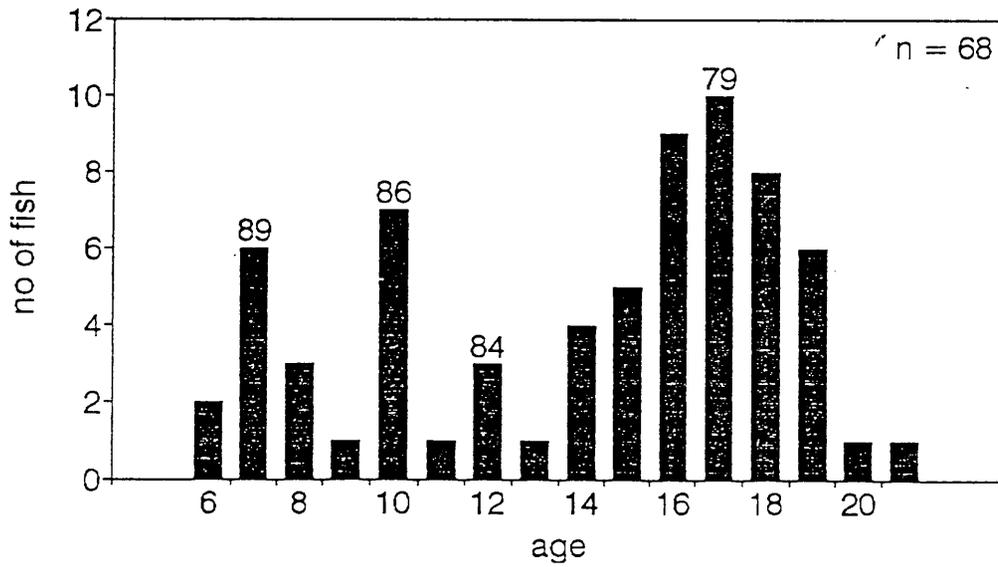
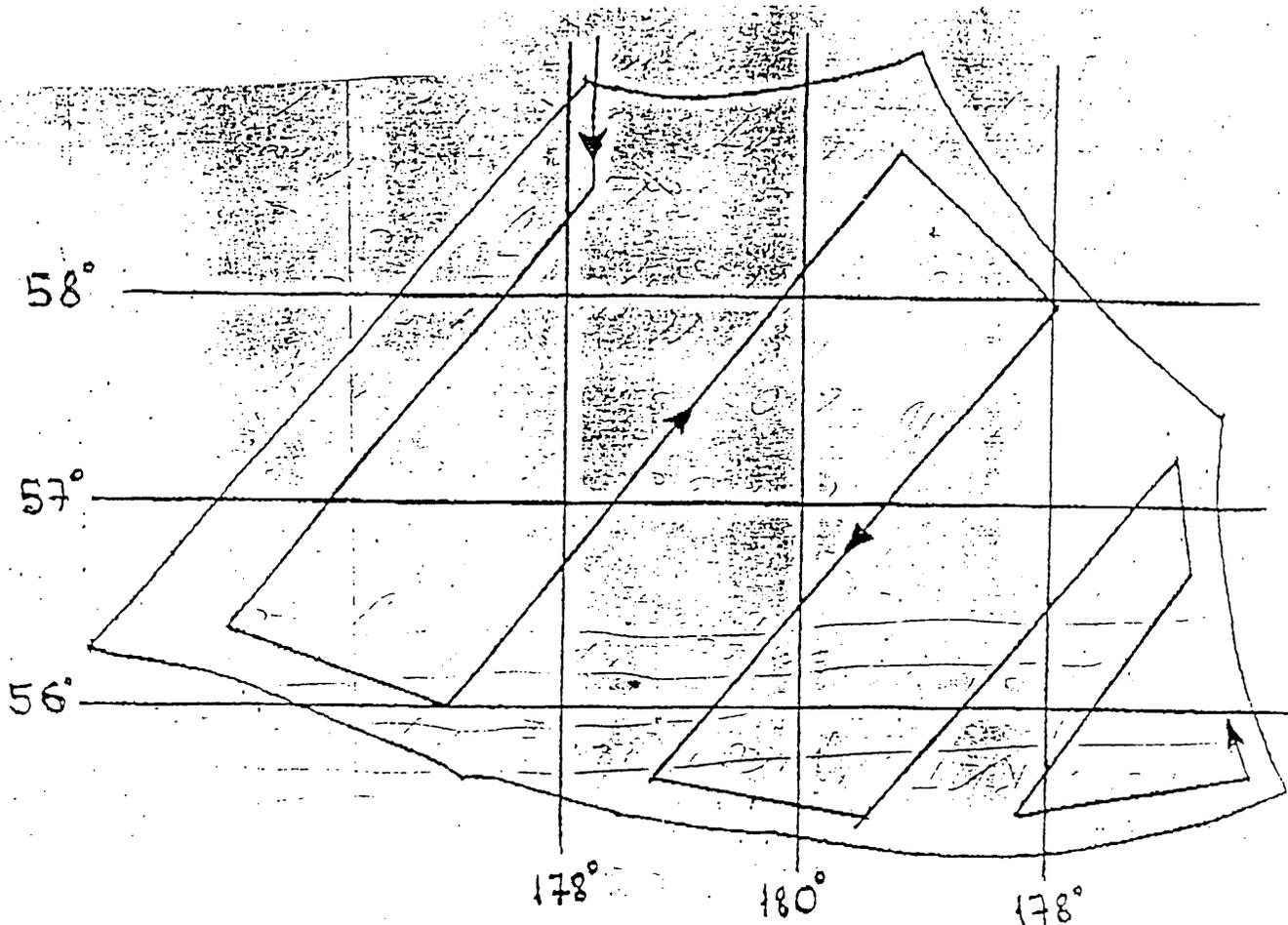


Fig. 3
Age distribution of pollock during Polish trial catches,
(September 1996)

Submitted (by fax) from Russian Federation to the Science Group meeting
(Sea Fisheries Institute, 3-5 Sept. 1997, Gdynia, Poland)

*Unofficial translation
from Russian language*

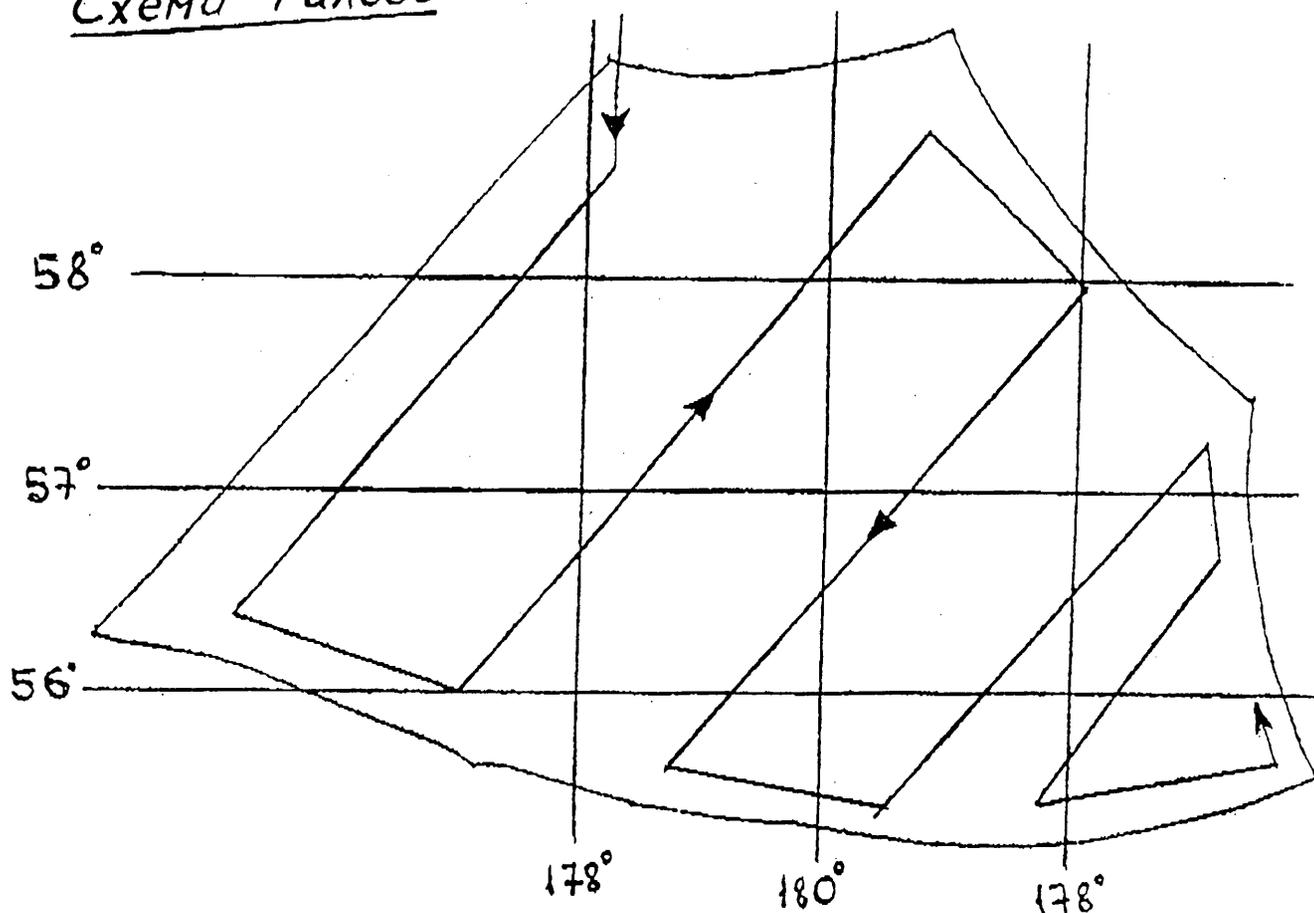
Diagram of hydroacoustic profiles



In the period from 16 till 19 August (inclusive) this year has been performed reconnaissance in the area 51 of the Bering Sea directed for finding the pollock concentrations, by F/V VIGO.

During hydroacoustic research the SIMRAD equipment has been used: the SIMRAD 240 sonar which has the possibility of penetration for remote distance, as well as the SIMRAD ES 381 type - the typical commercial fishfinding vertical echosounder.

During this research no fish has been detected in the layer from 0 to 500 metres. There were no records on the echosounding monitor of Deep Scattering Layer.

Схема галсов

В период с 16 по 19 августа включительно на МРКТ "ВИГО" были выполнены поисковые работы в 51-ом районе Берингова моря на предмет обнаружения скоплений минтая.

При гидроакустическом поиске применялась аппаратура фирмы "Simrad": Simrad - 240 - сонар кругового обзора с большой дальностью действия и Simrad ES 381 - промысловый эхолот.

За этот период наблюдений наличие каких-либо рыбных объектов в слое 0-500 м. отмечено не было, полностью отсутствовали записи - "ЗРС"

Pollock Stock Assessment Documents

Submitted by
the United States Party

for the
**Meeting of
The Science and Technical Committee**

**Convention on the Conservation and Management
of Pollock Resources in the Central Bering Sea**

September 3-4, 1997
Gdynia, Poland

Table of Contents

Document	Page
1. Preliminary Bering-Sea-Aleutian Islands Walleye Pollock Assessment for 1998.....	1
2. Bering-Sea-Aleutian Islands Walleye Pollock Assessment for 1997.....	2
3. Gulf of Alaska Walleye Pollock Assessment for 1997.....	50
4. Walleye Pollock abundance in the Southeastern Aleutian Basin near Bogoslof Island during February-March, 1997.....	114
5. Proposed Assessment Procedures for Aleutian Basin Pollock Utilizing Biennial Surveys in the Bogoslof Island Area.....	133

Preliminary
 Bering Sea-Aleutian Islands
 Walleye Pollock
 Assessment for 1998

Preliminary estimates are provided for eastern Bering Sea and Aleutian Islands pollock based on last years SAFE projections. A complete pollock survey (bottom trawl and midwater hydroacoustic) were again carried out in 1997. The results of these surveys need to be incorporated in assessment models to obtain a final 1998 ABC recommendation. A bottom trawl survey was also conducted in the Aleutian Islands in 1997, these results will also be utilized to estimate the Aleutian Islands ABC.

The preliminary 1988 eastern Bering Sea pollock ABC is 1.1 million t. The 1998 SAFE document projected an increasing trend in pollock based on slightly above average recruitment in 1999-2000. Preliminary observations from the 1997 surveys indicate that the 1996 year-class may extremely strong, therefore pollock abundance may increase much more than projected.

The Aleutian Islands preliminary estimate is the same as the 1997 estimate 17-28 thousand t. For the Bogoslov Island area 1998 ABC is estimated to be 58.8 thousand t based on a projection of the 1997 survey biomass estimate of 342 thousand t.

Summary of ABC Estimates, 1996-1998 by area.

Eastern Bering Sea	ABC Recommendation			
	1996	1997	1998	F
ABC at $F_{0.40}$	1.29 million t	1.13 million t	1.10 million t	.30
Aleutian Islands				
$F_{0.40}$	26,200 t	17,413 - 28,000 t	17,413 - 28,000 t	0.38
Bogoslov Island				
Biomass	682,000 t	342,000 t	280,000 t	
Yield $F_{0.40}$	286,000 t	115,000 t	58,801 t	0.27

Projected Age 3+ biomass (million t), catch (million t), age 3 recruits (billions) and exploitation rates at $F_{0.1}$ and $F_{.35}$ using cohort analysis estimates of abundance.

	Year	Age 3+ Biomass	Catch	Age 3 Recruits	F	Exploitation
$F=F_{0.40}$	1998	5.928	1.011	4.851	0.300	17%
	1999	6.861	1.036	7.952	0.300	15%
	2000	7.668	1.158	7.603	0.300	15%

Exploitation = Catch in biomass / Jan 1. Biomass

Recruits estimated from spawner-recruit relationship, 1998-2000.

Bering Sea-Aleutian Islands
Walleye Pollock
Assessment for 1997

Vidar G. Wespestad, James Ianelli, Lowell Fritz, Taina Honkalehto, Gary Walters

Summary

Pollock stocks in the eastern Bering Sea and Aleutian Islands (Excluding the central Bering Sea and the Bogoslov Island Region) are expected to be in the 6 million t range in 1997. The eastern Bering Sea biomass in 1996 was estimated to be 5.51 million t. by survey, and 6.1-6.2 million t. by age-structured models.

Summary of ABC Estimates for 1997 by area.

Eastern Bering Sea	TAC	ABC Recommendation		
Fishing Level	1996	1996	1997	F
F _{0.40}	1.19 million t	1.29 million t	1.10 million t	0.30
F overfishing			1.98 million t	0.46
Aleutian Islands				
F _{0.40}	35,600 t	26,200 t	17,413 - 28,000 t	0.38
F overfishing		At (F _{35%})	24,000 - 38,000 t	0.57
Bogoslov Island				
F _{0.40}	1,000 t	286,000 t	115,000 t	0.27
F overfishing			157,500 t	0.37

The 1996 assessment incorporates catch data from the 1995 eastern Bering Sea, and Aleutian Islands area fisheries. Also, included are biomass estimates and age composition estimates from the 1996 eastern Bering Sea bottom trawl and hydroacoustic-midwater trawl surveys (Appendix A). These data are used in catch-age models to estimate the current population size and project 1997 biomass and ABC estimates. A catch-age model is used to provide a fisheries based estimate of abundance for the Aleutian Islands area. A new catch-age model is applied for the eastern Bering Sea pollock population, and a detailed paper on the methodology is included (Appendix B). The results of a 1996 Bogoslov Island hydroacoustic-midwater trawl survey is included as Appendix C.

1.1

INTRODUCTION

This year's assessment updates the Bering Sea pollock assessment through the 1995 fishing year. Throughout the history of pollock fishing in the eastern Bering Sea the catch has averaged 1.1 million t, and has ranged from a minimum of 0.2 million t in 1964 to a maximum of 1.9 million t in 1972. Since the advent of the U.S. EEZ in 1977 the annual average eastern Bering pollock catch has been 1.2 million t and has ranged from 0.9 million in 1987 to 1.6 million t in 1991 while stock biomass has ranged from a low of 4-5 million to highs of 12-14 million t. The stability of the eastern Bering Sea pollock stock is remarkable in light of trends in most Asian pollock stocks and North Atlantic gadoid stocks which have collapsed or undergone strong fluctuations in catches and abundance. It appears that eastern Bering Sea pollock catches in the range of recent years are sustainable, and within the productive capacity of the stock and stock fluctuations observed over the history of the fishery.

This assessment updates the 1995 assessment by including results from 1996 eastern Bering Sea hydroacoustic and bottom trawl surveys, the 1996 Bogoslof hydroacoustic survey, and data from 1995 and 1996 pollock fisheries.

1.1.1

STOCK STRUCTURE

The stock structure of Bering Sea pollock is not well defined. In the U.S. portion of the Bering Sea pollock are considered to form three stocks for management purposes. These are: eastern Bering Sea which consists of pollock occurring on the eastern Bering Sea shelf from Unimak Pass to the U.S.-Russia Convention line; Aleutian Islands Region which encompasses the Aleutian Islands shelf region from 170°W to the U.S.-Russia Convention line; and Central Bering Sea -Bogoslov Island pollock, which are thought to be a mixture of pollock that migrate from the U.S. and Russian shelves to the Aleutian Basin around the time of maturity.

In the Russian EEZ pollock are considered to form two stocks, a western Bering Sea centered in the Gulf of Olyutorski, and a northern stock located along the Navarin shelf from 171°E to the U.S.-Russia Convention line. The northern stock is believed to be a mixture of eastern and western Bering Sea pollock with the former predominant.

1.2

CATCH HISTORY

Eastern Bering Sea

From 1954 to 1963, pollock were harvested at low levels in the Eastern Bering Sea and directed fisheries began in 1964. Catches increased rapidly during the late 1960s and reached a peak in 1970-75 when catches ranged from 1.3 to 1.9 million t annually (Figure 1.1). Following a peak catch of 1.9 million t in 1972, catches were reduced through bilateral agreements with Japan and the

USSR.

Since implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1977, catch quotas have ranged from 950,000 t to 1.3 million t. In 1980 United States vessels began harvesting pollock and by 1987 they were able to take 99% of the quota. Since 1988 the harvest has been taken exclusively by U.S. vessels. The history of the catch (in thousand t) since implementation of the MFCMA is presented in Table 1.1:

Aleutian Islands

Catches in the Aleutian region have always been less than those in the Eastern Bering Sea. The catch increased from 1980 to 1984 as a result of increased foreign effort and then decreased in recent years as the foreign fishery was phased out. Joint venture landings increased in 1986 through 1988, but JV catch for those years was about half of the average foreign catch for 1980 through 1985. In 1989 the catch declined to 16 thousand t, but increased to 79 thousand t in 1990 and 1991, and decreased to 54 and 26 thousand t in 1992 and 1993, respectively. Catch increased to 63 thousand t in 1995 and decreased to 26 thousand t in 1996.

Aleutian Basin

Foreign vessels begin fishing in the mid-1980's in the international zone of the Bering Sea (commonly referred to as the 'donut hole'). The donut hole is entirely contained in the deep water of the Aleutian Basin and is distinct from the customary areas of pollock fisheries, namely the continental shelves and slopes. Japanese scientists began reporting the presence of large quantities of pollock in the Aleutian Basin in the mid-to-late 1970's, but large scale fisheries did not occur until the mid-1980's. In 1984, the donut hole catch was only 181,000 t (Figure 1.1, Table 1.2). The catch grew rapidly and by 1987 the high seas catch exceeded the pollock catch within the U.S. Bering Sea EEZ. The extra-EEZ catch peaked in 1989 at 1.45 million t and has declined sharply since then. By 1991 the donut hole catch was 80% less than the peak catch, and data for 1992 and 1993 indicate very low catches (Table 1.2). A fishing moratorium was enacted in 1993 and only trace amounts of pollock have been harvested from the Aleutian Basin by resource assessment fisheries.

The Bogoslov fishery occurs in deep water off the Eastern Bering Sea shelf. In 1987 the catch was 377,000 t, but decreased to 88,000 t in 1988 and decreased further, to 36,073 t, in 1989 (Figure 1.1). Estimates for 1990 indicate that catch in the Bogoslof area increased to 152 thousand t and to 265 thousand t in 1991. The catch in Area 518 has primarily been composed of fish from the 1978, 1982, 1984 and 1989 year-classes, similar to the catch from the rest of the Aleutian Basin, suggesting that harvests came from the same group of fish. Directed pollock fishing was prohibited in the Bogoslof area in 1992 and only a small amount of pollock was taken as by-catch in other fisheries.

Prior to the mid-1980s, very few pollock were harvested in off-shelf areas of the U.S. EEZ and the small amount taken was included in status of stocks analyses for the Eastern Bering Sea area. However, since 1987, catches in the Bogoslof Island area (area 518) have not been included in the

Eastern Bering Sea analysis because the age composition and growth characteristics of pollock in area 518 are different from that observed in catches from the Eastern Bering Sea shelf, but similar to the pollock harvested in the "Donut Hole". The pollock catch from the Bogoslof Island area is included with the catch from the "Donut Hole" and other areas of the Aleutian Basin.

Pollock Fishery Catch and Length-Frequency Distributions, 1994-96

A-Season: Since the closure of the Bogoslof management district (518) to directed pollock fishing in 1992, the A-season pollock fishery on the eastern Bering Sea (EBS) shelf has been concentrated primarily north and west of Unimak Island, as it was in 1996 (Figure 1.2). In 1994 and 1995, the bulk of the A-season fishery occurred in this area, with little along the 100-m depth contour stretching northwesterly toward the Pribilof Islands (Figure 1.3). The largest pollock were generally caught in the Unimak area, with smaller fish to the northwest; this pattern is best shown in 1996 (Figure 1.2). Mean pollock weight per haul increased from 1994-96 in each A-season, due primarily to the individual growth of the 1989 year-class (Figures 1.2 and 1.4). On the southeast shelf (east of 172°30'W longitude), the modal length caught by the fishery also increased from 44 cm in 1994 to 47 cm in each of 1995 and 1996; very few fish larger than 60 cm were observed on the SE shelf (Figure 1.4).

In both the 1994 and 1995 A-seasons, there was limited fishing for pollock on the shelf NW of 172°30'W longitude. In each year, the modal length observed on the SE shelf was also found on the NW shelf. However, the length distribution was much broader to the NW, with significant numbers of pollock greater than 60 cm present, as well as a mode in the high 20 cms. Pollock in the high 20 cms in Jan-Mar were likely 3-year-old fish (in 1994, the 1991 year-class; in 1995, the 1992 year-class).

In the Aleutian Islands (AI), the fishery has fished further west each A-season from 1994-1996. In 1994 (Figure 1.2, 1.3), almost all of the AI pollock fishery was conducted in the eastern subarea (541) north of the Islands of Four Mountains, Amukta Pass, and Seguam Island, as well as a small area north of Atka Island. Much of this catch was likely "basin" fish, particularly since most of the fishery was conducted pelagically over deep water (much of > 500 m). In 1995, the pelagic catches in the region from the Islands of Four Mountains west to Seguam Island decreased, perhaps reflecting the decline in the "basin" stock. The fishery instead moved west in 1995 to the area north of Atka Island and to a small area north of Kanaga Island around Bobrof Island. These two areas were exclusively used in 1996, with no landings in the eastern portion of subarea 541. Despite the use of different areas by the fishery each year in the Aleutian A-season, the length-distribution of the catches were similar in 1994-96, with modes at 53-55 cm and very few fish smaller than 40 cm.

B-Season: After 1992, the B-season fishery has been conducted to a much greater extent east of 170°W than it was prior to 1992 (Figure 1.5).. To some degree, this is a reflection of the implementation of the Catcher Vessel Operational Area (CVOA) in the B-season as an exclusive operating area for shoreside-delivery boats. However, it also reflects the distribution of pollock by size, and the desire of the fleet to catch pollock larger than 35 cm. Not only are younger pollock

generally found on the northwest shelf, but individual growth rates are also lower there. In both 1994 and 1995, the dominant length mode caught on the northwest shelf (43 cm and 41 cm, respectively) was smaller than that caught to the southeast (47 cm and 48 cm, respectively), and there was in each year a smaller mode at 25 and 32 cm, respectively (Figure 1.4). To avoid these smaller pollock, the offshore fleet tended to concentrate north of the CVOA and east of the Pribilof Islands.

Only in 1994 were pollock targeted in the Aleutian Islands from August-December. An area within Amukta Pass (and to a lesser extent near the Islands of Four Mountains) was used by the fishery (Figure 1.3). It should be noted that the pollock fishery utilized a more inshore area during the late summer and fall than was used during the A-season, yet the length-distributions of the pollock caught were very similar (Figure 1.4).

Fisheries Catch Data

Observation of catch indicates that pollock discard is of significant magnitude that must be taken into account in estimation of population size and forecasts of yield. Observer length frequency observations indicated that discarded pollock include both large and small pollock. Without specific information on the size distribution of discarded pollock it is assumed that the size distribution of discarded pollock is similar to that of the retained catch. Discard data as compiled by the NMFS Alaska Regional Office have been included in estimates of total catch since 1990.

Pollock catch in the eastern Bering Sea and Aleutian Islands by area from observer estimates of retained and discarded catch, 1990-1994 are shown in Table 1.3. Discarded pollock since 1990 has ranged from a high of 11% of total pollock catch to a low of 7.7% in 1990 and 1994. Pollock discards in 1994 were 7.7%, slightly lower than in 1993, and decreased further in 1995 to 7.4%.

1.3 **CONDITION OF STOCKS**

1.3.1 Resource Surveys

Bottom Trawl Surveys

Trawl surveys have been conducted annually by the AFSC to assess the abundance of crab and groundfish in the Eastern Bering Sea. Until 1975 the survey only covered a portion of the pollock range. In 1975 and since 1979, the survey was expanded to encompass most of the range of pollock. Table 1.4 shows the biomass estimated from a standardized area from these surveys. Since 1984 the biomass estimates have been relatively high and showed an increasing trend through 1990 (Table 1.4). Between 1991 and 1995 the bottom trawl survey biomass estimate has ranged from 4.3 to 5.5 million t. The 95% confidence intervals indicate the estimates are not significantly different between years (Figure 1.6).

The 1996 AFSC crab/groundfish bottom trawl survey was conducted from June 5- July 28. The standard survey area, outlined in Figure 1.7, covered 463,000 km² using 355 stations. An additional 20 stations above the northwest corner of the survey covered 34,000 km² (Figure 1.7).

The distribution of walleye pollock was similar to previous years with major concentrations along the Alaska Peninsula, around the Pribilof Islands, and in the northwest corner of the survey area (Figure 1.7). The abundance estimate for the bottom trawl survey was 3,200,000 t with a 95% confidence interval of +/- 26% based on sampling variability alone. An additional estimate of 170,000 t was made for the small area outside the standard survey to the northwest. This is the lowest biomass estimate for the bottom trawl portion in the standard survey area since 1981.

Size and age distributions for the entire area surveyed are shown in Figure 1.8. As is normally the case, ages 2 and 3 are not well represented in bottom trawl samples. Other than age 1 fish, ages 5 through 7 dominated the catch. Age readers noted a particular problem in ageing fish 6 through 8 years with this year's sample. Therefore, the relative proportions of these fish may not represent the true distribution well.

Aleutian Islands

Survey effort has not been as extensive in the Aleutian Region as in the eastern Bering Sea. Bottom trawl surveys were conducted in 1980, 1983, 1986, 1991 and 1994. Recently, biomass estimates for the Aleutian Islands Region have been recalculated using revised estimates of survey area (Harrison 1993; Ronholt, Teshima and Kessler 1994). Table 1.5 shows the trend of pollock biomass from the triennial Aleutian Islands groundfish surveys. Two estimates are shown, one for the Aleutian Islands Region proper, and one for the Aleutian Islands Region and the Unalaska-Umnak area (Unimak Pass to Islands of Four Mountains). Historically, the total biomass from the Aleutian Islands and from the Unalaska-Umnak area have been combined as the Aleutian Islands biomass estimate. The rationale for including the Unalaska-Umnak area was that the area was not surveyed as part of the eastern Bering Sea survey, and the biomass should be accounted for in yield determination, so therefore the biomass was included in the Aleutian Islands estimates.

The biomass trend in Table 1.5 shows that pollock abundance peaked in 1983 and has been decreasing since that time. This trend is similar to the eastern Bering Sea. The biomass of pollock in the Aleutian Islands Region in 1994 was distributed among areas as follows:

Area	Range	Biomass	Catch
West	(177E-170E)	15,153 t	20 t
Central	(177E-177W)	33,326 t	559 t
East	(170W-177W)	37,895 t	58,058 t
Total	(170W-170E)	86,374 t	58,637 t
Unalaska-Umnak	(170W-165W)	65,070 t	51,584 t

The greatest biomass occurs in the eastern Aleutians and along Unalaska-Umnak islands in the eastern Bering Sea region. These biomass estimates do not include mid-water pollock and therefore represent an unknown portion of total biomass. The biomass in this area may be greater if the on-bottom/off-bottom distribution is similar to that of the eastern Bering Sea.

It is likely that most of the pollock population in the Aleutian Islands Region is interrelated with the eastern Bering Sea, and is likely not a separate stock. Pollock distribution in the 1994 survey showed that the largest concentrations are located in the eastern Aleutian Islands (Figure 1.9.). Length frequency distributions from the 1994 bottom trawl survey are similar between areas of the Aleutian Islands, and similar to the length frequency distributions from the 1994 Bering Sea bottom trawl survey taking into account differences in growth rates (Figure 1.10).

Biomass (Combination Hydroacoustic-Bottom Trawl) Surveys

In addition to bottom trawl surveys, hydroacoustic surveys have been conducted to estimate the midwater component of the eastern Bering Sea shelf pollock stock. The surveys are conducted triennially with the first occurring in 1979 (Traynor and Nelson 1985). The use of both techniques provides biomass estimates of both demersal and pelagic pollock (Table 1.4).

The most recent hydroacoustic-midwater trawl pollock survey was carried out 18 July-2 September, 1996 westward from north of Port Moller, Alaska to the U.S./Russia convention line. The trackline consisted of 5138 nautical miles (nmi) of north-south transects beginning at about 160° 30' W long. and proceeding westward to 179° W long. Transect lines were spaced about 20 nmi apart and were designed to coincide with lines of groundfish trawl stations sampled by demersal survey vessels. A detailed report of the survey is included as Appendix A.

Pollock were distributed throughout the survey area. The highest densities of pollock were observed from St. Matthew Island west to the U.S./Russia convention line. Moderate densities were observed between about 163°-166° W long. north of the Alaska peninsula and Unimak Island. A few isolated areas of very high pollock density were observed around the Pribilof Islands and between there and St. Matthew. Pollock biomass estimated for the entire eastern Bering Sea survey area in summer 1996 was 2.31 million tons.

Pollock ranged in fork length (FL) from 12 to 71 cm. Preliminary abundance estimates by length revealed dominant length modes at 17 cm and 36 cm north and west of the Pribilof Islands area, and around 50 cm near the Pribilof Islands and to the south and east. Fish northwest of the Pribilof Islands were, on average, smaller than fish near the Pribilof Islands and east. Nearly all fish less than 35 cm were observed northwest of the Pribilof Islands, with most near the U.S./Russia convention line. Pollock abundance by age in the northwest area was quite different than that from the southeast areas, reflecting the pattern observed in the population length distribution. In the northwest, the 1992 year class (age 4) dominated, followed by the 1995 year class (age 1). South and east of the Pribilof Islands, the 1989 year class (age 7) was most

numerous.

The eastern Bering Sea bottom trawl survey estimates exhibited an increasing trend during the 1980s, but were relatively stable from 1991 to 1995. This may be due, in part, to age related distributional changes within the pollock population. Results from combined bottom trawl and hydroacoustic surveys, which more fully sample the population, have shown that older pollock are more vulnerable to bottom trawls than younger pollock:

Year	Bottom trawl survey	Midwater survey	Total	Near bottom biomass (%)	Catch Mean Age
Biomass estimates in tonnes					
1979	3,204,300	7,457,573	10,661,873	30.0	3.9
1982	4,039,635	4,901,000	8,940,635	46.0	4.5
1985	5,522,200	4,798,500	10,320,700	53.5	5.6
1988	7,511,200	4,675,400	12,186,600	61.6	5.4
1991	5,109,000	1,360,000	6,469,000	79.0	7.2
1994	4,976,960	2,761,616	7,738,576	64.3	5.1
1996	3,204,000	2,306,000	5,510,000	60.0	N/A

In 1979 when a large proportion of the population consisted of age groups 1 to 3, most of the pollock were located in mid-water. However, as the population, composed primarily of 1978 and 1982 year-classes, aged through the 1980s, the bottom trawl proportion increased. The proportion in the bottom trawl decreased in 1994 due to the large numbers of 1989 and 1992 year-class pollock in mid-water. The ratio of demersal to pelagic pollock remained similar between 1994 and 1996, with between 60-64% of the biomass distributed near bottom.

The following table shows age-specific exploitation rates, given by the ratio of catch-at-age numbers to triennial hydroacoustic-bottom trawl estimates of numbers-at-age. The table results indicate that removals have been small relative to the survey estimates of population size. These results are similar to ratios of catch and catch-age estimates of population size shown in section 1.3.2:

Pollock catch-at-age relative to survey numbers-at-age estimates by year and the average for the years shown.

Age	Year						Average
	1979	1982	1985	1988	1991	1994	
1	0%	0%	0%	0%	0%	0%	0%
2	1%	0%	4%	1%	1%	1%	1%
3	11%	3%	4%	9%	3%	4%	6%
4	26%	10%	7%	7%	30%	14%	16%
5	30%	12%	8%	15%	20%	22%	18%
6	43%	17%	10%	11%	25%	22%	21%
7	25%	14%	18%	18%	24%	27%	21%
8	27%	15%	27%	13%	8%	11%	17%
9	29%	19%	31%	7%	17%	8%	18%
10	22%	13%	34%	7%	5%	7%	15%
11	17%	4%	75%	7%	24%	5%	22%
12	18%	52%	100%	16%	13%	5%	34%
13	49%	66%	88%	13%	21%	9%	41%
14	18%	40%	224%	18%	0%	2%	50%
Age 3-14	23%	19%	45%	10%	14%	10%	20%

1.3.2 Age-Structured Models

Eastern Bering Sea

Two age-structured population dynamics models have been employed to assess pollock: traditional cohort analysis model (Pope 1972); and a Bayesian age structured analysis. The models were "tuned" using auxiliary information from the triennial hydroacoustic and bottom trawl surveys.

The instantaneous natural mortality rates (M) used in the age-structured analyses are $M = 0.9$ for age 1, $M = 0.45$ for age 2, and $M = 0.3$ for ages 3 and older (Wespestad and Terry 1984).

Cohort Analysis

The cohort analysis model tuning requires three assumptions: 1) the relative age compositions of pollock obtained from the combined hydroacoustic-bottom trawl surveys are unbiased estimates of the age composition of the age 3+ population, 2) interannual changes in survey abundance are proportional to actual abundance changes in the population, and 3) the index of age 1 pollock in the bottom trawl survey is proportional to year-class strength, even though age 1 is not fully recruited to the survey gear.

Under the first assumption the terminal F values were adjusted until the proportional 1996 age composition from the model was identical to the estimated proportional age composition observed in the 1996 survey as shown below:

Age	Numbers (billions)	F	1996 Age Composition	
			Model	Survey
3	0.916	0.0003	9.32%	6.89%
4	3.055	0.021	31.11%	31.93%
5	1.620	0.075	16.49%	17.20%
6	1.739	0.18	17.71%	17.33%
7	1.571	0.35	15.99%	15.53%
8	0.461	0.22	4.69%	4.57%
9	0.135	0.2	1.38%	1.09%
10	0.113	0.08	1.15%	1.05%
11	0.077	0.065	0.78%	0.73%
12	0.125	0.1	1.28%	1.40%
13	0.002	1	0.02%	0.43%
14	0.005	0.8	0.05%	1.86%
15	0.002	2	0.02%	0.00%

The 1996 F values were then adjusted so the total number of age 3+ pollock in the cohort analysis approximated the trend in age 3+ pollock in the 1979-96 triennial trawl-hydroacoustic surveys.

Year		1979	1982	1985	1988	1991	1994	1995
Age 3 +	Model	7.18	21.99	23.03	16.07	8.52	12.33	8.02
Numbers	Survey	10.42	22.73	23.52	22.72	7.38	11.46	9.09

Terminal F for year-classes prior to the 1978 year-class was set equal to the average of the 3 preceding ages in the same year.

The cohort analysis was also fit using the solver function of Excel to obtain a variance minimization solution. An objective function consisting of three summed variance terms: the sum of squared differences of 1) the estimated population relative age composition and survey relative age composition in triennial survey years; 2) the age 3 recruitment estimate and the age 1 recruitment index; and 3) the relative change in age 3+ estimated population numbers and the relative age 3+ survey numbers in triennial survey years. A weight of 0.1 was placed on the relative age composition, which placed greater emphasis on the population trend and recruitment index. The relative age composition was given a lower weight because of the concentration of catch and biomass in the 1990 and 1989 year-classes in 1994. It was felt that the relatively lower number of older fish in conjunction with aging error forced poor model fits with a greater level of emphasis on relative age composition.

The value of the above objective function was minimized by solving for a terminal year (1994) F, a terminal year selectivity, and terminal F for the 1979 and 1978 year-classes. For terminal year-classes prior to 1978 the terminal F was the average of the 3 preceding ages in the same year. The

selectivity function is:

$$S = \alpha \times age_i^\gamma e^{-\beta \times age_i}$$

where:

$$\alpha = \left(\frac{\beta}{\gamma}\right) \gamma e^\gamma$$

$$\gamma = S_{\max} + \beta$$

The variables S_{\max} , β , terminal year F, and terminal F for the 1978 and 1979 year-classes were estimated by the model.

Estimated catch-at-age, numbers-at-age, biomass-at-age, and fishing mortality from cohort analysis, 1979-1994, are shown in Tables 1.6, 1.7, 1.8 and 1.9.

Bayesian age-structured analysis (BASA)

(Analysis performed by J. Ianelli)

The catch-at-age data and survey information was also analyzed based on recommendations from an external review committee. The primary differences include: 1) hydroacoustic survey data are modeled separately from the bottom trawl survey; 2) the bottom trawl survey age composition estimates are used from age 1 - 15+ for the years 1982-1994, and 1996 (1995 age composition data were not yet available); 3) a robust likelihood method is applied and evaluated; and 4) a comprehensive statistical treatment of available data is made. The manner of dealing with fishery selectivity variability is explicitly modeled in this analysis. The model details and results are presented in Appendix B.

Aleutian Islands

The NPFMC SSC requested that the data for the Aleutian Islands region be examined for the potential of an age structured stock assessment analysis. Geographically, there are large questions as to the appropriateness of defining pollock caught in the "Aleutian Islands" region as being from a separate stock. Clearly the potential that a very large fraction of removals from this area are from the EBS stock makes interpretation of results presented below questionable. With these caveats in mind, we present a simple age-structured model for this region.

Survey estimates of pollock in the Aleutian Island region are available from 1980, 83, 86, 91, and 1994. These values were used to tune a forward model with numbers and catch at age modeled in the usual way (i.e., instantaneous mortality rates and the Baranov catch equation). We assumed that the survey estimates represented the biomass of age 3 and older pollock. Catch biomass estimates for this area are presented in Table 1.1. An asymptotic selectivity form was estimated and assumed to be constant over time. Within the model, the annual fishing mortality rates were estimated so that

the predicted catch biomass matched the observed catch biomass precisely (CV = 1%). Catch-at-age data were available for the years 1978-82, 1984-85, 1991-1995 (Table 1.10). These were fit assuming a multinomial likelihood function with an assumed sample size of 200 individuals per year. Annual recruitment and initial age composition were also parameters to be estimated.

The model fit to the survey biomass estimates tends to be biased high (Figure 1.11). This may be due to interaction between the following assumptions: 1) survey estimates are unbiased and have the same catchability in all years; 2) the survey selectivity at age is fixed at 1.0 for all ages greater than 3 years; 3) fishery selectivity is asymptotic and constant over time with respect to the population; and 4) that the survey area covers the entire area of the stock. For reasons previously discussed, several of these assumptions probably contribute to model mis-specification. Model fits to age composition data also were poor (Figure 1.12). The index of recruitment shows similar strong year-classes observed for pollock in the EBS with 1989, 84, and 82 showing some prominence (Figure 1.13). The selectivity estimate suggests that the fishery in this region has harvested primarily fish older than 6 years of age (Figure 1.14). This is substantially older than what has been observed in the EBS and Gulf of Alaska fisheries.

1.3.3. Stock Trends and Current Exploitable Biomass

Eastern Bering Sea

Current exploitable biomass estimates (ages 3 and older) derived from catch-age models and survey abundance estimates suggest that the abundance of eastern Bering Sea pollock remained at a fairly high level from 1982-88, with estimates ranging from 13 to 15 million t. Peak biomass occurred in 1985 and declined to about 6-7 million t in 1991, then increased to over 8 million t in 1993. Results from the most recent combined bottom trawl-hydroacoustic survey (1996) estimate the biomass for all ages as 5.51 million t. Catch-age models estimate 1996 biomass near 6 million t, comparable to survey results.

All estimates show a strong increase in biomass from 1979 to the mid-1980's that resulted from a very strong 1978 and relatively strong 1982 and 1984 year-classes recruiting to the fishable population (Table 1.4, Figure 1.6). From 1985-86 to 1991-92 the fishable stock declined as these above average year-classes decreased in abundance with age and were replaced by weaker year-classes. In 1992 an upturn in abundance began with the recruitment of a strong 1989 year-class. The 1989 year-class increased abundance to above average levels. Biomass appears to have been decreasing since 1993. Except for the 1992 year-class, the year-classes now entering the fishery, or entering in the near future are expected to be below average, and a declining population trend is expected beyond 1997. A scheduled 1997 combined bottom trawl and hydroacoustic-midwater trawl survey will provide additional data on the abundance of the year-classes that will be recruiting to the exploitable population in 1998-2000.

The results of catch-age models indicate that pollock have been exploited relatively lightly compared to other gadid stocks. Catch rates on ages 3 and older have varied from 7 to 27% since 1979 as shown below:

	Bio 1	Bio 2	Catch	E 1	E 2
1979	4.51	4.61	0.94	21%	20%
1980	5.76	6.10	0.96	17%	16%
1981	10.63	11.35	0.97	9%	9%
1982	12.03	12.52	0.96	8%	8%
1983	13.17	13.65	0.98	7%	7%
1984	12.87	13.33	1.09	8%	8%
1985	14.23	14.62	1.14	8%	8%
1986	12.95	13.41	1.14	9%	9%
1987	13.11	13.23	0.86	7%	7%
1988	11.97	11.80	1.23	10%	10%
1989	10.02	9.57	1.23	12%	13%
1990	7.97	7.38	1.46	18%	20%
1991	6.67	5.89	1.61	24%	27%
1992	8.47	8.46	1.44	17%	17%
1993	8.61	8.87	1.39	16%	16%
1994	8.08	8.46	1.36	17%	16%
1995	7.58	7.93	1.26	17%	16%
1996	6.12	6.20	1.1	18%	18%
Average	9.71	9.85	1.17	14%	14%

Bio 1 = Jan 1. biomass estimates from Cohort Analysis using least squares fit

Bio 2 = Jan 1 biomass estimates from Cohort Analysis tuned to survey trend and 1994 survey age composition.

E 1 = Catch/Bio 1

E 2 = Catch/Bio 2

The reason for the low levels of exploitation appear to be partially due to the tendency toward producing conservative biomass estimates in the most recent assessments. This is shown in Figure 1.15 which show retrospective analyses for Cohort Analysis and the Bayesian age structured analysis. The trend over time is similar in both models, where it can be seen that biomass was grossly underestimated in the mid 1980s, and somewhat less in more recent years.

Aleutian Islands Region

The 1994 Aleutian Island bottom trawl survey estimated biomass at 151 thousand t. Survey biomass in this region peaked in 1983 and has shown a declining trend since then. However, the Aleutian

Islands Region has usually followed the same trend as the eastern Bering Sea. The 1994 survey indicated a strong mode of either age 1 or 2 pollock; 1992 or 1993 year-class. These fish should have entered the fishable population in 1996 and have stabilized or increased pollock biomass in the Aleutian Islands.

Catch-age data for an Aleutian Islands region assessment are limited. Analysis is also confounded by the question of stock definition. The available data suggest that the operational "stock" for this region is currently on the order of 100 - 220 thousand tons (for age 3+), and harvests in the most recent year have been on the order of 30 thousand tons, then continued harvests at around that level represents about a 20% harvest rate. This has been shown to be an appropriate level for pollock in other areas. Since the selectivity seems to be on older individuals, this rate would also be conservative on a per-recruit basis.

Aleutian Basin-Bogoslof Island Area

Aleutian Basin pollock spawning in the Bogoslof Island area have been surveyed annually since 1988. The following survey results show that population decline occurred between 1988 and 1994 and then increased in 1995 with the movement of pollock from the 1989 year-class to the Bogoslof Island area. Abundance of all ages increased between 1994 and 1995, but then decreased between 1995 and 1996. The trend between these years suggest that the 1995 estimate may have been an over estimate.

Bogoslof Island hydroacoustic survey biomass estimates, 1988-1995

Biomass (million t)								
<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>
2.4	2.1	--	1.3	0.9	0.6	0.54	1.1	0.68

Pollock harvested in the Bogoslof Island fishery (Area 518) are of a noticeably different age composition than those taken on the eastern Bering Sea shelf (Wespestad and Traynor 1989). Age data from the 1990 fishery show that the majority of fish harvested were from the 1978 year-class and the rest from the 1982 year-class, two strong year-classes. Length frequency data from the 1993 survey indicate that the 1982 and 1984 year-classes predominate in the Bogoslof area, along with some remaining 1978 year-class pollock. The 1994 survey also found that some age 5 pollock of the strong 1989 year-class have begun to move into the Aleutian Basin. In 1995 it appears that the 1989 year-class had continued to recruit to the Bogoslof area, which has led to the sharp increase in abundance. 1996 saw a drop in abundance and an increase in mean length, which suggests that there was no significant recruitment between 1995 and 1996. A full report of the 1996 survey is contained in Appendix C.

1.4

RECRUITMENT TRENDS

Estimates of recruitment were obtained from the annual groundfish surveys for age 1 pollock (fish smaller than 20 cm). These recruitment estimates were compared with age 3 pollock estimated from catch-age models. The comparison indicated a linear relationship which was used to project age 3 numbers in 1997-1998 (Figure 1.16, Table 1.11). Beyond 1998 a spawner-recruit relationship, derived from a non-linear regression of cohort analysis estimates of age 3 numbers and total number of mature pollock, was used. The relationship is:

$$R = 2.545 S e^{D \cdot 13575}$$

From catch-age models, the estimate of the median number of age 3 pollock entering the population between 1979 and 1996 is 4.5 billion. Age 3 recruitment has varied from a high of 18-21 billion in 1981 to .1-.9 billion in 1996. Table 1.11 shows that, recruitment has been above average in 5 of 16 years, 1979-1996. The strong year-classes have been the extremely strong 1978 year-class and the strong 1982, 1984, and 1989 year-classes.

The survey age 1 index indicated that the 1992 year-class was above average. However, tuned catch-age results are mixed. Synthesis results indicate that it is slightly above average, while cohort analysis results indicate that it is below average. The 1996 combined bottom trawl-hydroacoustic survey found the 1992 year-class to be the most abundant year-class, comprising 23% of the total biomass. The 1992 year-class was abundant near the U.S.-Russia Convention Line. There is evidence that it is continuously distributed into the Russian EEZ, where it may have been subject to heavy fishing.

Survey age 1 estimates indicate that the 1993, 1994, and 1995 year-classes may be below average (Table 1.11, Figure 1.16). Based on these recruitment estimates it is anticipated that exploitable pollock abundance will decrease in 1997 and 1998 as these weaker year-classes enter the fishable population.

For the Aleutian Island and Bogoslof areas, data are insufficient to estimate recruitment accurately.

1.5

BIOLOGICAL PARAMETERS

1.5.1 Natural Mortality, Age of Recruitment, and Maximum Age

Wespestad and Terry (1984) estimated $M=0.45$ for age 2 and $M=0.30$ for ages 3 and older. These latter values have been used since 1982 in catch-age models and forecasts and appear to approximate the true rate of natural mortality for pollock.

Pollock are commonly taken at age 2 by the commercial fishery, but are considered to be too small for effective utilization. Some age 3 fish are commonly utilized by the fishery. Full recruitment is not until age 4, however catch-age modeling indicates that the age 4 fish still have a partial

selectivity less than 1.0, particularly in recent years.

The oldest recorded pollock is a 31 year old specimen taken in 1990, however the average life span of pollock is not that long. The average age of pollock in the catch since 1964 is 4.8 years old.

1.5.2 Length and Weight at Age

Length, weight, and age data have been collected extensively for pollock. Length-age and weight-length relationships for each strata of pollock samples indicate that there are growth differences by sex, area, and year-class. General characteristics of length-weight-age relationships and other fishery parameters are given below:

Age	Natural mortality rate	Mean length (cm)			Mean weight (kg) EBS	Selectivity 1977-1994 Average	Maturity
		Area 51	Area 52	EBS			
2	0.45	29.8	25.9	28.2	0.170	5%	1%
3	0.3	36.1	31.9	34.5	0.303	27%	29%
4	0.3	41.1	36.7	39.5	0.447	50%	64%
5	0.3	45.1	40.6	43.4	0.589	70%	84%
6	0.3	48.2	43.7	46.6	0.722	90%	90%
7	0.3	50.7	46.2	49.1	0.840	100%	95%
8	0.3	52.6	48.3	51.1	0.942	88%	96%
9	0.3	54.2	49.9	52.7	1.029	89%	97%
10	0.3	55.4	51.2	54.0	1.102	77%	97%
11	0.3	56.4	52.3	55.0	1.163	79%	100%
12	0.3	57.1	53.1	55.8	1.212	79%	100%
13	0.3	57.7	53.8	56.5	1.253	77%	100%
14	0.3	58.2	54.4	57.0	1.286	87%	100%
15	0.3	58.6	54.8	57.4	1.312	87%	100%

Of note is that growth in length in Area 52 (northeast shelf) is less than in Area 51 (southeast shelf). This difference also occurs in weight and as a consequence biomass elaboration and yield is proportionately lower in Area 52.

Growth parameters for the eastern Bering Sea and the two subareas, Aleutian Basin, and Aleutian Island area are shown below.

	Area	L_{∞}	k	to	W_{∞}	alpha	beta	M
E. Bering Sea		59	0.228	-0.854	1.42	1.14E-05	2.877	0.3
Area 51		60.05	0.234	-0.929	1.53	1.19E-05	2.872	0.3
Area 52		56.63	0.217	-0.814	1.21	1.43E-05	2.812	0.3
Aleutian Basin		55.66	0.171	-2.474	1.28	1.29E-06	3.436	0.2
Aleutian Island		52.81	0.368	-0.584	1.04	2.73E-05	2.651	0.3

These parameters were used to compute $F_{0.1}$ for pollock in each area with knife-edge selectivity at age 3.

$M = 0.2$ is used for the Aleutian Basin, and $M=0.3$ is used for the Aleutian Island pollock under the assumption that mortality in this area is similar to the eastern Bering Sea.

1.6 MAXIMUM SUSTAINABLE YIELD

1.6.1 Eastern Bering Sea

Maximum sustainable yield for eastern Bering Sea pollock has been estimated for pollock using several different models. These include: an age-structured model (Walters 1969) that incorporates the Beverton and Holt (1957) yield equation, a population decay function, and a spawner recruit function; a surplus production model; and a delay-difference model. Detailed information on the models and the data utilized are contained in Wespestad (1990) and Wespestad and Terry (1984) for the Walters model and in Quinn and Collie (1990) for the other two models.

The results of the models are presented in the following table:

	Walters	Delay-Difference	Surplus Production
MSY	1.88	1.82	1.73
Biomass _{MSY}	6.00	6.06	6.33
F_{MSY}	0.38	----	0.34
MSY/BMSY	0.31	0.3	0.27

The results of the models are quite similar in all of the MSY parameters. MSY is about 1.8 million and is achieved at an exploitation rate of 30% of biomass. In the absence of fishing Quinn and Collie (1990) estimated that the eastern Bering Sea pollock stock would stabilize at 11.9 million t and the Walters model estimated an unfished population of 13.4 million t.

The results of the Walters model are most sensitive to the spawner-recruit relationship. The spawner-recruit relationship indicates the maximum number of recruits is 6.88 billion and maximum

recruitment occurs at an adult spawning population of 6.84 billion (Figure 1.17). Age specific selectivity is not considered in these models, so resulting MSY values are greater than what will occur in analysis using age specific selectivity.

1.6.2 Aleutian Islands

MSY for the Aleutian Islands is not as well defined as for the eastern Bering Sea.

1.7

ACCEPTABLE BIOLOGICAL CATCH

1.7.1 Eastern Bering Sea

Currently, the biomass of eastern Bering Sea pollock is near 6.0 million t level that will produce the MSY of 1.8 million t. Historically, eastern Bering Sea pollock ABC has been set at the $F_{0.1}$ level of fishing, derived from the yield per recruit model with knife-edge recruitment at age 3. The estimated level is $F=0.31$, $U=0.23$. The F_{30} level of fishing derived from spawning biomass per recruit model is $F=0.46$, $U=0.44$. The F_{35} level of fishing derived from spawning biomass per recruit model is $F=0.38$, $U=0.28$. The F_{40} level is $F=0.30$, $U=.23$.

Projecting the catch-age model's population estimates forward from 1996 and using recruitment estimates from Table 1.11 and an estimated catch of 1.1 million t for 1996, the estimated harvest at the $F_{40\%}$ level is projected to be 1.1 million t in 1997 (Table 1.12). Beyond 1997 the exploitable biomass and yields are dependent on the level of the recruiting year-classes. If recruiting year-classes are as weak as projected then exploitable biomass is projected to decrease in 1998.

$F_{OFL} = F_{msy} * F_{30} / F_{40} = 0.38 * 0.46 / 3 = 0.58$. Applying this rate to the exploitable biomass with age specific selectivity results in an OFL of 1.975 million t.

The ABC at F_{msy} is estimated to be 1.39 million t.

These projections are based on results from cohort analysis using two tuning methods.

1.7.2 Aleutian Islands

In the Aleutian Islands region the status and dynamics of pollock are not well understood. Catch-age data are limited, and most data are from the eastern Aleutians. Trawl survey data show that most of the biomass is located in the eastern Aleutian Islands and along the north side of Unalaska-Umnak islands in the eastern Bering Sea region (Figure 1.9). Biomass from the Unalaska-Umnak islands area was included in the Aleutian Islands Region estimate because this area was surveyed as part of the Aleutian Islands survey, and was never included the eastern Bering Sea trawl survey. We do not

believe it is appropriate to include biomass from the Unalaska-Umnak islands area in the Aleutian Islands estimates, because pollock in that area are included in the eastern Bering Sea catch, and assessed via catch-age models.

It is likely that pollock in the eastern Aleutian Islands is not a discrete stock, since pollock are continuously distributed from the eastern Bering Sea. In prior assessments it was assumed that stock dynamics in the Aleutian Islands are similar to that of eastern Bering Sea pollock and the biomass trend the same.

Following the past procedure of adjusting the Aleutian Islands survey biomass by the projected change of eastern Bering Sea shelf biomass between 1994 and 1997, the projected 1996 Aleutian Island biomass is 72% (6.12 million t/8.5 million t) of the 1994 biomass, which is $(0.72 * 86,374 \text{ t})$ or 62,189 t.

However, catch-age model results indicate that biomass may be much higher than indicated by bottom trawl surveys. One possible reason may be the non-estimation of the pelagic component of the population, which in the eastern Bering Sea currently accounts for approximately 50% of the exploitable biomass. Therefore, assuming a low catch-age model estimate of 100,000 t would not be extreme.

Based on the growth parameters presented in Section 1.5.2 the $F_{.35\%}$ exploitation rate for the Aleutian Islands is $F=0.46$, $U=.32$. $F_{0.1}$ exploitation rate for the Aleutian Islands is $F=0.47$, $U=.33$. $F_{40\%}$ is 0.38 , $U=.28$ and $F_{30\%}$ is 0.57 , $U.38$.

Following past procedures the ABC for the Aleutian region stock is estimated to be 17,413 t ($0.28 * 62,189 \text{ t}$) at $F_{.40}$. Based on the catch-age model estimates a minimum ABC would be 28,000 ($.28 * 100,000 \text{ t}$) at $F_{.40}$.

The OFL is at the $F_{30\%}$ rate ($F= 0.57$) which equals 24,000 t at a biomass of 17,413 t and 38,000 t at a biomass of 100,000 t.

1.7.3 Bogoslof Island - Aleutian Basin

The survey estimated abundance of pollock in the Bogoslof area decreased in 1996 (Appendix C). Based upon the 1996 survey estimate of exploitable biomass of 0.682 million t and $M = 0.2$ the estimated 1997 biomass is projected to be 0.558 million t. Using the 0.558 million t estimate and an $F_{.40}$ exploitation rate computed from growth parameters of $F=0.27$ which equates to an exploitation rate of 21% then the 1997 ABC is estimated to be 115,000 t for the Bogoslof Island pollock fishery.

The information available for pollock in the Aleutian Basin and the Bogoslof Island area indicates that these fish belong to the same "stock", which as 4-5+ old adults, are distinct from eastern Bering

Sea pollock. Data on the age structure of Bogoslof-Basin pollock show that a majority of pollock in the Basin originated from year-classes that are strong on the shelf, 1972, 1978, 1982, 1984, 1989. The mechanism causing pollock to move from the shelf to the Basin appears to be density related, with the abundance in the Basin proportional to year-class size.

Differences in spawning time and fecundity have been documented between eastern Bering Sea pollock and Aleutian Basin pollock. In addition Aleutian Basin pollock are smaller at a given age than pollock on the eastern Bering Sea shelf. Pollock in the northern shelf have a similar size at age as Aleutian Basin pollock although a very different age composition.

However, Aleutian Basin pollock are likely not an independent stock. Very few pollock younger than 5 years old have ever been found in the Aleutian Basin including the Soviet portion. Recruits to the basin are coming from another area, most likely the surrounding shelves either in the US or Soviet EEZ.

The question is whether the pollock present in the Bogoslof Island-Aleutian Basin is a distinct self-sustaining population, or surplus from the shelf population which makes an unknown reproductive contribution to future recruitment either on the shelf or in the basin. The available data are not conclusive. However, it appears that recruits to the basin are a result of density-dependent emigration of members of strong year-classes from the shelf, and not the progeny of spawning in the Bogoslof area. Harvests in the Aleutian Basin-Bogoslof Island area may have little or no influence on eastern Bering Sea stock biomass trends. However, the spawning products from spawning in the Bogoslof Island area of the southeastern basin may be carried onto the eastern Bering Sea shelf, based on satellite-tracked drifter buoy data, and possibly contribute some recruits to the eastern Bering Sea exploitable stock.

1.8 Stock and Fishery Considerations

Recent information obtained from wide-scale Bering Sea hydroacoustic surveys, and from Russian scientists indicate that the eastern Bering Sea pollock stock has a distribution that is continuous into the Russian EEZ. The 1994 Miller Freeman hydroacoustic survey found a contiguous distribution of pollock from Bristol Bay to south of Cape Navarin, and in 1996 continuous distribution to the U.S.- Russia Convention Line (See Appendix C). Russian data also suggest that pollock in the Russian EEZ east of 176 E. are predominantly of eastern Bering Sea origin (Shuntov et al. 1993). Further, it is thought that most of the juvenile fish in this area will recruit to the eastern Bering Sea spawning stock as adults. This was evident with the 1989 year-class, which was found in relatively low abundance in the US EEZ, but was found to be very abundant in the Russian EEZ early in life. The 1989 year-class subsequently was found to be the one of the largest year-classes produced within the eastern Bering Sea.

The problem of a straddling pollock stock is that the western Bering Sea pollock stock is currently at a low level of abundance . Biomass estimates are not available for the northern Bering Sea stock,

but catch shows a declining trend. With the decrease in western Bering Sea pollock abundance Russian and joint-venture fishing effort may have increased in the Russian EEZ northern area.

If significant harvests of juvenile pollock that will recruit to the eastern Bering Sea exploitable population occur in the Russian EEZ, then there may be a reduction in the exploitable biomass and yield in the US EEZ. The following table contains the reported catch for the Navarin area (176E to the Convention Line) received from TINRO, the catch as a percentage of the total western Bering Sea catch, and the age composition of the catch for ages 1,2,3, and 4 and older:

Year	Navarin Catch		Catch Age Composition				
	1000 t	Percent of Total Russian Bering Sea EEZ Catch	0	1	2	3	4+
1976	467	85%	0.0%	0.0%	4.7%	77.8%	17.5%
1977	180	68%	0.0%	0.0%	3.4%	13.2%	83.5%
1978	254	61%	0.1%	2.8%	6.1%	20.5%	90.6%
1979	284	52%	14.0%	22.8%	54.9%	5.6%	2.7%
1980	404	49%	0.0%	0.7%	14.7%	78.1%	6.5%
1981	850	75%	0.0%	0.2%	6.1%	39.1%	54.7%
1982	625	64%	0.0%	0.5%	9.9%	22.8%	66.8%
1983	654	65%	8.4%	30.0%	2.5%	20.7%	38.6%
1984	378	50%	0.0%	5.7%	0.2%	1.7%	95.4%
1985	384	58%	0.3%	43.7%	31.0%	13.8%	11.2%
1986	598	69%	0.0%	8.0%	44.9%	14.2%	32.9%
1987	512	63%	0.0%	0.0%	5.8%	27.6%	66.6%
1988	1009	76%	0.0%	1.0%	6.6%	22.0%	69.6%
1989	720	70%					
1990	431	53%					
1991	197	39%					
1992	316	53%					
1993	311	46%	0.0%	1.8%	7.0%	11.1%	80.1%
1994	159	43%	0.0%	0.3%	10.9%	17.4%	69.7%
1995	399	98%	0.0%	0.1%	15.6%	22.1%	62.2%
1996	485	95%					
Average	457	62%	1.4%	7.4%	14.0%	25.5%	53.0%

The average catch since 1976 in the Navarin area has been 457 thousand t, which was 62% of the entire western Bering Sea catch. The proportion of total catch has risen in recent years, presumably as a result of the decline of "western Bering Sea" stock of pollock. The age composition of the catch (in numbers) indicates that 53% of the catch consists of adult pollock (4+), and juveniles, ages 2 and 3, respectively average 14 and 26%. In the eastern Bering Sea during the same time period the catch (in numbers) of ages 2 and 3 were 4% and 14%, and age 4+ was 82%.

The historic level of fishing within the Navarin area does not appear to have had an adverse impact on the eastern Bering Sea stock, however, eastern Bering Sea stocks have been at high levels and have decreased to lower levels in recent years. It is a possibility that the eastern Bering Sea stock could be impacted at lower stock levels by current fishing practices in the Russian EEZ.

The age 4 pollock harvested in this region are likely resident, or have a low probability of moving to the US EEZ, however, this is not the case for younger pollock. A pollock increases in weight 3 to 4 fold between ages 2 to 4, so the harvest of juvenile pollock in the Russian EEZ could have a substantial impact on eastern Bering Sea biomass.

From the high percentage of juvenile pollock present in the catch, it does not appear that established regulations are being effectively enforced. The problem may be acute if, as reported from several sources, juvenile pollock are being taken in large numbers and not reported in harvest reports by Russian and foreign fishing vessels. Verification and validation of Russian regulations and enforcement are needed to get a full understanding of the current situation.

1.9 REFERENCES

- Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fish. Invest., Lond., Ser. 2, 19.
- Deriso, R. B., T. J. Quinn II, and P. R. Neal. 1985. Catch-age analysis with auxiliary information. Can J. Fish. Aquat. Sci. 42:815-824.
- Fair, L.F. 1994. Eastern Bering Sea walleye pollock: revised estimates of population parameters, relation of recruitment to biological and environmental variables, and forecasting. M.S. Thesis, University of Alaska Fairbanks, Fairbanks AK. 131 p.
- Harrison, R. C. 1993. Data Report: 1991 bottom trawl survey of the Aleutian Islands area. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS-AFSC-12.
- Pope, J. G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Res. Bull. Int. Commn. NW Atlant. Fish. 9: 65-74.
- Quinn II, T. J. and J. S. Collie. 1990. Alternative population models for eastern Bering Sea pollock. INPFC Symposium on application of stock assessment techniques to gadids. Int. North Pac. Fish. Comm. Bull. 50:243-258.
- Ronholt, L. L., K. Teshima, and D. W. Kessler. 1994. The groundfish resources of the Aleutian

Islands region and southern Bering Sea, 1980, 1983, and 1986. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS-AFSC-31.

Shuntov, V. P., A. F. Volkov, O. S. Temnykh, and E. P. Dulepova. 1993. Pollock in the ecosystems of the Far East Seas. TINRO, Vladivostok.

Traynor J. J. and M. O. Nelson. 1985. Results of the U.S. hydroacoustic survey of pollock on the continental shelf and slope. In: R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. Int. North Pac. Fish. Comm. Bull. 44: 192-199.

Walters, C. J. 1969. A generalized computer simulation model for fish population studies. Trans. Am. Fish. Soc. 98:505 -512.

Wespestad, V. G. 1990. Walleye pollock. Condition of groundfish resources in the Bering Sea-Aleutian Islands region as assessed in 1989. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/AKC.

Wespestad, V. G. and J. M. Terry. 1984. Biological and economic yields for eastern Bering Sea walleye pollock under differing fishing regimes. N. Amer. J. Fish. Manage., 4:204-215.

Wespestad, V. G. and J. Traynor. 1989. Walleye pollock. In: L-L. Low and R. Narita (editors), Condition of groundfish resources in the Bering Sea-Aleutian Islands region as assessed in 1988. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/AKC-178.

Table 1.1 Pollock catch (1000 t) in the eastern Bering Sea and Aleutian Islands retained by foreign and domestic fisheries, 1977-1996.

Year	Eastern Bering Sea				Aleutian Islands				Total
	Foreign	Domestic		Total	Foreign	Domestic		Total	
		JVP	DAP			JVP	DAP		
1977	978	0	0	978	8	0	0	8	986
1978	979	0	0	979	6	0	0	6	985
1979	914	0	0	914	10	0	0	10	924
1980	948	11	0	959	58	0	0	58	1,017
1981	931	42	0	973	56	0	0	56	1,029
1982	903	53	0	956	56	2	0	58	1,014
1983	835	145	1	981	56	3	0	59	1,040
1984	862	230	6	1,098	70	7	4	81	1,179
1985	771	370	38	1,179	51	7	1	59	1,238
1986	337	805	47	1,189	15	30	1	46	1,235
1987	4	1,015	218	1,237	0	28	1	30	1,267
1988	0	739	489	1,228	0	41	2	43	1,271
1989	0	227	952	1,230	0	5	11	16	1,246
1990	0	22	1,335	1,347	0	0	79	79	1,426
1991	0	0	1,074	1,074	0	0	79	79	1,153
1992	0	0	1,047	1,047	0	0	49	49	1,096
1993	0	0	1,216	1,216	0	0	57	57	1,273
1994	0	0	1,256	1,256	0	0	59	59	1,315
1995	0	0	1,263	1,263	0	0	63	63	1,326
1996 *	0	0	1,100	1,100	0	0	26	26	1,126

* to
10/19

Table 1.2 Catch from the eastern Bering Sea by area, the Aleutian Islands and the Bogoslof Island area, 1979-95.

Year	Eastern Bering Sea			Aleutians	Donut Hole	Bogoslof I.
	Southeast	Northwest	Total			
1979	368,848	566,866	935,714	9,504		
1980	437,253	521,027	958,280	58,156		
1981	714,584	258,918	973,502	55,516		
1982	713,912	242,052	955,964	57,978		
1983	687,504	293,946	981,450	59,026		
1984	442,733	649,322	1,092,055	81,834	181,200	
1985	604,465	535,211	1,139,676	58,730	363,400	
1986	594,997	546,996	1,141,993	46,641	1,039,800	
1987	529,461	329,955	859,416	28,720	1,326,300	377,436
1988	931,812	296,909	1,228,721	30,000	1,395,900	87,813
1989	904,201	325,399	1,229,600	15,531	1,447,600	36,073
1990	640,511	814,682	1,455,193	79,025	917,400	151,672
1991	712,206	505,095	1,217,301	78,649	293,400	264,760
1992	663,457	500,983	1,164,440	48,745	10,000	160
1993	1,095,314	231,287	1,326,601	57,132	1,957	886
1994	1,183,360	180,098	1,363,458	58,637	NA	566
1995	1,170,828	91,939	1,262,766	63,047	trace	264

1979-1989 data are from Pacfin.

1990-1995 data are from NMFS Alaska Regional Office, includes discards.

Table 1.3. Estimated retained, discarded, and percent discarded of total catch in the Aleutians, Northwest and Southeastern Bering Sea, 1990-1995.

Area	Catch			Discard Percentage
	Retained	Discard	Total	
	1990			
Southeast (51)	582,660	57,851	640,511	
Northwest (52)	764,369	50,313	814,682	
Aleutians	69,682	9,343	79,025	
Total	1,416,711	117,507	1,534,218	7.7%
	1991			
Southeast (51)	614,889	97,317	712,206	
Northwest (52)	458,610	46,485	505,095	
Aleutians	73,608	5,041	78,649	
Bogoslof	245,467	19,293	264,760	
Total	1,318,966	163,095	1,482,061	11.0%
	1992			
Southeast (51)	600,861	62,596	663,457	
Northwest (52)	445,811	55,172	500,983	
Aleutians	45,246	3,498	48,745	
Total	1,091,919	121,266	1,213,185	10.0%
	1993			
Southeast (51)	1,011,020	84,294	1,095,314	
Northwest (52)	205,495	25,792	231,287	
Aleutians	55,399	1,733	57,132	
Total	1,271,914	111,819	1,383,732	8.1%
	1994			
Southeast (51)	1,091,547	91,813	1,183,360	
Northwest (52)	164,020	16,078	180,098	
Aleutians	57,325	1,311	58,637	
Total	1,312,892	109,202	1,422,094	7.7%
	1995			
Southeast (51)	1,083,381	87,447	1,183,360	
Northwest (52)	82,226	9,713	91,939	
Aleutians	63,047	1,382	64,429	
Total	1,228,654	98,542	1,339,728	7.4%

Table 1.4. Biomass of eastern Bering Sea walleye pollock in (million t) as estimated by surveys and catch-age models, 1979-1996.

	Surveys					Catch-Age Models			
	Bottom Trawl			Hydro-acoustic	Combined Surveys	Cohort Analysis		BASA	
	Mean	Low	High			Tuned	Solver	Biomass	CV
1979	2.000	0.000	5.100	1.550	3.550	4.506	4.611	3.667	23
1980	0.990	0.590	1.390			5.756	6.099	5.330	21
1981	2.270	1.670	2.870			10.627	11.348	9.731	17
1982	3.540	2.340	4.740	4.640	8.180	12.029	12.523	10.728	17
1983	4.810	3.810	5.810			13.165	13.653	11.330	16
1984	3.960	2.960	4.960			12.868	13.331	10.547	16
1985	4.360	2.760	5.960	5.450	9.810	14.232	14.616	12.024	13
1986	4.310	3.310	5.310			12.954	13.408	10.865	13
1987	5.030	3.830	6.230			13.108	13.226	10.741	13
1988	5.940	4.240	7.640	4.160	10.090	11.968	11.803	9.742	12
1989	4.780	3.680	5.880			10.020	9.573	7.980	13
1990	7.700	5.600	9.800			7.966	7.375	6.048	15
1991	5.100	3.830	6.390	1.400	6.500	6.667	5.886	4.474	17
1992	4.300	3.300	5.340			8.470	8.459	7.418	18
1993	5.500	4.560	6.480			8.608	8.869	8.800	22
1994	4.980	3.930	6.020	2.760	7.740	8.082	8.462	7.310	26
1995	5.410	3.350	7.470			7.576	7.925	7.671	29
1996	3.200	2.368	4.032	2.239	5.439	6.122	6.203	6.230	34

Cohort analysis and Synthesis model results are for ages 3 to 14+ tuned to 1979, 1982, 1985, 1988, 1991, 1994, and 1996 survey estimates.

Survey results are for ages 3 and older in all years, except 1995 for which age compositions are not complete and estimates include all ages.

Table 1.5. Trend of pollock biomass in the Aleutian Islands Triennial Groundfish Survey, 1980-1994.

	Aleutian Islands and Unalaska-Umnak area (~165W-170W)	Aleutian Region (170E-170W)
1980	308,745	252,013
1983	778,666	495,982
1986	550,517	448,138
1991	183,303	179,653
1994	151,444	86,374

Table 1.6. Estimated Jan 1. biomass of pollock for ages 3 and older in million t in the eastern Bering Sea by age and total biomass estimated by least squares (solver) cohort analysis, 1979-1996.

Year	Age												Total
	3	4	5	6	7	8	9	10	11	12	13	14	
1979	1.23	0.93	1.11	0.57	0.26	0.17	0.14	0.11	0.06	0.03	0.01	0.00	4.61
1980	2.78	1.07	0.70	0.76	0.33	0.17	0.11	0.07	0.06	0.03	0.01	0.01	6.10
1981	6.39	2.72	0.82	0.47	0.50	0.21	0.11	0.07	0.03	0.02	0.00	0.00	11.35
1982	2.00	6.60	2.33	0.60	0.33	0.38	0.14	0.07	0.04	0.02	0.01	0.00	12.52
1983	2.69	2.12	5.85	1.85	0.44	0.25	0.27	0.09	0.04	0.03	0.01	0.00	13.65
1984	1.49	2.88	1.91	4.80	1.44	0.33	0.18	0.20	0.06	0.03	0.02	0.00	13.33
1985	3.69	1.59	2.59	1.43	3.66	1.09	0.24	0.12	0.14	0.04	0.02	0.01	14.62
1986	1.12	3.89	1.49	2.12	1.00	2.68	0.78	0.15	0.07	0.08	0.02	0.00	13.41
1987	2.42	1.19	3.42	1.22	1.55	0.65	1.98	0.56	0.11	0.05	0.06	0.01	13.23
1988	0.86	2.61	1.12	2.84	0.95	1.19	0.45	1.34	0.39	0.04	0.01	0.01	11.80
1989	0.52	0.76	2.33	0.86	2.06	0.61	0.87	0.32	0.95	0.28	0.02	0.01	9.57
1990	0.44	0.55	0.67	1.83	0.62	1.24	0.41	0.59	0.21	0.60	0.20	0.01	7.38
1991	0.89	0.46	0.42	0.48	1.23	0.41	0.68	0.26	0.36	0.16	0.39	0.14	5.89
1992	4.52	0.96	0.41	0.29	0.30	0.70	0.28	0.33	0.18	0.16	0.10	0.22	8.46
1993	1.99	4.66	0.86	0.31	0.16	0.13	0.32	0.12	0.09	0.08	0.07	0.06	8.87
1994	0.97	2.07	3.97	0.72	0.22	0.09	0.06	0.18	0.07	0.04	0.05	0.04	8.46
1995	1.23	1.03	1.83	2.91	0.49	0.14	0.05	0.03	0.12	0.05	0.02	0.03	7.93
1996	0.03	1.32	0.94	1.41	1.96	0.30	0.08	0.03	0.02	0.07	0.03	0.00	6.20

Table 1.7. Eastern Bering Sea walleye pollock catch by age in numbers (millions), 1979-1995.

Year	Age														Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1979	101	543	720	420	393	216	56	26	36	27	18	8	3	1	2567
1980	10	462	823	443	252	211	84	38	22	24	25	16	8	3	2421
1981	1	72	1013	638	227	103	52	30	16	9	8	5	2	1	2175
1982	5	25	161	1172	422	104	36	36	22	9	5	3	2	1	2004
1983	5	119	158	313	817	218	41	25	20	11	8	5	4	2	1744
1984	2	46	89	431	492	654	134	36	25	16	7	3	3	2	1938
1985	3	55	382	122	367	322	444	113	37	26	25	11	9	4	1920
1986	3	86	92	749	214	378	222	214	60	15	3	3	0	1	2040
1987	0	20	112	78	416	140	123	91	249	54	39	22	29	6	1378
1988	0	11	455	423	253	546	225	105	39	97	18	10	4	6	2192
1989	0	5	55	149	453	167	574	97	104	33	129	11	4	3	1784
1990	1	33	57	221	202	480	130	370	66	102	9	60	9	5	1746
1991	1	61	41	85	142	157	396	52	217	22	115	15	74	61	1439
1992	0	79	722	144	98	125	145	277	109	165	59	50	14	91	2079
1993	0	9	275	1145	103	64	62	54	85	22	34	13	13	27	1905
1994	0	31	60	383	1110	180	55	21	13	20	9	11	8	16	1918
1995	0	0	75	147	398	765	132	35	11	6	15	4	7	11	1607

Table 1.8. Estimated number (billions) of eastern Bering Sea pollock by age and total estimated by cohort analysis tuned to the triennial hydroacoustic-bottom trawl trend, survey age composition and survey age 1 index, 1979-1996.

Year	Age												Total
	3	4	5	6	7	8	9	10	11	12	13	14	
1979	4.06	2.08	1.88	0.79	0.31	0.18	0.13	0.10	0.05	0.02	0.01	0.00	9.61
1980	9.17	2.39	1.18	1.05	0.40	0.18	0.11	0.07	0.05	0.02	0.01	0.00	14.63
1981	21.09	6.08	1.39	0.66	0.60	0.22	0.10	0.06	0.03	0.01	0.00	0.00	30.25
1982	6.59	14.75	3.96	0.83	0.40	0.40	0.14	0.06	0.04	0.01	0.01	0.00	27.19
1983	8.86	4.74	9.92	2.57	0.53	0.26	0.27	0.08	0.04	0.02	0.01	0.00	27.31
1984	4.91	6.43	3.24	6.64	1.72	0.35	0.17	0.18	0.05	0.02	0.01	0.00	23.74
1985	12.19	3.56	4.39	1.98	4.36	1.16	0.23	0.11	0.12	0.03	0.01	0.01	28.15
1986	3.69	8.70	2.53	2.94	1.19	2.85	0.76	0.14	0.06	0.07	0.02	0.00	22.93
1987	7.99	2.65	5.80	1.69	1.85	0.69	1.92	0.51	0.09	0.04	0.05	0.01	23.31
1988	2.83	5.83	1.90	3.94	1.13	1.27	0.43	1.21	0.33	0.03	0.01	0.01	18.92
1989	1.71	1.71	3.95	1.19	2.45	0.65	0.85	0.29	0.81	0.23	0.02	0.00	13.85
1990	1.47	1.22	1.13	2.54	0.74	1.32	0.39	0.54	0.18	0.49	0.16	0.01	10.20
1991	2.93	1.04	0.72	0.67	1.47	0.43	0.66	0.24	0.31	0.13	0.31	0.11	9.01
1992	14.91	2.14	0.69	0.41	0.36	0.75	0.28	0.30	0.16	0.13	0.08	0.17	20.37
1993	6.57	10.43	1.46	0.43	0.19	0.14	0.31	0.11	0.08	0.06	0.05	0.05	19.89
1994	3.19	4.63	6.74	0.99	0.26	0.09	0.06	0.16	0.06	0.03	0.04	0.03	16.28
1995	4.06	2.31	3.10	4.04	0.58	0.15	0.05	0.03	0.10	0.04	0.01	0.02	14.49
1996	0.11	2.94	1.59	1.95	2.33	0.32	0.08	0.03	0.02	0.06	0.03	0.00	9.46

Table 1.9. Estimated fishing mortality (F) for pollock in the eastern Bering Sea by year and age.

Year	Age											
	3	4	5	6	7	8	9	10	11	12	13	14
1980	0.110	0.243	0.286	0.265	0.280	0.274	0.261	0.541	0.938	1.598	1.910	1.000
1981	0.057	0.130	0.211	0.201	0.105	0.168	0.201	0.190	0.362	0.477	0.710	1.000
1982	0.029	0.097	0.132	0.157	0.111	0.111	0.198	0.186	0.179	0.287	0.406	1.000
1983	0.021	0.080	0.101	0.104	0.096	0.115	0.091	0.165	0.263	0.274	0.687	1.000
1984	0.021	0.081	0.194	0.121	0.095	0.124	0.183	0.107	0.168	0.145	0.294	1.000
1985	0.037	0.041	0.102	0.210	0.126	0.120	0.203	0.329	0.277	0.466	1.551	1.000
1986	0.030	0.105	0.103	0.162	0.244	0.091	0.096	0.134	0.070	0.046	0.020	1.000
1987	0.016	0.035	0.087	0.101	0.080	0.167	0.163	0.132	0.687	1.003	1.245	1.000
1988	0.207	0.088	0.168	0.176	0.263	0.102	0.112	0.098	0.066	0.433	0.524	1.000
1989	0.038	0.107	0.143	0.179	0.318	0.191	0.154	0.141	0.204	0.057	0.335	1.000
1990	0.046	0.235	0.231	0.248	0.229	0.395	0.216	0.250	0.059	0.154	0.064	1.000
1991	0.016	0.101	0.261	0.319	0.377	0.149	0.483	0.115	0.561	0.147	0.324	1.000
1992	0.058	0.081	0.179	0.439	0.636	0.564	0.614	1.017	0.586	0.587	0.223	1.000
1993	0.050	0.136	0.086	0.191	0.464	0.583	0.377	0.259	0.686	0.258	0.330	1.000
1994	0.022	0.101	0.212	0.237	0.278	0.313	0.313	0.158	0.182	0.534	0.275	1.000
1995	0.022	0.076	0.162	0.249	0.306	0.321	0.297	0.250	0.194	0.141	1.000	1.000
Average	0.060	0.118	0.173	0.220	0.250	0.234	0.255	0.263	0.352	0.418	0.608	1.000

Table 1.10. Numbers of pollock by age in the Aleutian Islands pollock catch, 1978-1995.

Year	Age												
	3	4	5	6	7	8	9	10	11	12	13	14	
1978	0.016	0.220	0.615	0.292	2.116	0.682	0.967	1.210	0.945				
1979	0.000	1.300	1.648	2.049	2.323	2.148	1.400	1.268	0.082				
1980	3.554	2.384	3.729	6.916	14.123	10.584	10.127	4.835	4.746				
1981	0.000	9.664	8.161	6.301	7.611	12.720	12.848	11.019	8.117				
1982	0.000	0.083	46.090	9.933	4.506	6.383	9.177	8.720	4.752				
1983													
1984	0.057	2.600	0.000	8.036	38.166	18.855	24.567	17.379	11.305				
1985	0.161	0.692	11.886	3.010	7.963	32.382	10.880	7.782	7.448				
1986													
1987													
1988													
1989													
1990													
1991	0.055	0.812	2.145	12.561	20.702	5.404	15.423	2.390	7.727	6.735	10.400	6.939	
1992	1.032	0.325	1.930	3.694	1.985	5.520	1.231	5.981	3.645	3.582	2.426	12.779	
1993	0.334	3.783	1.753	4.420	5.267	2.578	6.520	3.072	3.367	2.884	1.346	2.542	
1994	0.045	1.224	11.103	3.163	4.393	5.344	4.571	3.280	1.586	3.708	1.330	1.094	
1995	0.206	0.714	2.064	14.116	2.016	5.316	4.940	1.607	2.836	2.278	4.006	0.864	

Table 1.11. Eastern Bering Sea bottom trawl index of age 1 pollock, cohort analysis estimate of age 3 abundance of the same year-class, and the forecast recruitment at age 3 based the regression of age 3 cohort analysis estimates on age 1 survey estimates.

Regression parameters		Solver		Fit		
				1.392036	1.553534	
alpha				2.662574	2.578556	
beta						
Survey Year	Year-class	Survey Age 1	Fishery Age 3	Regression	Fishery Age 3	Regression
1979	1978 ✓	5.855	21.089	16.981	19.868	16.651
1980	1979	2.031 ↗	6.588	6.800	7.390	6.791
1981	1980	1.015	8.864	4.095	8.655	4.171
1982	1981	0.854	4.909	3.666	4.758	3.756
1983	1982 ✓	3.933	12.186	11.864	12.225	11.695
1984	1983	0.400	3.687	2.457	3.225	2.585
1985	1984 ✓	✓ 4.201	7.995	12.578	8.944	12.386
1986	1985	2.117	2.831	7.029	3.477	7.012
1987	1986	0.303	1.714	2.199	2.412	2.335
1988	1987	0.880	1.465	3.735	1.805	3.823
1989	1988	0.620	2.933	3.043	3.580	3.152
1990	1989 ✓	1.425	14.912	5.186	12.382	5.228
1991	1990	2.077 ↘	6.567	6.922	6.040	6.909
1992	1991	1.297 ↘	3.192	4.845	3.250	4.898
1993	1992	2.100 ↘	4.061	6.983	4.212	6.969
1994	1993	1.251 ↘	0.111	4.723	0.916	4.779
1995	1994	1.597 ↘		5.644		5.671
1996	1995	1.299 ↘		4.851		4.903
Average		1.848	6.444	6.397	6.446	6.401

Table 1.12. Projected Age 3+ biomass (million t), catch (million t, age 3 recruits (billions) and exploitation rates at $F_{0.1}$ and $F_{.35}$ using cohort analysis estimates of abundance.

	Year	Age 3+ Biomass	Catch	Age 3 Recruits	F	Exploitation
Solver						
$F=F_{0.40}$	1996	6.203	1.109	0.111	0.245	18%
	1997	6.124	1.134	5.644	0.300	19%
	1998	5.928	1.011	4.851	0.300	17%
	1999	6.861	1.036	7.952	0.300	15%
	2000	7.668	1.158	7.603	0.300	15%
Fit						
$F=F_{0.40}$	1996	6.122	1.103	0.916	0.262	18%
	1997	6.088	1.094	5.671	0.300	18%
	1998	5.963	1.004	4.903	0.300	17%
	1999	6.915	1.048	8.007	0.300	15%
	2000	7.707	1.170	7.591	0.300	15%

Exploitation = Catch in biomass / Jan 1. Biomass

Recruits estimated from spawner-recruit relationship, 1998-2000.

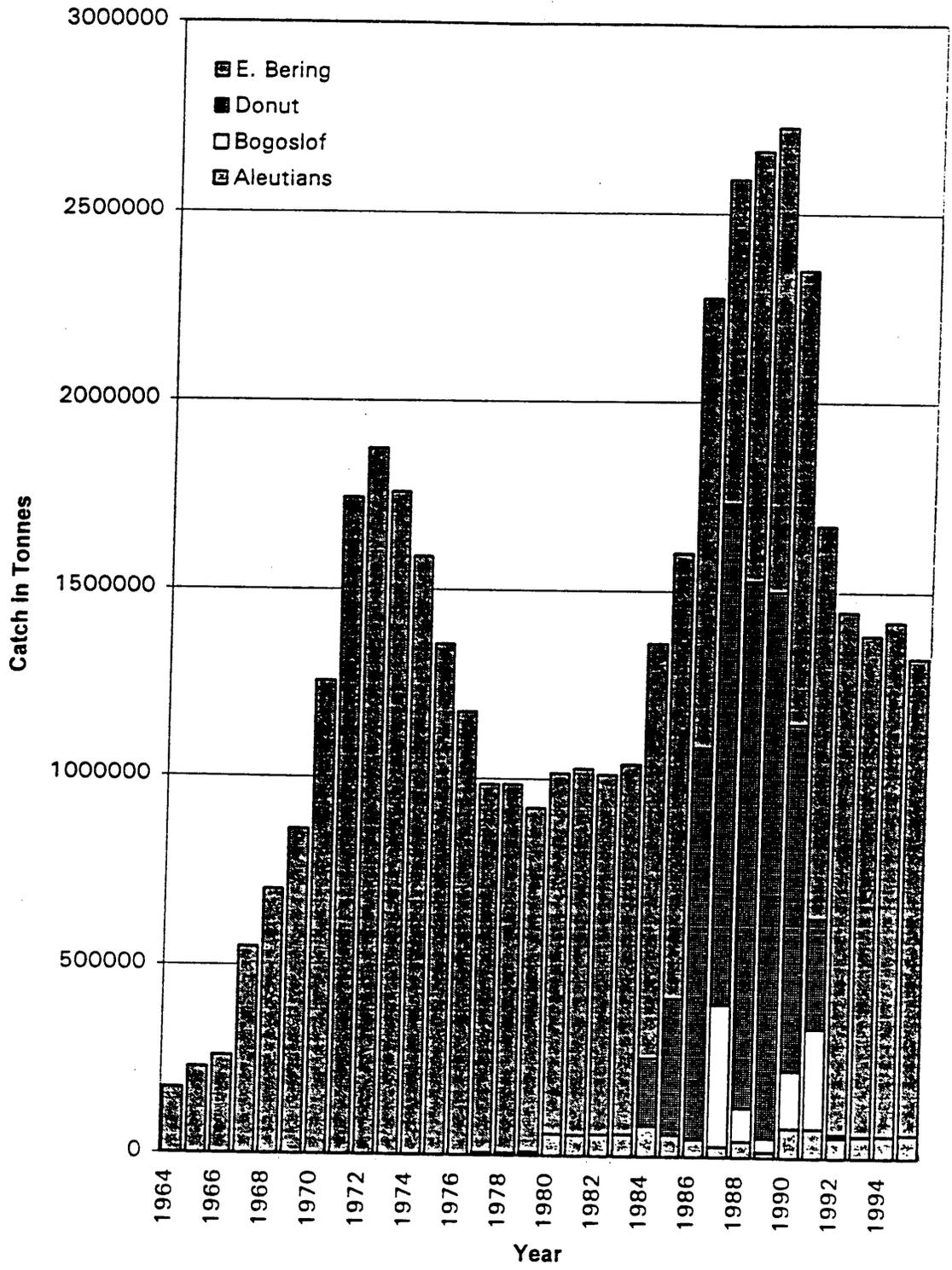


Figure 1.1 -- Walleye pollock catch in the eastern Bering Sea, Aleutian Islands, Bogoslof Island, and Donut Hole, 1964-1992

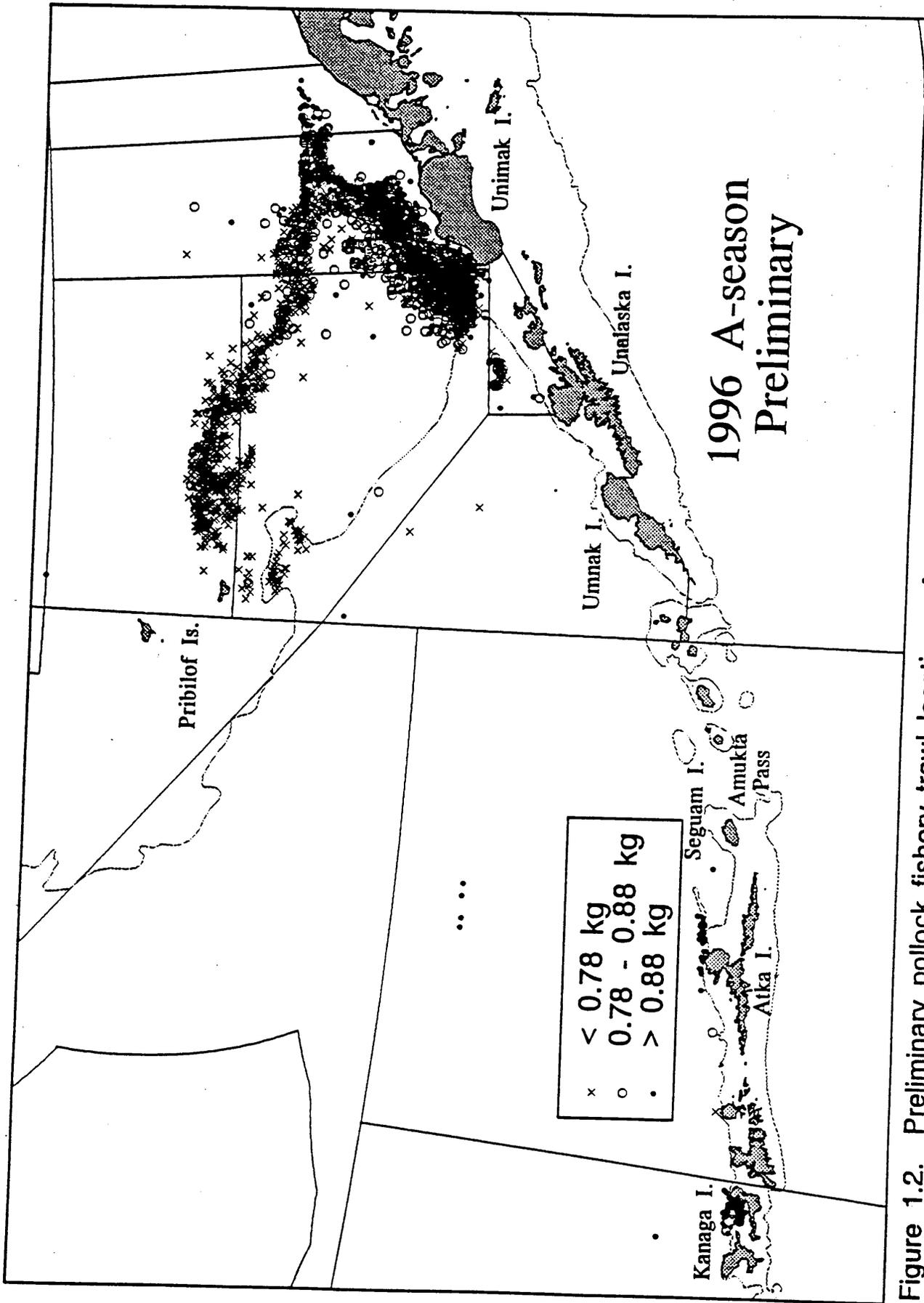


Figure 1.2. Preliminary pollock fishery trawl locations, A-season 1996. Different symbols indicate mean pollock weight in the haul; each symbol represents 33% of the data.

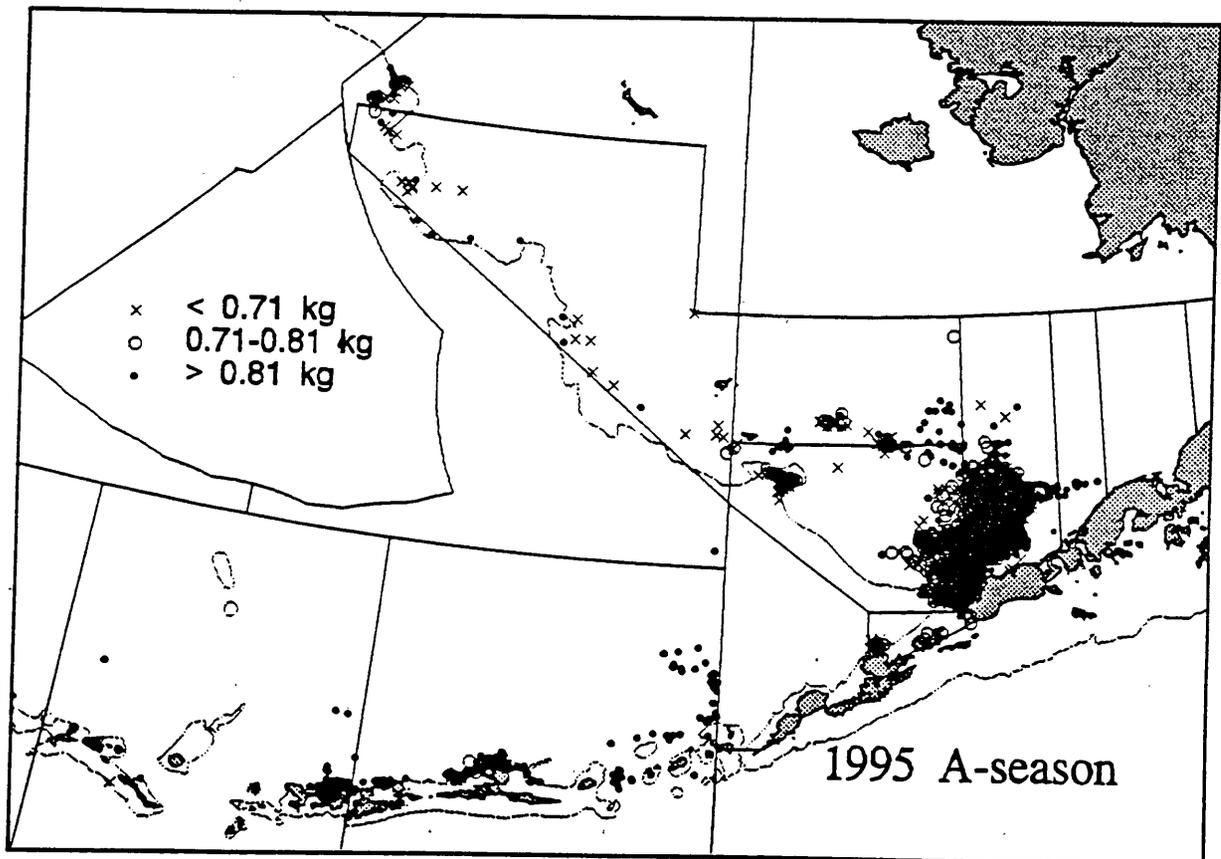
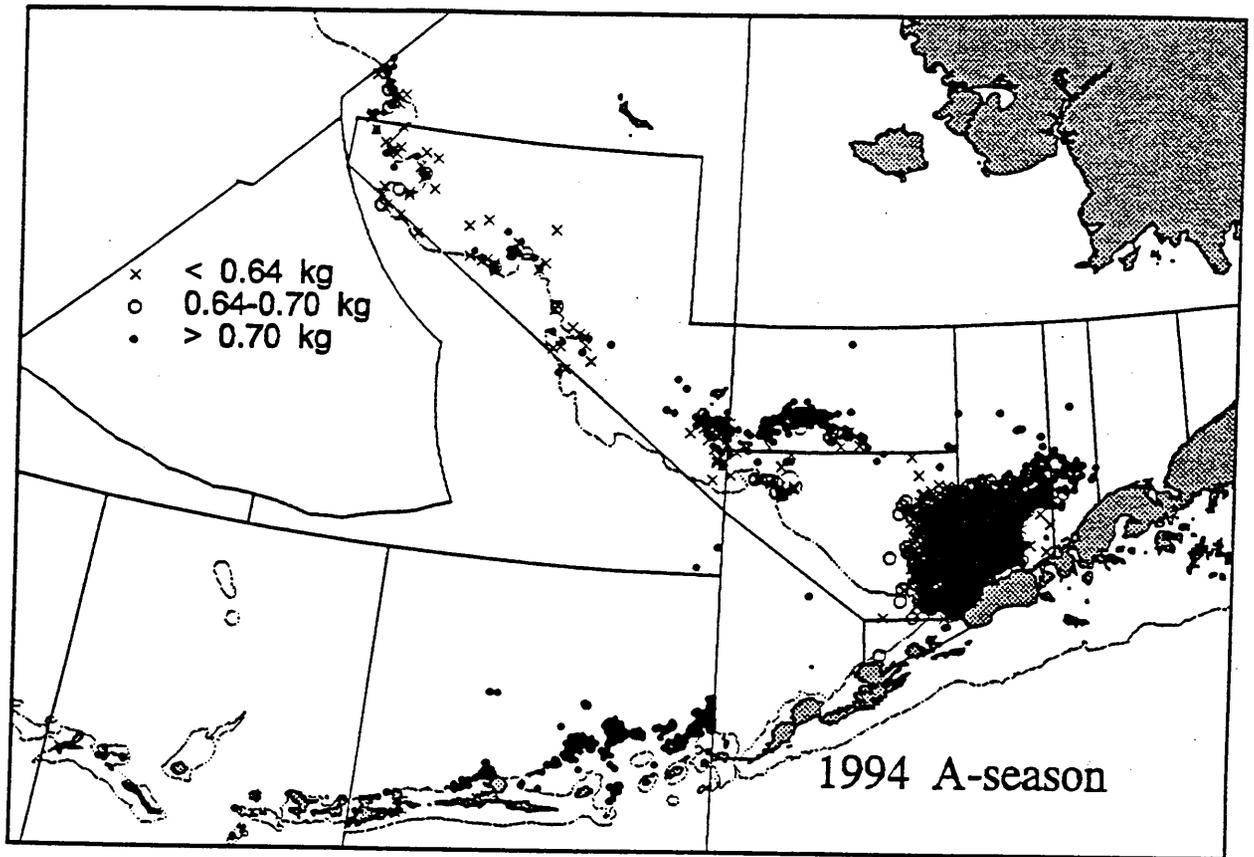


Figure 1.3. Pollock fishery trawl locations in the A-seasons of 1994 and 1995. Different symbols indicate mean pollock weight in the haul; each symbol represents 33.3% of the data.

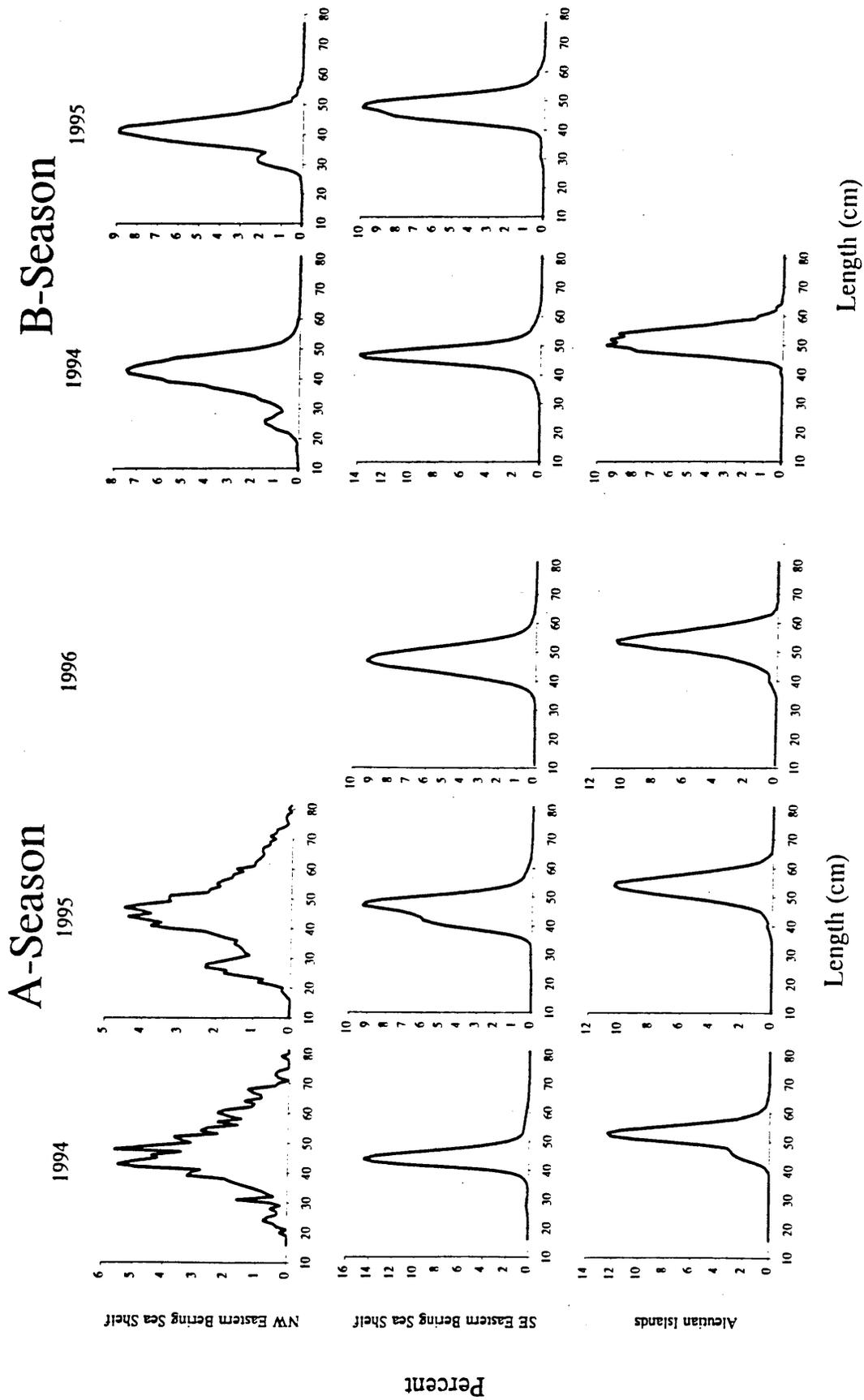


Figure 1.4. Percent length-frequency of pollock caught by the fishery in the A (Jan-Mar) and B (Aug-Dec) Seasons of 1994-96 on the eastern Bering Sea (EBS) shelf and in the Aleutian Islands. The EBS shelf area was divided into two areas, NW and SE, at the 172°30' meridian.

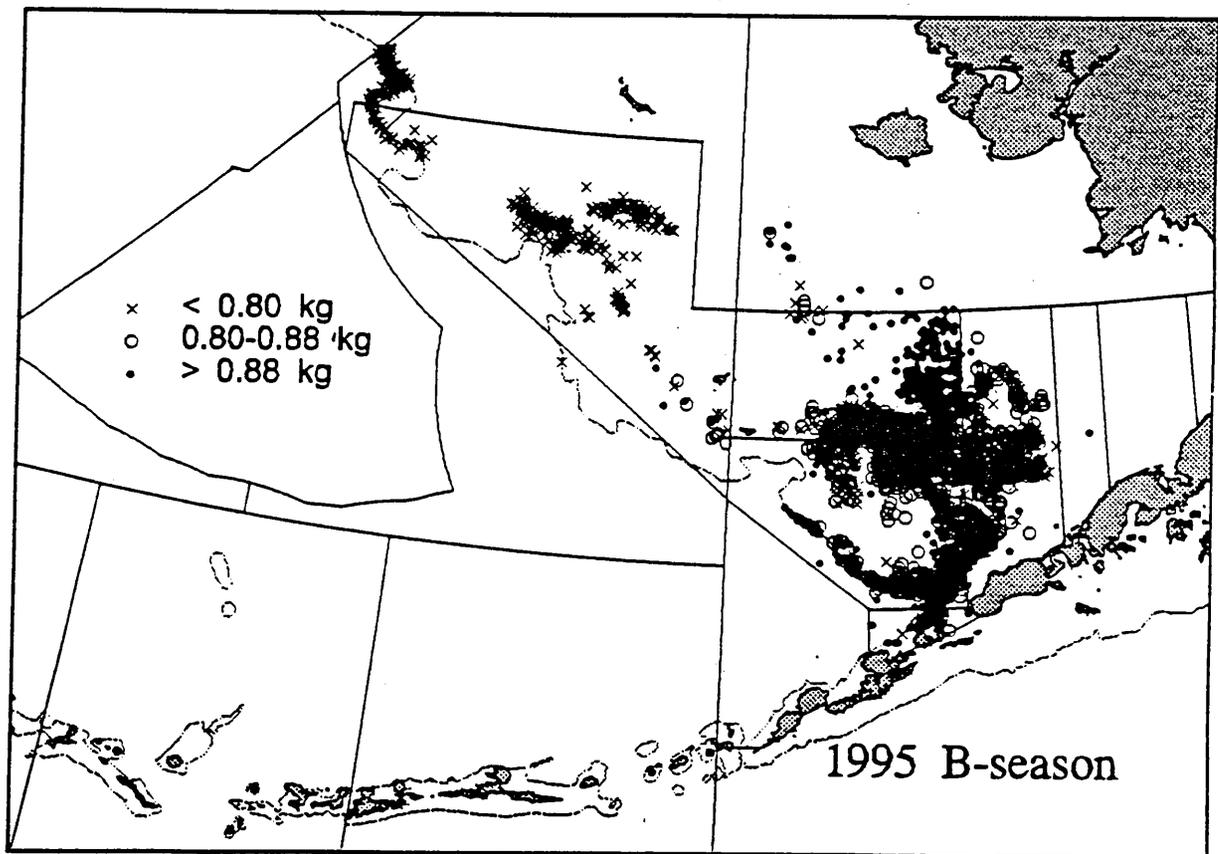
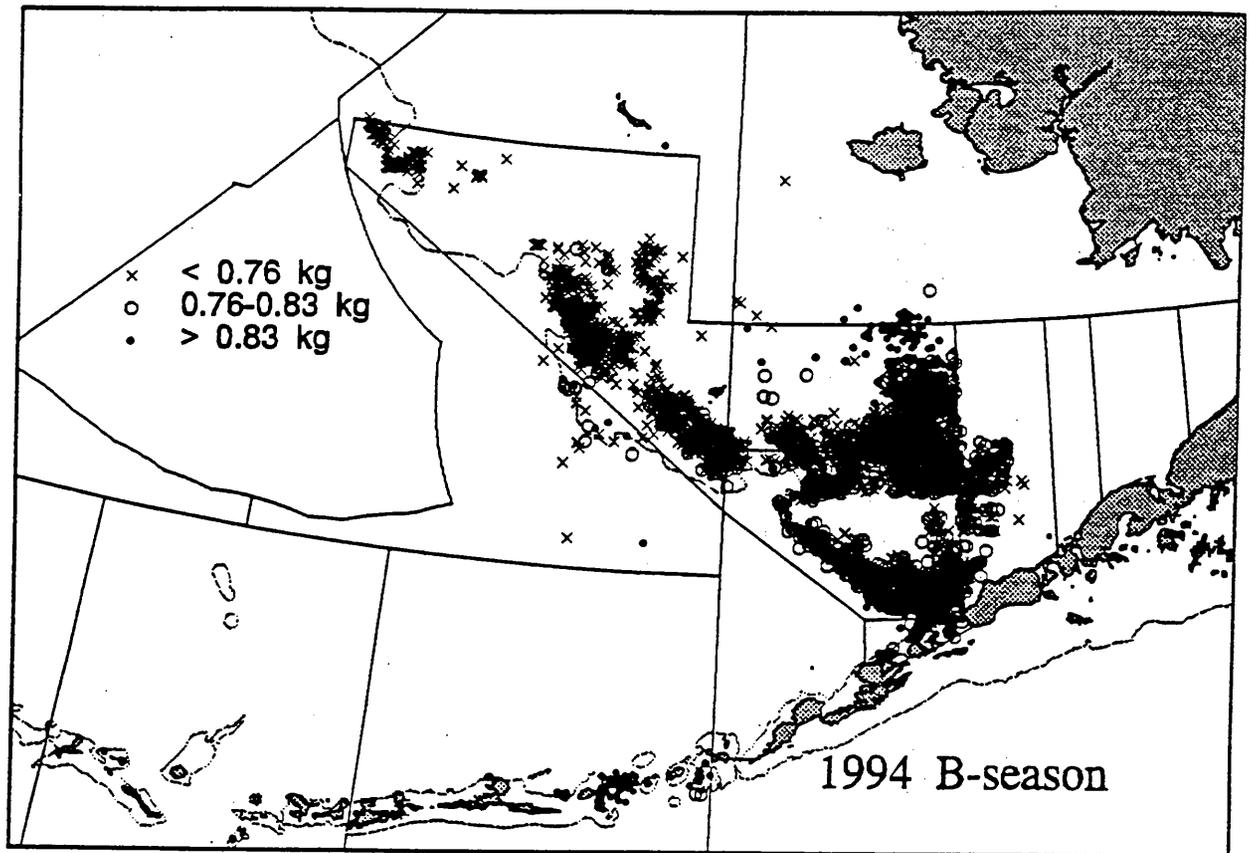


Figure 1.5. Pollock fishery trawl locations in the B-seasons of 1994 and 1995. Different symbols indicate mean pollock weight in the haul; each symbol represents 33.3% of the data.

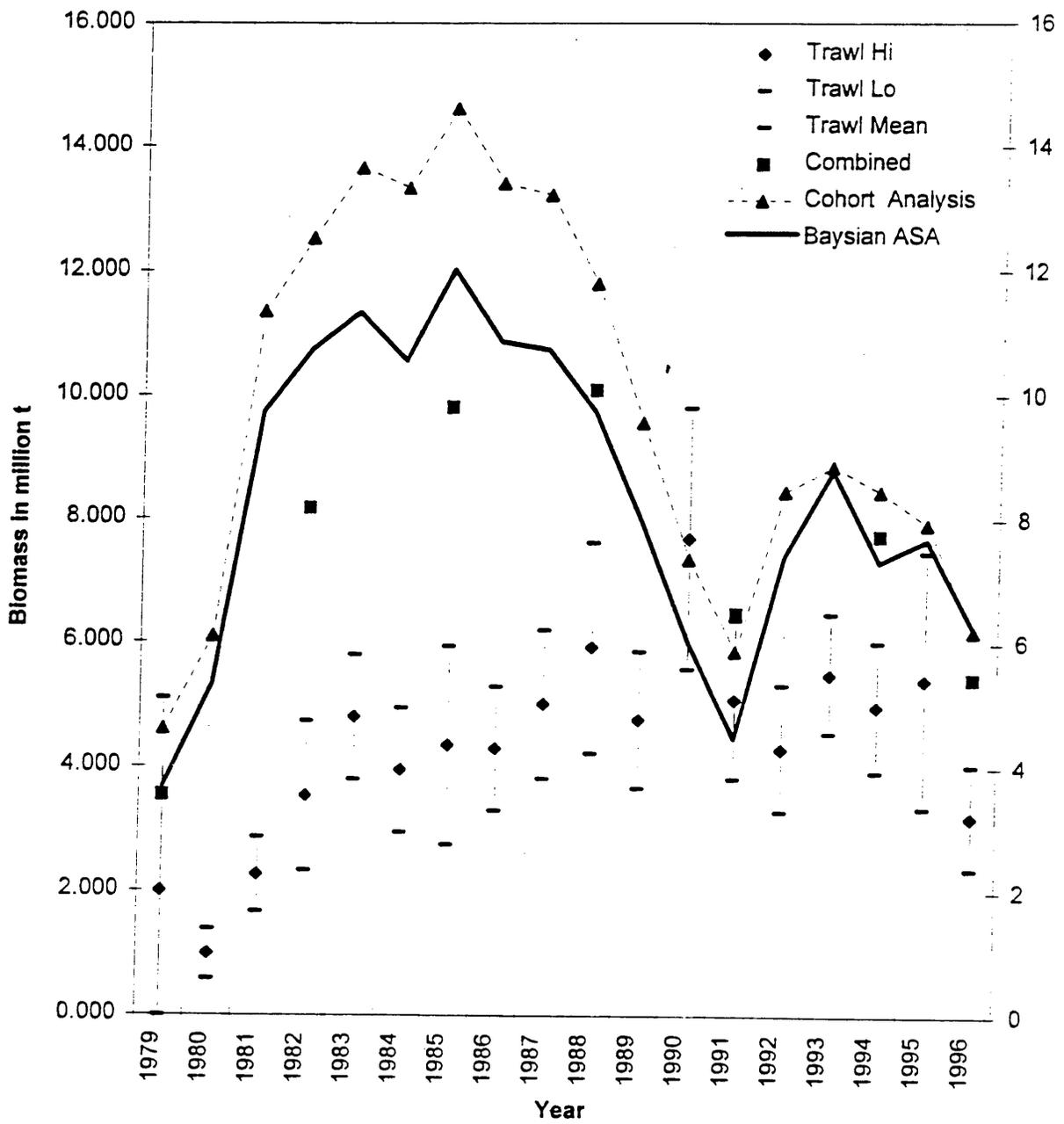


Figure 1.6. Eastern Bering Sea pollock abundance trends, 1979-1996 as estimated in trawl surveys, combined hydroacoustic-bottom trawl surveys, and catch-age models.

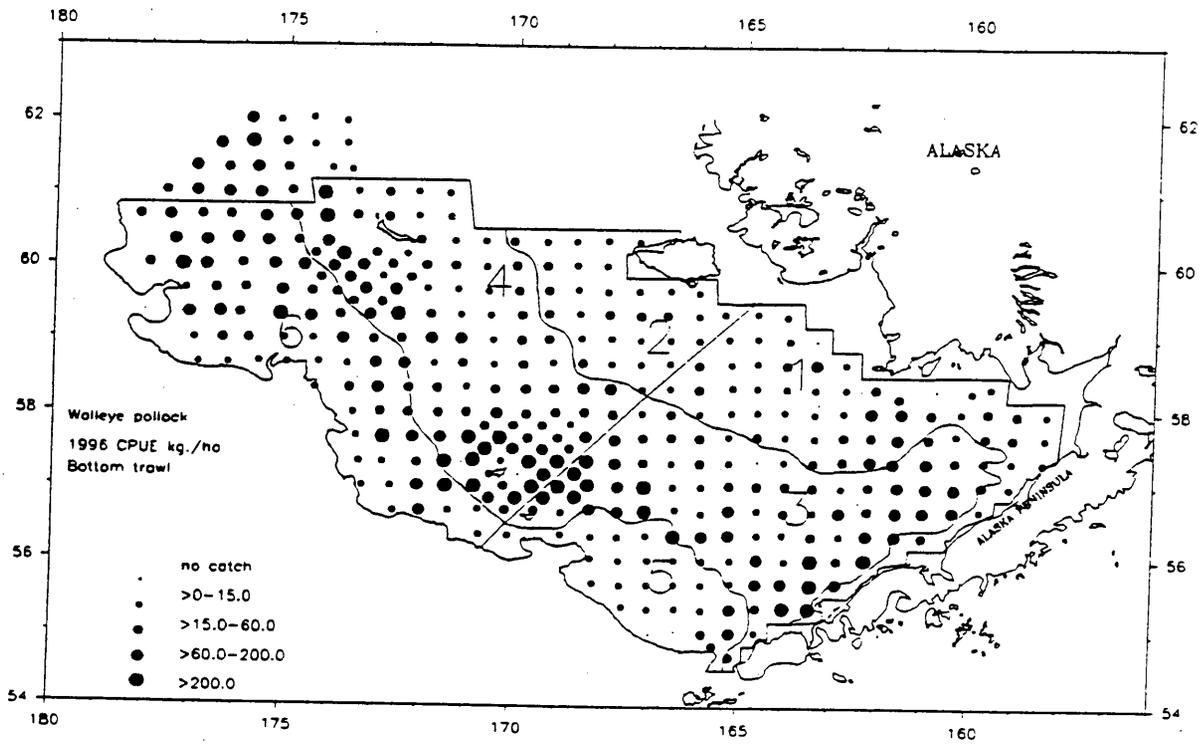


Figure 1.7. Distribution of walleye pollock during the 1996 eastern Bering Sea bottom trawl survey.

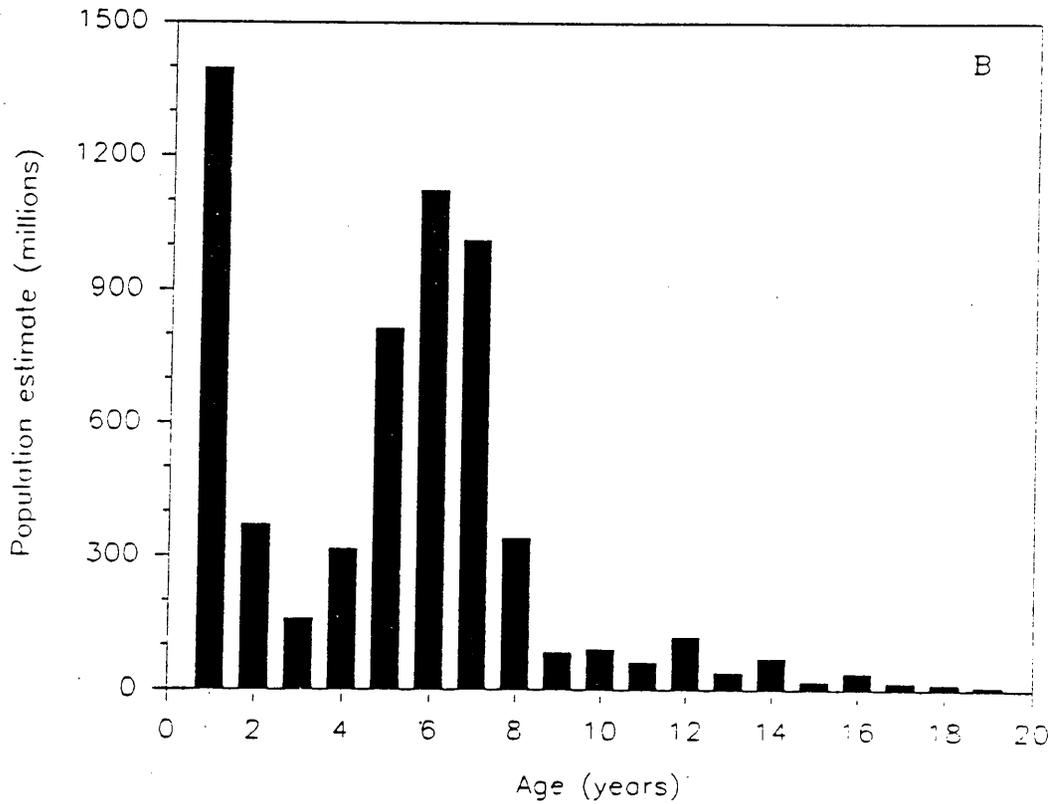
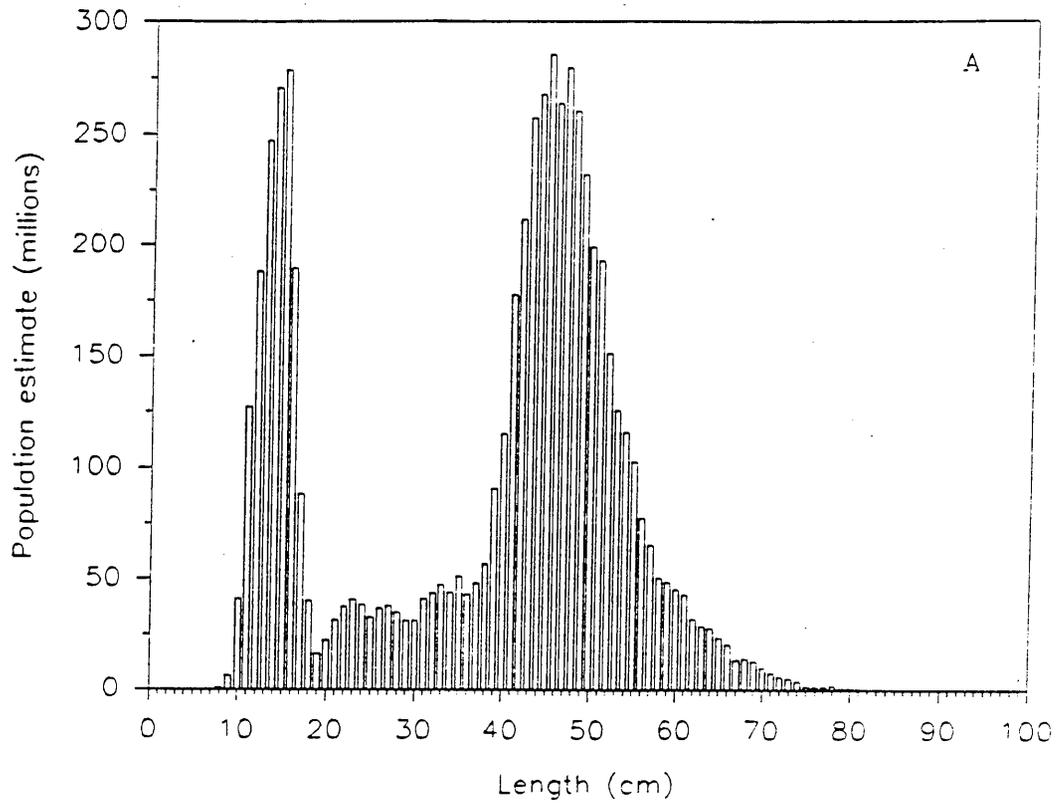


Figure 1.8. Distribution of sizes (A) and ages (B) for walleye pollock from the total area surveyed during the 1996 eastern Bering Sea bottom trawl survey.

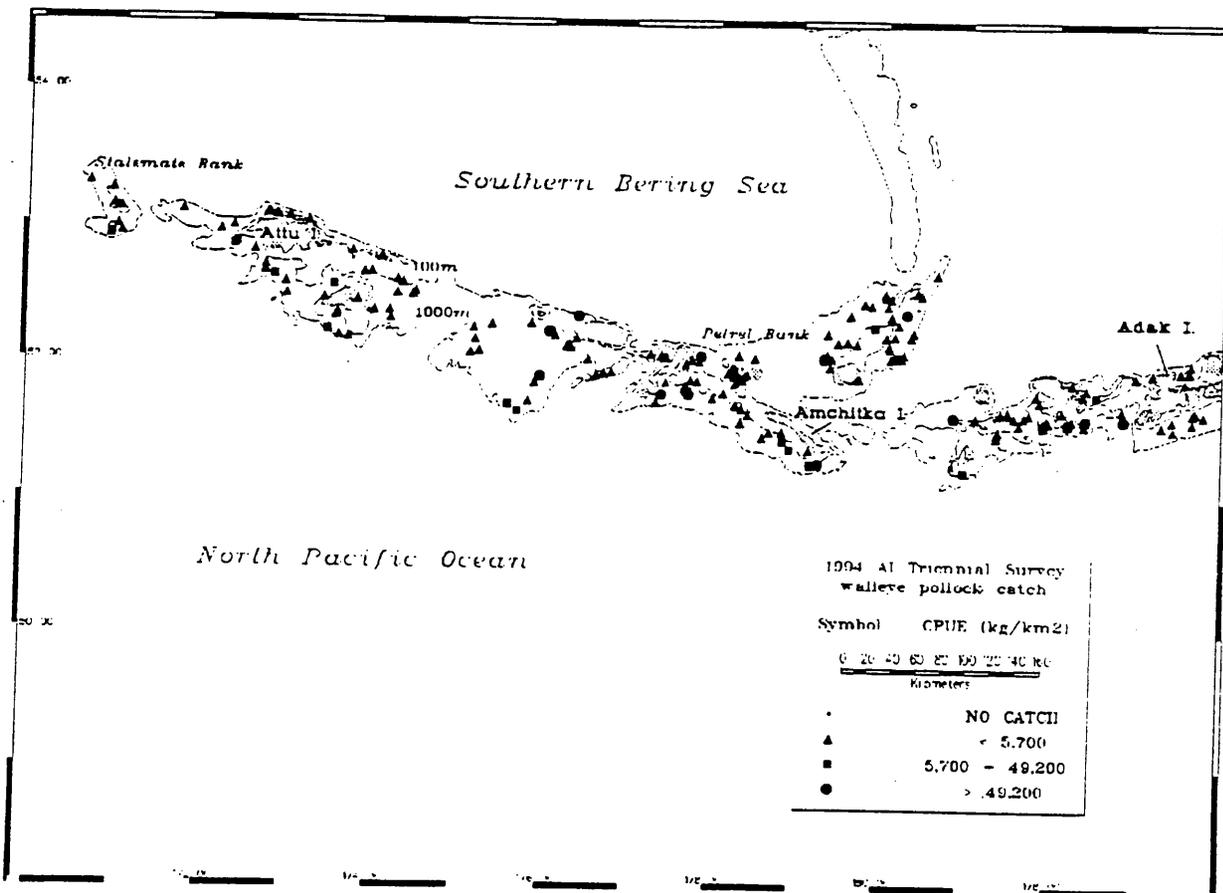
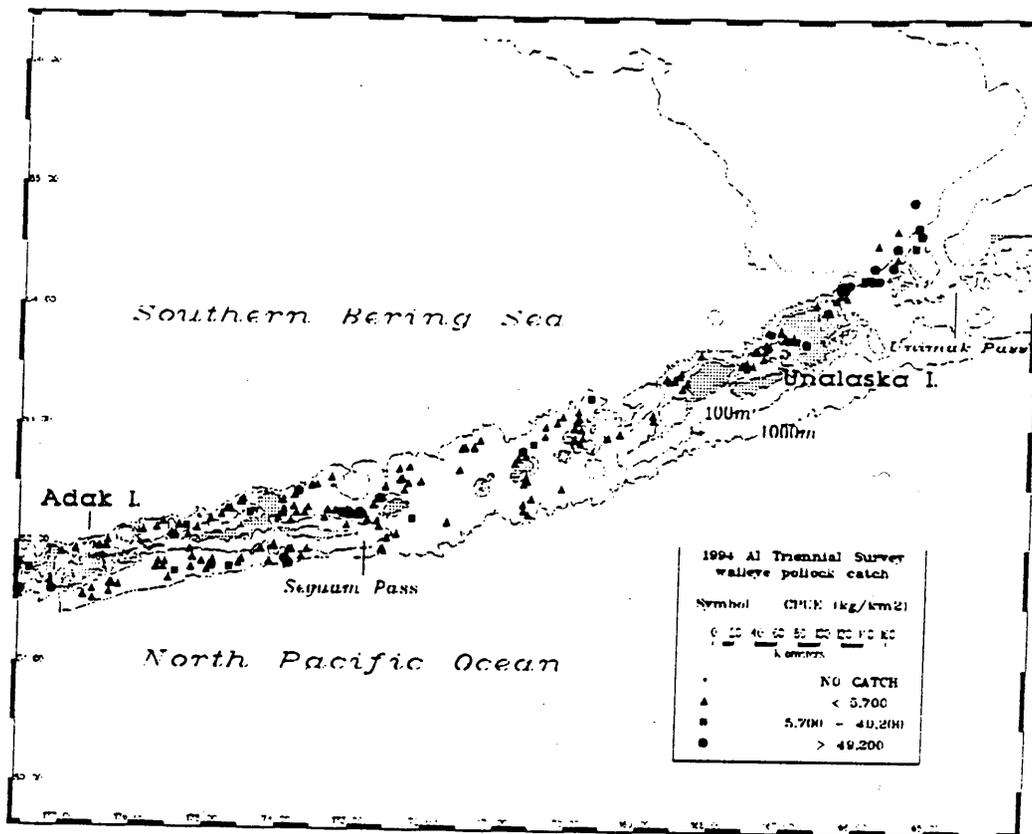


Figure 1.9. - Walleye pollock catch distribution and relative abundance during the NMFS 1994 Aleutian Islands triennial survey. Catch abundance categories are: 1) none, 2) less than the mean (5,700 kg/km²), 3) between the mean and two standard deviations and 4) greater than two standard deviations above the mean.

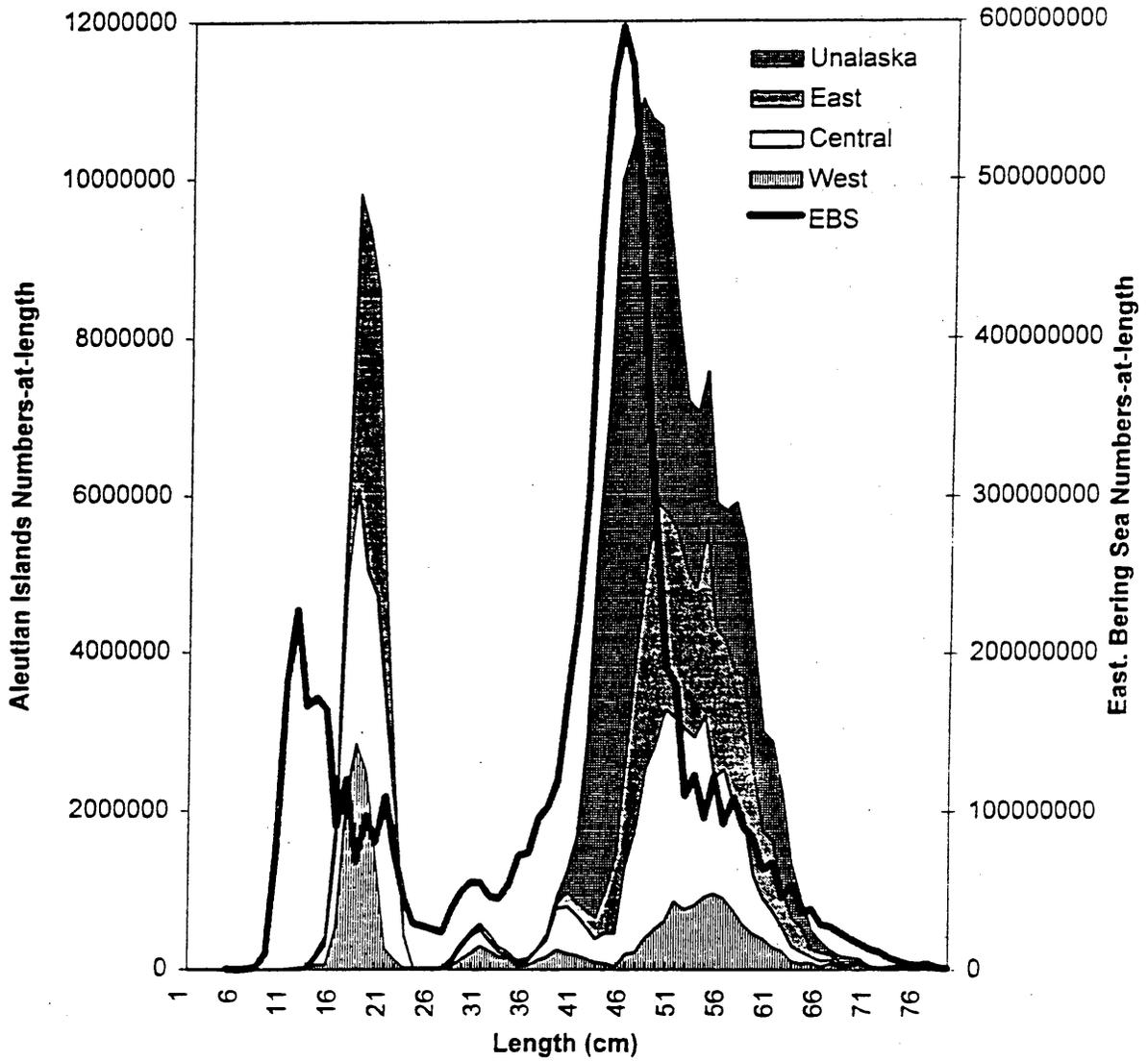


Figure 1.10--Length frequency of pollock in the 1994 eastern Bering Sea bottom trawl survey, and the 1994 Aleutian Islands bottom trawl survey by subarea.

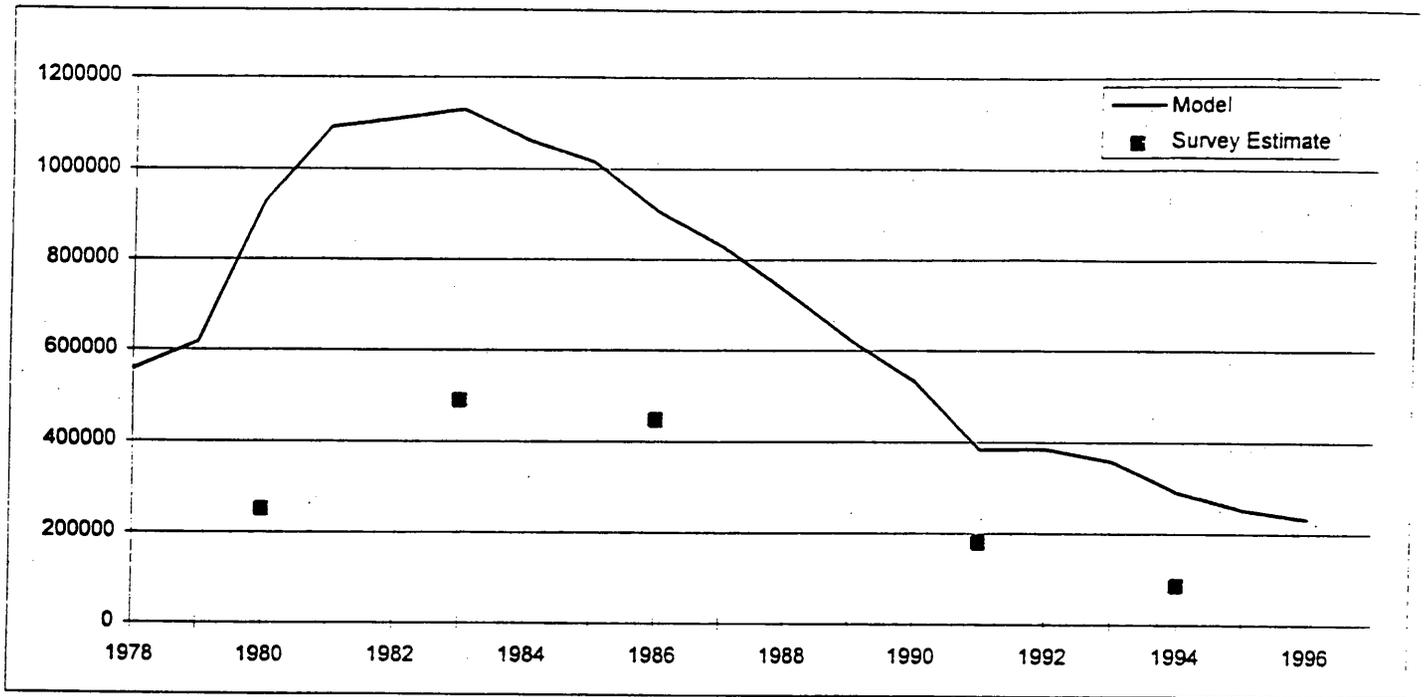


Figure 1.11.--Estimated age 3+ biomass trend of Aleutian Islands pollock by bottom trawl surveys (squares) and catch-age modeling (line), 1978-1996.

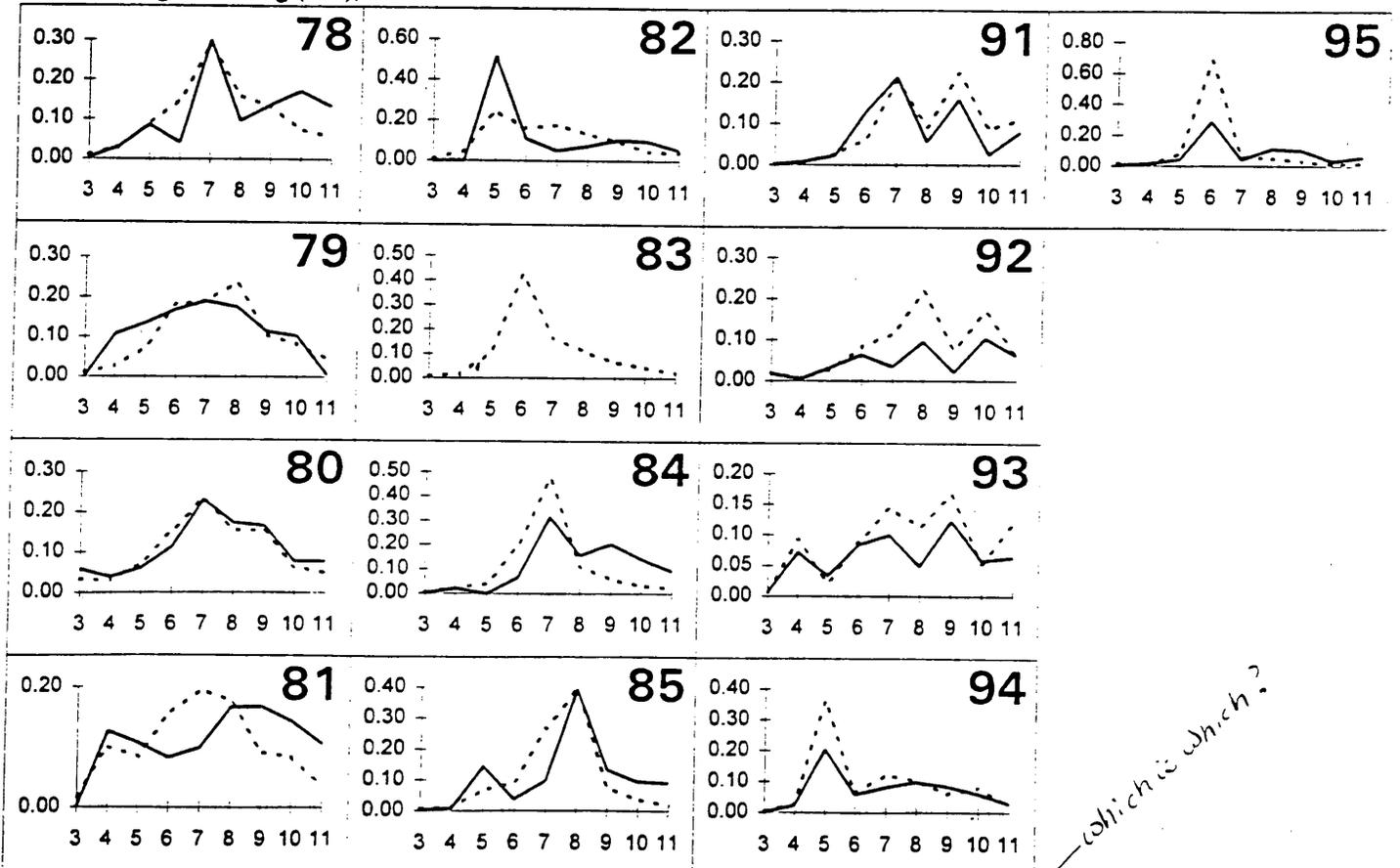


Figure 1.12.-- Aleutian Islands survey and catch-age model estimates of proportion at age, 1979-1995.

— which is which ?

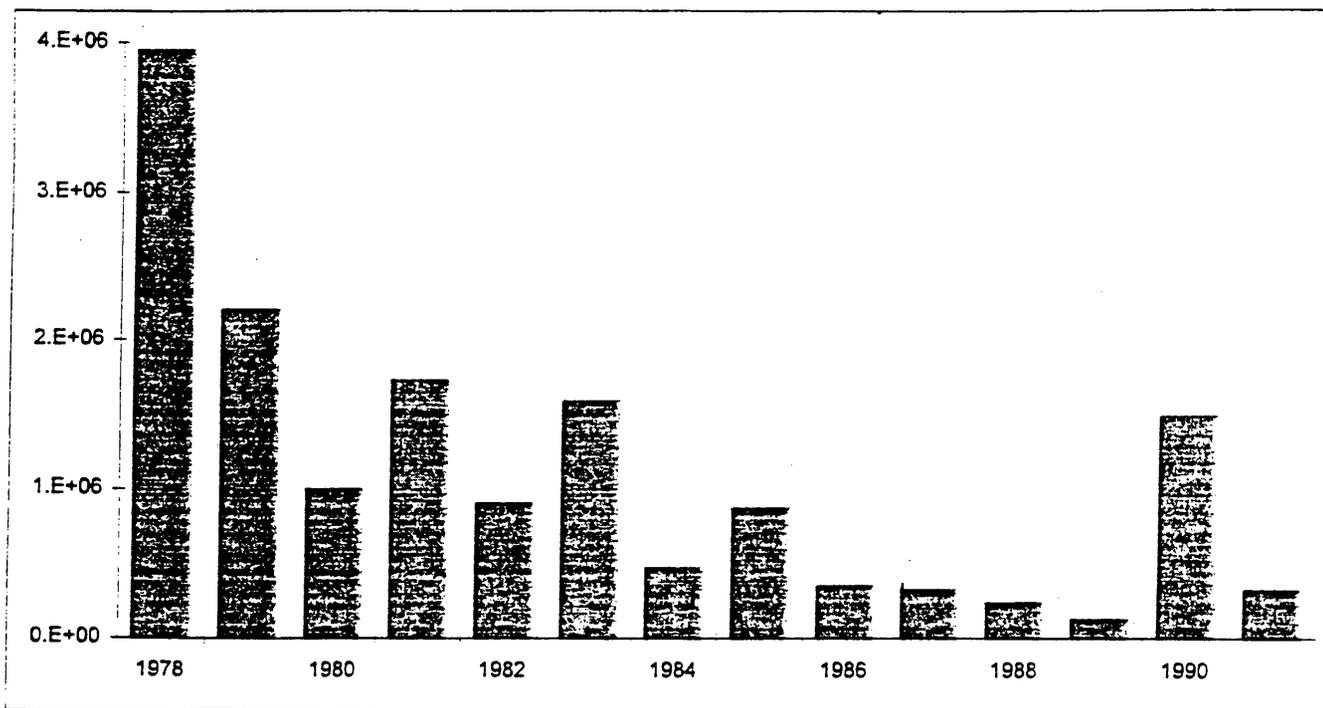


Figure 1.13.-- Estimated year-class abundance at age 1 in the Aleutian Islands area based on catch-age analysis.

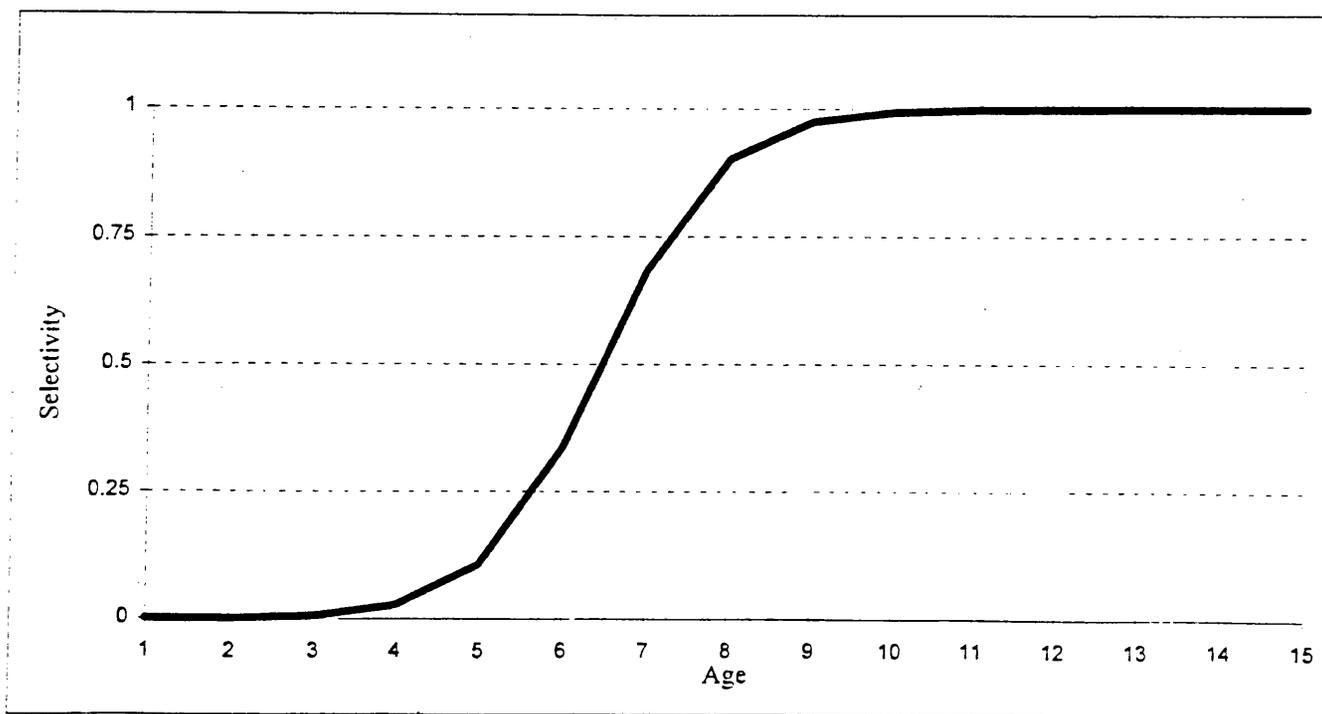


Figure 1.14.-- Fishery selectivity of Aleutian Island pollock as estimated by catch-age analysis.

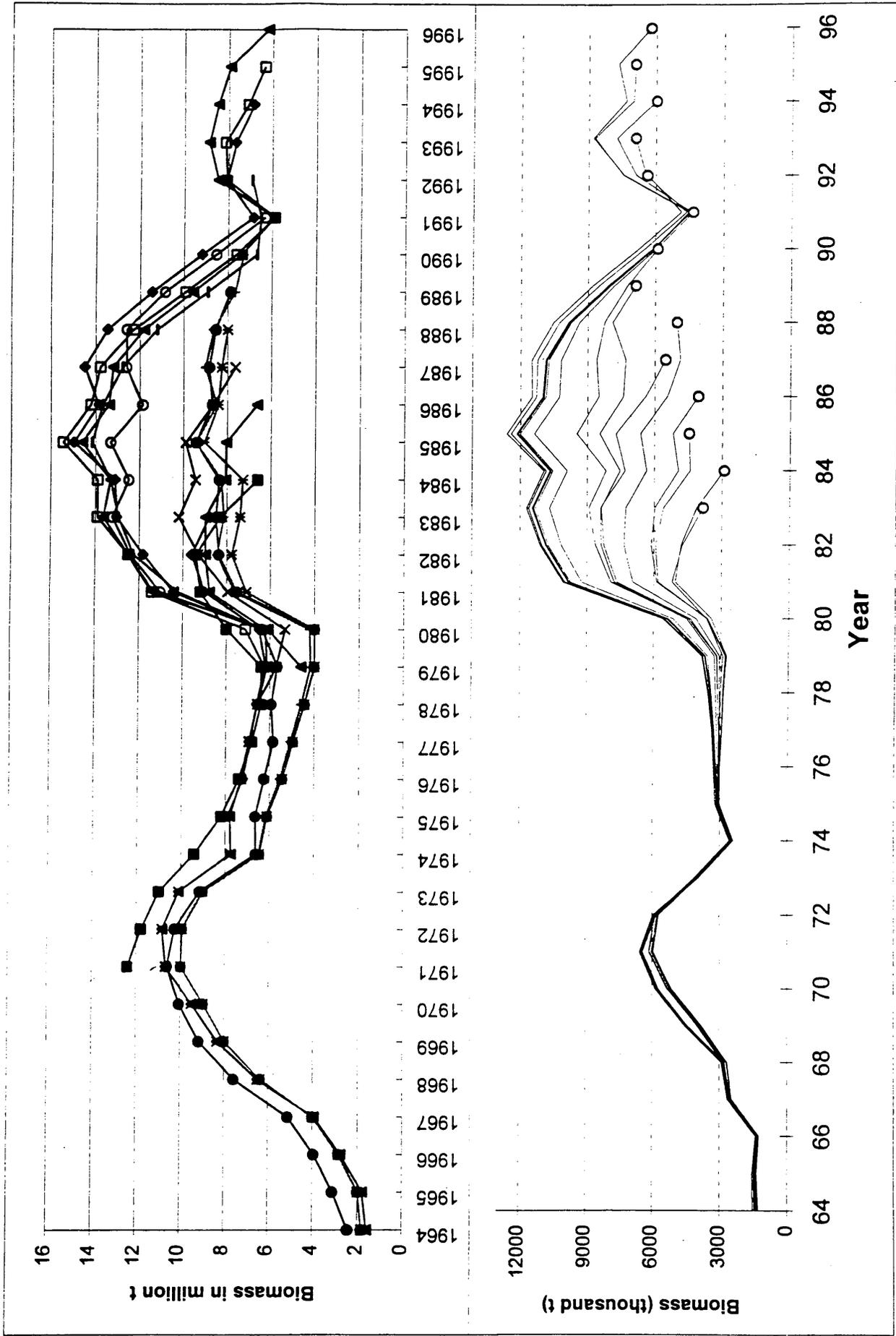


Figure 1.15.--Retrospective estimates of eastern Bering Sea pollock from cohort analysis (upper panel) and Bayesian ASA (lower panel) by assessment year, 1964-1996.

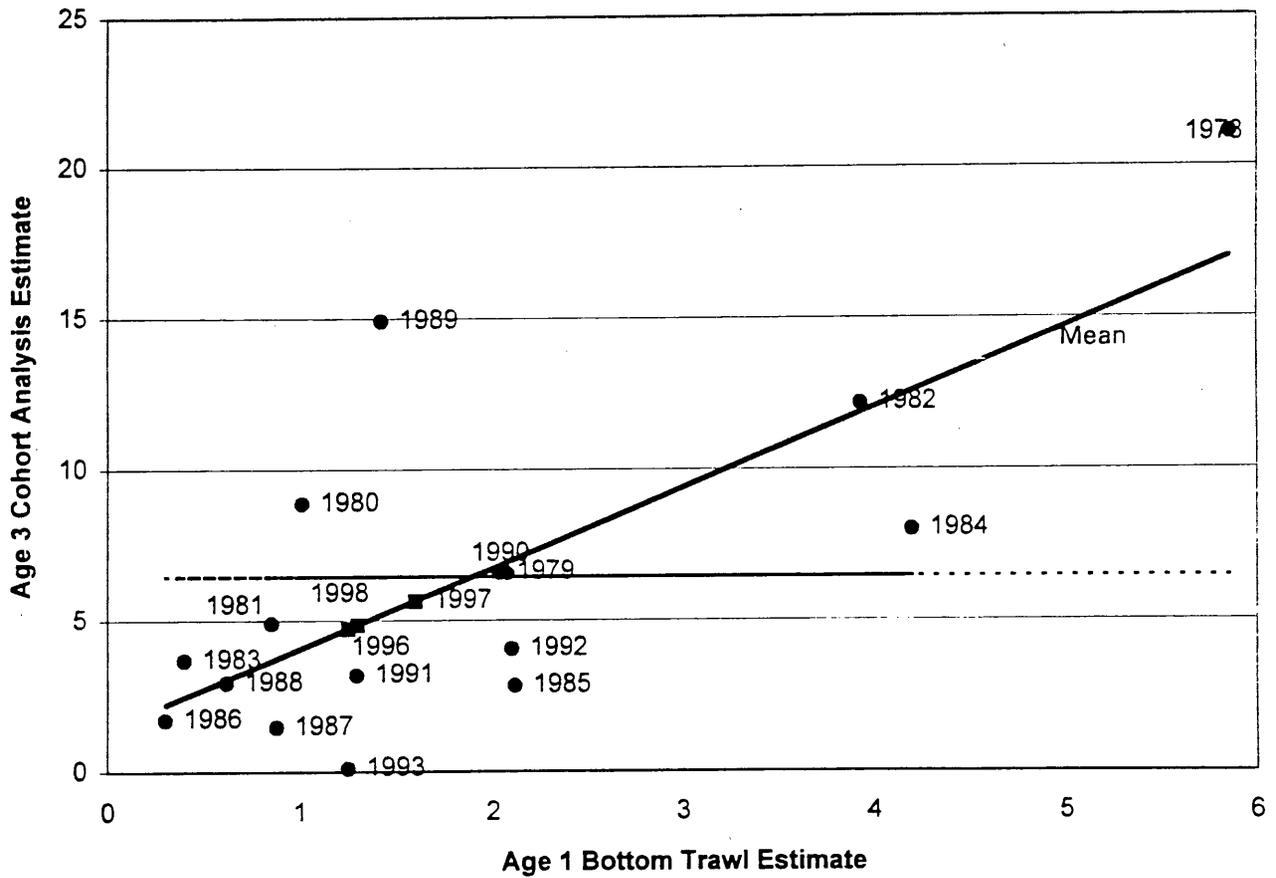
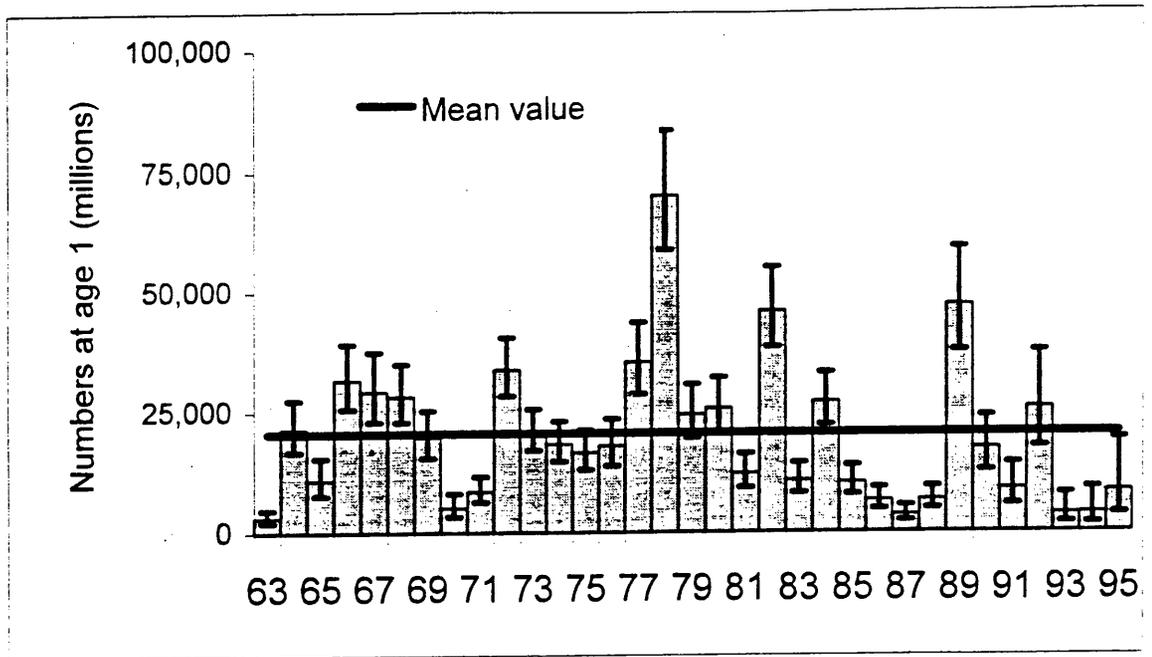


Figure 1.16 -- Top Panel: Age 1 Abundance Trend from Bayesian ASA, 1963-1996. Lower panel: Eastern Bering Sea pollock recruitment index: relationship of age 1 survey abundance to age 3 cohort Analysis estimates by year-class. Predicted 1996, 1997, and 1998 age 3 recruitment shown by labeled squares.

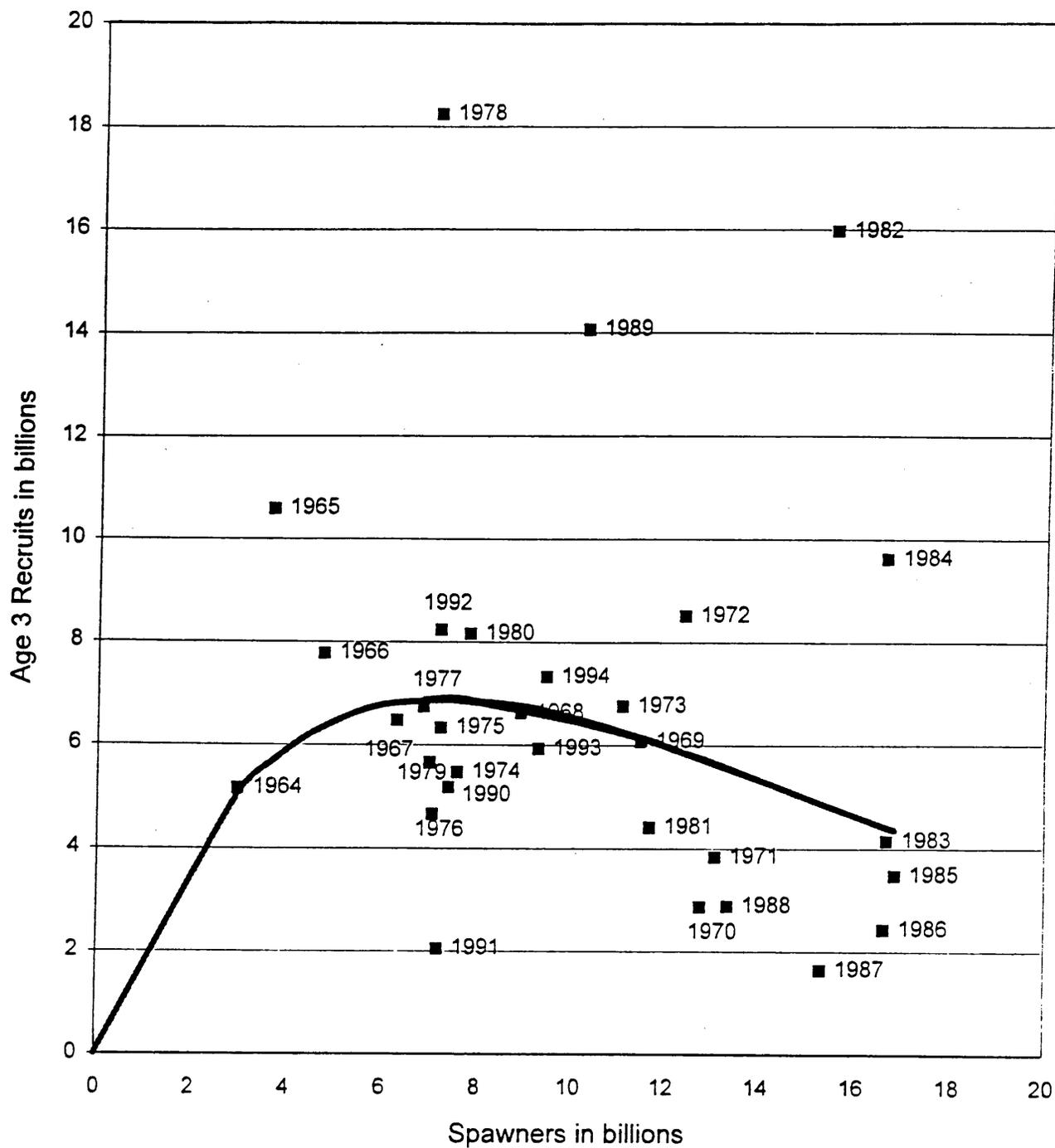


Figure 1.17.-- Eastern Bering Sea pollock spawner-recruit relationship, 1964-1994 year-classes.

Section 1

SUMMARY OF CHANGES TO THE GULF OF ALASKA POLLOCK DOCUMENT

The ABC recommendation for the 1997 fishing season for walleye pollock is 74,400 t in the Western and Central regulatory areas and 6,800 t for the Eastern regulatory area. The ABC for the Eastern regulatory area was calculated using the relative proportions of pollock biomass in the Western-Central and Eastern regulatory areas observed in the 1996 bottom trawl survey.

New information incorporated in this SAFE chapter included: the 1996 triennial bottom trawl biomass estimate, the 1996 Shelikof Strait echo integration trawl survey biomass estimates, length frequency information from this survey, and 1995 catch-at-age data. A sensitivity analysis was conducted in this assessment to explore the impact of a variety of assumptions regarding emphasis on survey biomass estimates and the catchability of the bottom trawl survey. The 1996 EIT estimate of pollock abundance in Shelikof Strait was 745,400 t compared to 725,200 t from the 1995 survey. The 1996 triennial bottom trawl biomass estimate for the entire Gulf of Alaska was 707,434 t. The predicted begin year biomass in 1997 is 1,105,420 t. The expected increase in biomass in 1997 is due to an incoming strong 1994 year class.

The recommended ABC harvest rate is 0.275, and was based on new NPFMC harvest guidelines. This rate is lower than $F_{40\%}$ (0.329), $F_{35\%}$ (0.390) and $F_{30\%}$ (0.468). The recommended fishing mortality in 1997 is lower than $F_{40\%}$ because the projected female spawner biomass in 1997 (237,258 t) is below the $B_{40\%}$ level of 289,689 t.

program calculates the population numbers-at-age on the mid-date, assuming constant fishing and natural mortality throughout the period. The standard errors associated with survey estimates of abundance were included as well. Standard errors for the EIT biomass estimates observed in 1992 were applied for all subsequent surveys.

Egg production estimates of spawning stock biomass were included in the model by setting the age specific selectivity pattern equal to the estimated percent mature at age (Hollowed et al. 1991). The catchability coefficient (Q) for the egg production estimates was assumed to be equal to that estimated for the EIT survey of Shelikof Strait .

Years with similar selectivity patterns were combined as discussed in Hollowed et. al. (1994, 1995). Originally, year specific selectivity curves were estimated for the years 1972 - 1974, and 1985 - 1993 and a single selectivity curve was estimated for the years 1975-1984. In the 1995 assessment, the selectivity patterns estimated for 1989 and 1990 were very similar, and the 1992 and 1993-95 selectivity patterns both peaked at age 5. Based on these observations, the preliminary stock assessment model utilized a single selectivity pattern for the period 1989-90 and the period 1992-1997. In this assessment the selectivity patterns for recent years was re-examined (see below).

Description of Stock Assessment Runs

New pieces of information used in the 1996 model included: a) the 1996 spring EIT survey estimate of spawning biomass in Shelikof Strait, b) the 1996 EIT survey length frequency data. c) the 1995 fishery age composition data. d) catch information for 1995, the 1996 bottom trawl biomass estimate, and estimates of the number of age 2 and 3+ fish captured in the 1996 bottom trawl survey. A sensitivity analysis was conducted to examine the impact of various model configurations (Appendix 1). The overall fit of the Stock Synthesis models (see description of stock assessment runs) is documented in Appendix 1. The results of these exploratory runs revealed that the egg production index should be included in model runs, the 1984 bottom trawl survey could be re-introduced, and the number of length bins could be reduced from 10 to 7.

Six additional exploratory runs were made after receiving the 1996 bottom trawl data. Differences between models is outlined in the following configurations:

Model	Fishery Selectivity 1992 - 1995	Bottom Trawl Survey Selectivity	Foreign Fishery Selectivity	Age 7+ Natural Mortality	EIT Emphasis
Model A	Combined*	Free	Free	0.3	1.00
Model B	Separate**	Free	Free	0.3	1.00
Model C	Separate	Asymptotic	Free	0.41	1.00
Model D	Separate	Asymptotic	Asymptotic	0.46	1.00
Model E	Separate	Free	Free	0.3	0.0001
Model F	Separate	Asymptotic	Asymptotic	0.733	0.001

**Separate = 1987-1988 combined, 1991, 1992, 1993, 1994, 1995-1996 combined

*Combined = 1986, 1987, 1988, 1991 - 1996 combined

Model A is configured in the same manner presented in the preliminary SAFE with the exception that information from the 1996 bottom trawl survey was used. Examination of the results of Model A revealed poor fits to the recent domestic fishery age composition data. Therefore, Model B was included to examine the influence of using separate selectivity vectors for the period 1992 - 1995. Model C explored the influence of assuming the bottom trawl survey selectivity was asymptotic and that fish age 7 and older exhibit higher natural mortality. The higher natural mortality rate was estimated by the model. Model D explored the possibility that the selectivity of all bottom trawls, whether they were used in the foreign fishery or the bottom trawl, was asymptotic and natural

mortality for older fish was estimated in the model. Model E explored the impact of placing low (0.0001) emphasis on the EIT survey biomass, age composition and length composition data. Model F explored the influence of placing a low emphasis on EIT data when bottom trawl and foreign fishery selectivity patterns were assumed to be asymptotic.

ASSESSMENT PARAMETERS

With the exception of Models C, D and F, natural mortality was assumed to be 0.3 for all ages. Hollowed and Megrey (1990) estimated natural mortality using a variety of methods including estimates based on: a) growth parameters (Alverson and Carney, 1975, and Pauly (1980), b) GSI (Gunderson and Dygert, 1988), c) monitoring cohort abundance, and d) stock synthesis. These methods produced estimates of natural mortality that ranged from 0.24 - 0.30. Additional information regarding synthesis model results under a variable natural mortality schedule is found in Appendix 1. The maximum age observed was 22 years. We used the maturity at age schedule from Hollowed and Megrey (1991):

	AGE									
	2	3	4	5	6	7	8	9	10+	
MATURITY	0.034	0.116	0.325	0.639	0.867	0.960	0.989	0.997	1.000	

Weight-at-age estimates (Table 1.5) used in the Stock Synthesis model were derived from length-weight and length-age relationships estimated by Hollowed et al. (1995). Parameters for these relationships, were derived using growth information from six strong cohorts of pollock (1972, 1975-1979). Estimates of mean weight at age were determined by a five-step process. First, length at age was estimated from fits to the von Bertalanffy growth equation for each of the seven cohorts for each sex and area cell. Second, the estimates of length at age were averaged across years and area to produce an expected length at age for each sex. Third, parameters for a length - weight relationship were calculated for each year class, sex, and area using the equation:

$$W = a * L^{\beta} \quad [2]$$

where L and W were the observed length and weight. Fourth, the length-weight parameters for each year class for each sex and area, were applied to the estimate of mean length at age for the sex/ area cell. These estimates were averaged over year class to obtain an estimate of weight at age for each of the sex/ area cell. Finally, the estimates were averaged over sex and area to obtain a single estimate of weight-at-age (Table 1.6). The parameters for Equation 1 fit to the mean of the fitted length at age for males and females combined were $L_{\infty} = 56.20$ cm and $k = 0.328$. Parameters for equation 2 fit to the mean of the fitted length and weight for males and females combined were, $a = 1.27 \text{ E-}05$ and $\beta = 2.885$.

Parameters for equation 1 were also estimated from the 1991 and 1992 age - length data collected from the EIT survey. The estimated parameters were $L_{\infty} = 12.7$, $L_{\text{max}} = 59.7$, and $k = .234$. These growth parameters were used to develop the transition matrix used to incorporate length frequency data used in the Stock Synthesis model.

ABUNDANCE TRENDS

Triennial Bottom Trawl Survey

The Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering (RACE) Division, conducted the fifth comprehensive triennial bottom trawl survey during the summer of 1996. Chartered commercial bottom trawlers conducted trawling operations in the Gulf of Alaska. All vessels used standard RACE Division Poly-Nor'eastern high opening bottom trawls rigged with roller gear. These trawls are

constructed with 5" stretched-mesh polyethylene web with a 1-1/4" mesh nylon liner in the cod end. Trawl tows were 15 min. in duration. A total of 804 successful tows were achieved throughout the survey area.

The gulfwide biomass estimate of pollock was 707,434 t (95% CI 509,934 t -904,934 t). The time series of pollock biomass used for the stock synthesis model is based on regions west of Cape St. Elias, 653,905 t, a 14% drop from 1993 (Table 1.6). The long term trend in pollock biomass in regions west of Cape St. Elias has been remarkably flat (Table 1.6).

The regional distribution of pollock biomass shifted between each of the five bottom trawl surveys. In 1996 the largest concentration of pollock biomass was in the Chirikof area (39%), followed by the Kodiak (30%) and Shumagin areas (22%) (Table 1.7). Large concentrations of pollock were observed in the western Gulf of Alaska, Shumagin Islands, and in regions surrounding Kodiak Island (Figure 1.2).

Relative to 1993, pollock biomass estimates in the eastern Gulf of Alaska (Yakutat and Southeast combined) increased 45%. Most of this increase occurred in the Southeast area in the shallow 0-100m depth range (Table 1.7). 1996 was the first year bottom trawl samples were taken in shallow waters in the Southeast region. The biomass in the Yakutat region dropped from 35,413 t in 1993 to 19,587 in 1996.

1996 Echo Integration Trawl Survey

Scientists from the Alaska Fisheries Science Center (AFSC) conducted an EIT survey directed at walleye pollock in the Gulf of Alaska from March 15 -27, 1996. This was the latest in a series of annual surveys which have been conducted since 1981 (except 1982) to assess the spawning biomass of pollock in the Shelikof Strait area. A more complete description of the survey is provided by Wilson et al. (Appendix 1).

The 1996 biomass estimate for pollock in Shelikof Strait was 745,400 t (Appendix 1). This estimate was adjusted, as described below, to 588,870 t to allow comparison with estimates from earlier surveys (1981-1991) which were generated with an older, less sophisticated acoustic system.

Earlier work had demonstrated that similar biomass estimates were obtained between the present acoustic system and the older system when the volume backscattering (S_v) threshold of the new system was adjusted to -58.5 dB (Hollowed et al. 1992). Because of the newer system's lower noise level, abundance estimates since 1992 have been based on an S_v threshold of -69 dB. For the 1992 and 1993 surveys, a biomass estimate was produced for each S_v threshold. The average of the two biomass ratios (-58.5/-69) for these surveys was used to adjust current abundance estimates (-69 dB) to values comparable with the earlier estimates (Hollowed et al. 1994). The average ratio (0.79) has been used since 1994 to adjust the abundance estimates.

Egg Production Estimates of Spawner Biomass

Estimates of spawning biomass in Shelikof Strait derived from egg production methods were included in this assessment. A complete description of the estimation process is presented by Picquelle and Megrey (1993). The estimates of spawning biomass in Shelikof Strait show a pattern similar to the hydroacoustic survey (Table 1.6). The annual egg production spawning biomass estimate for 1981 is questionable because of sampling deficiencies during the egg surveys for that year (Picquelle and Megrey 1990).

Alaska Department of Fish and Game Surveys

The Alaska Department of Fish and Game (ADFG) has conducted standardized bottom trawl surveys of nearshore areas of the Gulf of Alaska since 1987. These trawl surveys are designed to estimate the population trends of Tanner crab and red king crab. Walleye pollock and other fish are captured incidentally in the crab surveys making them a potential source of information for the pollock stock assessment. Although there is considerable overlap between the NMFS triennial survey and the ADF&G crab survey, the ADF&G crab survey

has a higher density of sampling stations in the nearshore areas that could augment the NMFS triennial bottom survey. In addition, the ADF&G survey samples some areas that are not assessed by the NMFS vessels.

Details of the equipment utilized and the sampling procedure can be found in Blackburn and Pengilly (1994). Bottom trawls were first utilized to survey the crab populations in 1980 and completely replaced pot gear surveys in 1988 (Urban 1993). Standardized survey methods were employed from 1987 to the present. The survey was restricted to the Kodiak region in 1987. Budget restrictions in 1991 limited the amount of finfish data that were recorded.

Biomass trends are documented within three regions (Kodiak, Chignik and South Peninsula). The most complete time series of biomass estimates is for the Kodiak region (Table 1.6). The Kodiak region had the highest biomass estimates until 1993 when the concentration shifted to the South Peninsula region. This westward shift in pollock biomass is similar to that observed in the 1993 NMFS triennial survey (Hollowed et al. 1994). Within regions, the pollock abundance shifted from the eastern side of Kodiak Island to the area northeast of the Shumagin Islands (Hollowed et al 1994).

1996 Stock Assessment Model Results

Examination of the likelihoods for each of the Models revealed that Model B provides the best fit to the data available (Table 1.8). Exploratory runs revealed a marked improvement in the overall fit of the model when selectivity patterns for recent years were estimated separately (Table 1.9). Fixing the bottom trawl selectivity and foreign fishery selectivity to be asymptotic degraded the fit to the age composition data from all sources (Table 1.8). Reducing the emphasis on EIT survey data resulted in a marked improvement to the bottom trawl and domestic fishery age composition data. Model F produced a much higher biomass trend with a peak begin year biomass estimate for age 3+ fish of 8.5 million t. This high biomass is achieved by estimating a low selectivity for young fish (age 2 - 6 is less than 35%). The results of Model F demonstrate the danger of eliminating the EIT survey biomass estimates from the analysis. Since the bottom trawl time series shows little variation over the period 1975 - present, the model can adjust fisheries and survey selectivity to fit the age composition time series in a variety of ways. Furthermore, removing the 1996 EIT survey length composition data resulted in an unreasonably large estimate of the 1994 year class of 12 billion age 2 fish. Model B was chosen as the best estimate of the status of the pollock resource in 1996.

Estimates of survey selectivity from Model B are consistent with the assumption that the spawning population in Shelikof Strait does not include all of the pollock within the Western-Central Gulf of Alaska. The steeply sloping descending limb of the EIT selectivity pattern suggests that many of the older fish are unavailable to the survey (Table 1.9).

Population trends were similar in both the 1995 and 1996 assessment models (Figure 1.3). The years 1964-1968 were truncated from the biomass time series because these biomass estimates were influenced by initial starting conditions. Comparison of the 1995 and 1996 models revealed that the 1996 model has a slightly higher biomass level in most years (Figure 1.3). Estimates of recruitment revealed the age 2 year class in 1996 is expected to be larger than any observed incoming year class (Figure 1.3). Time series of spawner biomass and recruitment estimates for this model are found in Table 1.10.

The fit of the model to the survey biomass estimates was best during recent years (Figures 1.4-1.6). In general the model provides a good fit to the age composition and length composition data from fisheries and surveys (Figure 1.7). As with previous models, the model produced poor fits to the early EIT and egg production biomass estimates (Figures 1.4 and 1.6) and the 1981 EIT age composition (Figure 1.7). Trends in fishing mortality generated from the 1996 model are shown in Table 1.10. Please note, however, that full selection fishing mortality rates have little meaning independent of the schedule of the age-specific selectivity estimates for each fishery.

TRENDS IN YEAR CLASS STRENGTH

1996 Bottom Trawl Survey Length Frequency

Length frequency distributions from the 1996 bottom trawl survey show evidence of a strong 1994 year class in the Western and Central Gulf of Alaska (Figure 1.8). In the Eastern Gulf of Alaska, and the Shumagin region, a second small length mode was observed (the 1995 year class) (Figure 1.8). A rough estimate of the number of age 2 fish (the 1994 year class) in the Western and Central Gulf of Alaska can be made by summing the total number of fish between 21 and 28 cm (138,000,000 fish). This number is higher than the previous estimate of age 2 fish in 1993 of 47,600,000 fish (Table 1.11).

Echo Integrated Trawl Survey Length Frequency

Annual length frequency distributions from the 1989 to 1996 acoustic mid-water trawl surveys in Shelikof Strait show the movement of the strong 1988 year class through the population (Figure 1.9). In 1994 a bi-modal distribution of population numbers was observed, suggesting that the 1993 year class of pollock may be a moderate year class. In 1995 and 1996, evidence of an apparently strong 1994 year class was present. A rough estimate of the number age 2 pollock observed in the 1996 EIT survey was calculated by summing the number of fish observed between 16 and 26 cm. Based on this rough calculation, the 1994 year class should be approximately equal to the 1979 year class (Table 1.12).

ADF&G Crab Survey Length Frequency

Length-frequency diagrams for the Kodiak, and combined Chignik and S. Peninsula region for 1988-1993 (excluding 1991) reveal a strong mode of large fish (> 45 cm) (Figure 1.10 and 1.11). The predominance of large fish in the ADFG survey may result from the selectivity of the gear. The configuration of the ADFG crab survey net is designed to capture bottom organisms like crab. Small pollock (< 20 cm) were observed in the Kodiak region in 1988, 1989 and 1995 (Figure 1.11).

Fisheries Length Frequency

Recent information on length frequency was available from the 1995 and 1996 fisheries. Length distributions of pollock landed by fisheries in the Gulf of Alaska were based on data collected by port samplers and domestic observers. Nelson et al. (1981) described the sampling procedure used by observers to obtain length frequency data.

Examination of the 1995 and 1996 commercial fishery length frequency for regions and sex revealed that large (> 40 cm) fish dominated the catch in these two years (Figures 1.12, 1.13). Small fish were not observed in the 1995 fishery data. However, evidence of the 1994 year class was noted in the Kodiak and Shelikof regions by a mode of unsexed fish between 18 and 25 cm in the 1996 data (Figure 1.13).

1995 Fishery Catch at Age

Otoliths collected during the 1995 commercial fishery were aged using the revised criteria described in Hollowed et al. (1995). Age samples were stratified by four regions (Shumagin, Kodiak and Chirikof combined, and Yakutat) and three trimesters (when possible) as follows:

Region	Temporal Strata	No. Ages		No. Lengths	
		Female	Male	Female	Male
Shumagin	First and Second Trimester	128	133	6,027	6,941
Kodiak and Chirikof	First Trimester	188	169	7,217	7,751
Kodiak and Chirikof	Second Trimester	279	234	11,357	9,760
Kodiak and Chirikof	Third Trimester	97	94	5,822	8,583
Yakutat	First Trimester	74	63	2,172	1,648

These age samples were used to estimate catch at age following the methods of Kimura (1989). The catch-at-age data show strong 1988 and 1989 year classes (Tables 1.3 and 1.13). The 1989 year class (age 6) dominated the Shumagin region data, and the Kodiak and Chirikof second trimester data. In 1995, the 1988 and 1989 year classes were present in roughly equal proportions in the Kodiak and Chirikof regions in the first and third trimesters (Table 1.13). The 1988 year class was most abundant in the Yakutat region in 1994 and 1995 (Table 1.14).

Wespestad et al. (1994) presented evidence of a strong 1989 year class of Bering Sea pollock. The presence of the strong 1989 year class in the Shumagin INPFC region might suggest widespread mixing of pollock stocks between the Bering Sea and Gulf of Alaska. Alternatively, 1989 oceanic conditions may have favored recruitment in the western Gulf of Alaska more than in the central portion.

1993 Bottom Trawl Age Composition

The age composition of the 1993 NMFS triennial bottom trawl survey revealed strong 1988 (age 5) and 1989 (age 4) year classes (Table 1.11).

Other Sources of Recruitment Information

Scott Hatch of the Alaska Fish and Wildlife Research Center noted that the consumption of juvenile pollock by marine birds in 1991 was low, suggesting a below-average 1991 year class. More recent information on Tufted Puffin diets shows evidence of a strong 1994 year class.

FOCI Prediction

The Fisheries Oceanography Coordinated Investigations (FOCI) group annually makes a prediction regarding incoming year class strength for pollock in the Gulf of Alaska. Historically six sources of information are utilized in making this prediction: quantitative results from a refitting of the nonlinear transfer function time series model, quantitative results from analysis of time series of recruitment data points, and four qualitative sources of information. In 1996, four qualitative elements were available.

1996 Year Class Prediction

This forecast is based on four elements, three of which involve purely physical properties, and one of which involves a biological survey: 1) observed Kodiak rainfall, 2) wind mixing energy at [57N, 156W] computed from sea-level pressure gradient analyses, 3) advection of ocean water in the vicinity of Shelikof Strait as inferred from drogued drifters deployed during the spring of 1996, and 4) rough counts of pollock larvae from a survey conducted during late May 1996.

KODIAK RAINFALL - According to FOCI's conceptual model of survival, above average precipitation in late winter indicates greater frequency of storms (and increased circulation because of their winds) and greater stored water for spring and summer runoff (Megrey et. al. 1996). These factors promote good recruitment. Above average spring and early summer rainfall favors increased baroclinity after spawning. Because baroclinity is associated with eddy formation, above average spring/early summer rainfall is also considered good for recruitment.

1996 Kodiak rainfall statistics

During 1996, there was below average precipitation for all months except April:

Jan	41% of average (1962-1991)
Feb	36%
Mar	36%
Apr	231%
May	31%
Jun	43%

These figures indicate that 1996 precipitation has generally not, been conducive to larval survival. By computing the departure of each month's observed total rainfall from the 30-year mean, then weighing those departures by the representative month's contribution to the conceptual model of survival, a quantitative estimate of rainfall's cumulative expected effect on recruitment is calculated.

Based on precipitation data alone, the proportion of the 1996 year class spawned in Shelikof Strait would be projected to exhibit weak to average recruitment (numerical score of 1.72 in the continuum of 1 (weak) to 3 (strong)).

WIND MIXING - FOCI's conceptual model suggests that strong wind mixing prior to spawning is beneficial because it conditions the water for larval feeding. After hatching, weak wind mixing is advantageous as demonstrated by Bailey and Macklin (1994).

1996 wind mixing statistics

During 1996 wind mixing was generally counter to that expected to promote survival of young fish. The exception was in February when mixing energy was about twice the 30-year average.

Jan	69% of average (1962-1991)
Feb	193%
Mar	29%
Apr	147%
May	107%
Jun	108%

By computing the departure of each month's observed mixing from the 30-year mean, then weighing those departures by the representative month's contribution to the conceptual model of survival, a quantitative estimate of mixing's cumulative expected effect on recruitment is calculated.

Based on wind mixing data alone, the proportion of the 1996 year class spawned in Shelikof Strait would be projected to exhibit weak to average recruitment (numerical score of 1.67 in the recruitment continuum of 1 (weak) to 3 (strong)).

ADVECTION - We examined trajectories of drifters drogued at typical larval depths that were released during spring 1996 in the Shelikof Strait region. Circulation was sluggish with long-lasting eddies. Because transport was so low, this physical process would retain pollock larvae on the shelf, which is considered beneficial to larval survival. However, it is not clear that such circulation would allow larvae to reach the Shumagin Islands, which may be an important destination for survival. Also, based on estimates of wind driven circulation, the pre-spawn circulation may not have been very vigorous. Based on a qualitative evaluation of advection only, the potential is for an average to strong year class. It should be noted that advective conditions encountered in spring 1996 are unique and their effects on pollock recruitment are without historical precedence. Large concentrations of *Phaeocystis*, a musilage producing algae were also encountered, which is unusual.

LARVAL ABUNDANCE - Intuitively, strong recruitment should not occur if year class larval abundance is low. However, high larval abundance does not necessarily guarantee high recruitment, because of the possibility of high mortality after the larval stage. FOCI has conducted larval surveys since the mid-1980s to develop a larval abundance index. This index can only be used to predict years of weak recruitment (i.e. years of low abundance). Furthermore, these larval abundance indices are from rough counts made at-sea and do not account for mortality (small larvae are known to have very high mortality rates, so larval size needs to be accounted for). Mortality - adjusted larval abundance indices may vary from larval abundance from rough counts. However, an absence of larvae in the rough counts is indicative of recruitment failure in the historical data.

1996 larval abundance statistics

From a FOCI survey of late larvae conducted during the last part of May 1996, rough counts of late-stage pollock larvae are relatively evenly distributed over the survey grid, and show abundance that is categorized as average to strong (~450 larvae per 10 square meters).

Conclusion

Based on these four elements and the weights assigned in the table below the preliminary FOCI forecast of the 1996 year class is average ("a").

Element	Weight	Rank	Score	Total
Rain	0.250	w-a	1.72	0.43
Mixing	0.250	w-a	1.67	0.42
Advection	0.250	a-s	2.50	0.63
Larval abundance	0.250	a-s	2.50	0.63
Total	1.000			2.10
Forecast				a

Legend: a = average, w = weak, s = strong.

1995 Year Class Prediction

With the addition of information from the 1996 EIT survey, FOCI is able to include the EIT length element into the forecast of the 1995 year class. Preliminary survey results put the 1995 year class in the weak category as determined by Wilson et. al. (in press).

Incorporating the EIT length forecast rank and adjusting the weights of the forecast elements gives a revised forecast of average ("a") recruitment for the 1995 year class of walleye pollock in Shelikof Strait.

1995 Year class (Revised)

Element	Weight	Rank	Score	Total
Time series model	0.150	a	2.00	0.30
Time sequence	0.150	s	3.00	0.45
EIT length	0.300	w	1.00	0.30
Rain	0.100	a-s	2.50	0.25
Mixing	0.100	a	2.00	0.20
Advection	0.100	a	2.00	0.20
Larval abundance	0.100	s	3.00	0.30
Puffin diet	0.000	----	0.00	0.00
Total	1.000			2.00
Forecast				a

1994 Year Class Prediction

FOCI estimated the 1994 year class to be strong. Information from the 1995 and 1996 EIT shows that the abundance of the 1 and 2 -year-olds (the 1994 year class) is high. This year class made up almost 15% of the assessed biomass at age 1. Also information from tufted puffin nesting diets shows a strong 1994 year class. These data are somewhat questionable because prey selectivity preferences make it difficult to infer population abundance from diet data alone. In addition, the information is from Middleton Island only, and may not be reflective of gulfwide patterns. Recent bio-physical modeling results indicate that simulated late larval and age-0 juvenile distributions for 1994 show similarities to those for 1978, which produced a very strong year class in contrast to distributions for 1987, and 1988 which produced weaker year-classes (Hermann pers. Comm.). The revised prediction is consistent with the previous prediction of average to strong.

REFERENCE FISHING MORTALITY AND YIELDS

Estimation of Reference Points

The Stock Synthesis model was used to estimate $F_{30\%}$, $F_{35\%}$, and $F_{40\%}$. Unlike previous years the model included age 2 pollock. Spawner biomass was used in the estimation of spawner biomass per recruit. Spawn month was assumed to be March 15th. Following Plan Team requests, the 1994 year class was set equal to the median of the upper quartile of the estimated recruitment. Estimates of full recruitment fishing mortality at $F_{40\%}$, $F_{35\%}$, and $F_{30\%}$ ranged between 0.329 and 0.468 (Table 1.15).

Estimates of $F_{30\%}$, $F_{35\%}$, and $F_{40\%}$ are all sensitive to assumptions regarding the selectivity pattern of the fishery. Hollowed et al. (1994) observed that selectivity patterns of the pollock fishery appear to change over time. They found that two patterns of fishery selectivity are evident in the pollock fishery, a steeply ascending pattern that tends to occur when weak year classes are present, and a more gradual ascending curve that occurs when recruitment is strong and an older group of fish is still present in the population. To address this issue, three selectivity scenarios were examined:

Scenario 1: An average selectivity based on the domestic fishery selectivity (1985 - Present) was used to estimate $F_{40\%}$, and to project future yield.

Scenario 2: Average selectivity for the domestic fishery (1985 - Present) was used to estimate $F_{40\%}$, and short term projections were based on recent fishing patterns using the average selectivity observed since 1992.

Scenario 3: An average selectivity pattern based on recent fishing patterns (1992 - Present) was used to estimate $F_{20\%}$ and short term projections.

The selectivity patterns was used to estimate reference fishing mortality rates are found in Table 1.9.

Description of Stochastic Simulation Model

Stochastic simulations based on preliminary stock assessment runs were used to estimate alternative harvest rates for the Gulf of Alaska pollock fishery. These simulations are documented here and were not updated. The similarities between the preliminary runs presented in the September 1996 SAFE and those presented here, indicate that a similar harvest rate would be estimated if the simulations were updated.

Hollowed et al. (1995) describe simulation model runs made over a 70- year time horizon that was initialized using the 1996 Stock Synthesis estimated age composition of the pollock population in 1976 and observed catches from 1976 to 1986. The "risk" associated with a given fishing strategy was defined as the proportion of realizations in which the spawner biomass fell below the threshold value during the last 50- year segment of the 70- year projection. Threshold spawner biomass levels was set at 20% of the unfished level. Quinn et al. (1990) and Thompson (1994) both noted that maintaining a spawning stock above the 20% level is a useful constraint to ensure against overfishing. Beddington and Cooke (1983) also used the 20% criterion to define threshold biomass.

There are many ways to choose a target fishing mortality. Our method focused on the tradeoffs between increased yield and the probability of falling below the threshold. Specifically, we measured changes in yield and "risk" at different values of F . We defined the target fishing level to be the value that satisfies following objective function:

$$\text{MAX} [(Y_{\bar{F}}/\text{Max}Y) - \{\text{Pr}(\text{SB} < \text{THBIO})\}F], \quad [4]$$

where $Y_{\bar{F}}$ equals the average yield over the 50- year time period at a given level of F , $\text{Max}Y$ is the maximum average yield observed over all levels of F , and Pr is the probability that the spawner biomass (SB) will fall below the threshold biomass level (THBIO). The optimal value was determined by iteratively solving for the fishing mortality value that maximized the difference between the yield index and the probability of falling below the threshold. When the spawner biomass dropped below the threshold level, the probability of a strong year class was modeled as a decreasing linear function of spawner biomass that dropped to zero at the origin. The pristine spawner biomass (1,909,000 t. males and females combined) was estimated by running the simulation model with no fishing. The threshold was thus set equal to 381,000 t (20% of pristine).

Spawner-recruitment data show no evidence of a reliable relationship (Figure 1.14). Examination of the spawner recruit data revealed that the majority of the above average year classes occurred during the 1970's. In the last 15 years, only four above average year classes were observed (Figure 1.14). To simulate population trends under recent recruitment conditions, the probability of a strong year class was set equal to 0.2.

Results of Stochastic Simulations

With the probability of an above average year class set at 0.2, the target fishing mortality rate was 0.32 (Figure 1.15.). This value was close to the value of 0.3 presented in Hollowed et al. (1995). This value was approximately the same as the fishing mortality rate associated with $F_{20\%}$ (Table 1.15). At $F=0.32$, the true probability of the spawner stock biomass falling below the threshold was 0.18 (Table 1.16).

Alternative Exploitation Strategies

Additional exploitation strategies were explored, as recommended by the NPFMC Gulf of Alaska Plan Team. The NPFMC Gulf of Alaska Plan Team requested short-term stock projections out to the year 2000, initialized with the current age composition and then random recruitment selected from the 1982-1993 year classes. The Plan Team requested projections assuming an average as well as a strong 1994 year class. This short term projection model will be referred to as the stochastic projection model. These runs were conducted for the preliminary SAFE chapter and were not updated in this assessment.

PROJECTED CATCH AND ABUNDANCE

All yield projections were made by estimating the number of fish at the beginning of 1997 using stock synthesis the model (Table 1.17). The 1994 year class was set equal to the median of the upper quartile of observed age 2 recruitment from Model B (2.033 billion fish). Projections were made using spawning biomass in March based on a weight vector appropriate for that time of year. Estimation of spawning biomass in March rather than the beginning of the year was required to make the estimation of current year spawner biomass consistent with the estimation of $B_{40\%}$. Projections were made by decaying begin year numbers at age by natural mortality and fishing mortality assuming a $F_{40\%}$ exploitation rate for the first 3.5 months of the year. In any projection year, if the spawner biomass fell below $B_{40\%}$, the fishing mortality rate was adjusted downwards as described in Amendment 44 (Tier 3).

Recruitment Scenarios

Above-average, average and below-average year classes were defined by dividing the observed recruitment points into quartiles. Above average or below average year classes were defined as the mean of the upper or lower quartile of the recruitment estimates respectively.

Three different recruitment options were explored for the static projection model. Option A. The 1995 year class was assumed to be average and all others weak. Option B. The 1995 - 1999 year classes were all assumed to be weak. Option C. The 1995 - 1999 year classes were all assumed to be average.

Two recruitment alternatives were explored in the stochastic projection model: 1) the 1994 year class was strong and all others were randomly selected from the 1982-1993 observed recruitments, and 2) all year classes including the 1994 year class were randomly selected from the 1982-1993 year classes. Three fishing mortality levels were explored 0.2, 0.25, and 0.3.

Stock Projections

Stock projections show the spawner biomass level in 1997 will be below $B_{40\%}$ (Tables 1.15 and 1.18). Short term projected yield (age 3+) ranged from 72,100 t to 75,800 t (Table 1.18). Projections based on selectivity scenario 2 are recommended because $F_{40\%}$ was estimated using the best historical representation of domestic selectivity patterns, and the recent fishery selectivity patterns is used to make the projections. $F_{40\%}$ is 0.329 under scenario 2 and $B_{40\%}$ was 280,689 (Table 1.15).

New definitions for acceptable biological catch (ABC) were presented to the North Pacific Fishery Management Council at the June 1996 meeting. Under the new guidelines, the maximum allowable rate is prescribed through a set of six tiers differentiated by the amount of information known about the stock. In the case of walleye pollock in the Gulf of Alaska, estimates of $F_{40\%}$ and $B_{40\%}$ are available (Tier 3). Using spawner biomass to define $B_{40\%}$, selectivity scenario 2, and recruitment option A or C, the 1997 female spawner biomass (237,258 t) falls below $B_{40\%}$ (289,689 t), therefore, the acceptable fishing mortality rate is 0.275. The 1997 yield would be 74,386 t (age 3+) or 76,079 (age 2+) under the revised harvest guidelines (Table 1.18). Under all recruitment options, the spawner biomass will peak in 1999.

Short term stochastic model projections show that under recruitment alternative 1, if the 1994 year class was strong, during the period 1996-2000, at $F=0.2$ - $F=0.3$, only one of the stock projections fell below 381,000 t which was the threshold spawner stock biomass estimated from the simulation model 381,000 t (Table 1.17). Under recruitment alternative 2, there was a 63% - 77% chance that the spawner stock would fall below the 381,000 t level in 1998 (Table 1.19).

ABC RECOMMENDATIONS

We recommend that the 1996 ABC be set at 74,400 t based on the NPFMC guidelines. This recommendation is conservative because the median of the strong year classes prior to 1994 was used as an estimate of the 1994 recruitment level. Model estimates indicate the 1994 year class could be considerably larger than the level used to make projections. This recruitment option is recommended because of uncertainty regarding the absolute magnitude of the 1994 year class. While all evidence is that the 1994 year class will be strong, comparison of the number of age 2 fish observed in the EIT survey indicates it may be of similar magnitude to the 1979 year class. The harvest level recommended here is similar to that proposed in the 1995 stock assessment. Regional allocation of the Western Central ABC could be based on the 1996 bottom trawl biomass estimates for fish 20 cm or larger (25% Shumagin, 42% Chirikof, 33% Kodiak).

The ABC for the Eastern Gulf of Alaska is 5,600 t. This estimate was derived by multiplying the ABC for the Western Central GOA by the 1996 biomass ratio of the Western-Central region to the Eastern Gulf. Fish smaller than 20 cm were excluded from the biomass ratio because small fish (the 1995 year classes) were the abundant in the bottom trawl length frequency data from the Eastern Gulf of Alaska. Since these small fish will not be of harvestable size in 1997, they were not included in the biomass ratio. It should be noted that 42% of biomass in the Eastern Gulf was found in the 0-100m depth interval of Southeast Alaska.

OVERFISHING DEFINITION

Overfishing is defined as any amount of fishing in excess of a prescribed maximum allowable rate. The NPFMC approved a six tier prescription to define the overfishing level for Gulf of Alaska groundfish. The six tiers correspond to the amount of information available for determining the overfishing rate. The information available for the Gulf of Alaska pollock resource places it in the third tier where it is possible to estimate $F_{40\%}$ and $B_{40\%}$. The estimate of $B_{40\%}$ is 289,689 t for the Gulf of Alaska pollock stock (Table 1.15). Because the projected 1997 spawner biomass is 237,258 t, the overfishing level is less than $F_{30\%}$. $F_{30\%}$ equals 0.383 and is associated with a yield in 1997 of 103,500 t. The full recruitment fishing mortality rate (0.275) associated with a 74,400 t harvest in 1997 is well below the overfishing level of 0.383. The 1997 overfishing level for the Eastern Gulf of Alaska is 7,800 t. This estimate was derived by multiplying the Western Central overfishing level by the biomass ratio of the Western - Central region to the Eastern region.

ECOSYSTEM CONCERNS

Juvenile pollock are an important component of the diet of several marine fish, marine birds, as well as some marine mammals. The available information regarding the abundance of pollock in the Gulf of Alaska pollock indicates that an above-average year class (1988) and a strong incoming 1994 year class will be supporting the stock during the next few years. The 1996 EIT survey results and the 1996 catch data supports the conclusion that the 1994 year class is above average.

10.0

SUMMARY

Management parameters of interest are as follows.

Parameter	Value
M	0.3
F _{30%}	0.468
F _{35%}	0.390
F _{40%}	0.329
1997 female spawner biomass	237,258 t
1997 begin year biomass age 2+	1,105,402 t
F _{abc}	0.275
Recommended ABC	74,400 t
F _{overfishing}	0.383
Overfishing level	103,500 t

ACKNOWLEDGMENTS

We would like to thank Michiyo Shima, and Jim Blackburn for their assistance in the analysis of the ADFG bottom trawl data. We also appreciated thoughtful comments by Grant Thompson, Martin Dorn and Jim Ianelli.

Literature Cited

- Bailey, K. M. And S. A. Macklin. 1994. Analysis of patterns in larval walleye pollock (*Theragra chalcogramma*) survival and wind mixing events in Shelikof Strait, Gulf of Alaska. Mar. Ecol. Prog. Ser. 113:1-12.
- Beddington, J. R. and J. Cooke. 1983. The potential yield of previously unexploited stocks. FAO Fish. Tech. Pap. No. 242. Food and Agriculture Organization of the United Nations, Rome, Italy.
- Blackburn, J. and D. Pengilly. 1994. A summary of estimated population trends of seven most abundant groundfish species in trawl surveys conducted by Alaska Department of Fish and Game in the Kodiak and Alaska Peninsula areas, 1988 through 1993. Alaska Department of Fish and Game. Regional Information Report No. 4K94-31. 19p.
- Fritz, L. W. 1993. Trawl locations of walleye pollock and Atka mackerel fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska from 1977-92. AFSC Processed Report 93-08. NMFS, AFSC, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.
- Hollowed, A.B. and B.A. Megrey. 1990. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for the 1991 Gulf of Alaska Groundfish Fishery. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.
- Hollowed, A.B., B.A. Megrey, P. Munro, and W. Karp. 1991. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for the 1992 Gulf of Alaska Groundfish Fishery. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.
- Hollowed, A.B., B.A. Megrey, and E. Brown. 1993. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for the 1994 Gulf of Alaska Groundfish Fishery. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.
- Hollowed, A.B. and B. A. Megrey. 1993. Evaluation of risks associated with application of alternative harvest strategies for Gulf of Alaska walleye pollock. In Management of Exploited Fish Populations. Alaska Sea Grant, AK-SG-93-02. 291-320.
- Hollowed, A.B., C. Wilson, E. Brown, and B.A. Megrey. 1994. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for the 1995 Gulf of Alaska Groundfish Fishery. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.
- Hollowed, A.B., E. Brown, P. Livingston, B.A. Megrey and C. Wilson.. 1995. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for Gulf of Alaska As Projected for 1996. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.
- Hughes, S.E. and G. Hirschhorn. 1979. Biology of walleye pollock, *Theragra chalcogramma*, in Western Gulf of Alaska. Fish. Bull., U.S. 77:263-274.
- Kimura, D. K. 1989. Variability in estimating catch-in-numbers-at-age and its impact on cohort analysis. p. 57-66. In R.J. Beamish and G. A. McFarlane (editors) Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment methods. Can. Spec. Pub. Fish. Aquat. Sci. 108.

- Kimura, D. K. and S. Chikuni. 1987. Mixtures of empirical distributions: and Iterative application of the Age - Length Key. *Biometrics* 43, 23-25.
- Kimura, D. K. and J. A. Lyons. 1991. Between reader bias and variability in the age determination process. *Fish. Bull.* 89:53-60.
- LaLanne, J.J. 1979. The validity and consistency of age determinations from otoliths of Pacific pollock (*Theragra chalcogramma*). *Int. North Pac. Fish. Comm., Annu. Rep.* 1977:99-107.
- McKelvey, D. (in press). Juvenile pollock (*Theragra chalcogramma*) distribution and abundance in Shelikof strait - What can we learn from acoustic survey results?. In: R. D. Brodeur, P. A. Livingston, T. R. Loughlin and A. B. Hollowed (eds.), *Ecology of Juvenile Pollock*. NOAA Tech. Rept.
- Megrey, B.A. 1988. Exploitation of walleye pollock resources in the Gulf of Alaska, 1964-1988: portrait of a fishery in transition. *Proc. International Symp. on the Biology and Management of Walleye Pollock, Lowell Wakefield Fisheries Symp., Alaska Sea Grant Rep.* 89-1, 33-58.
- Megrey, B. A. 1994. Sensitivity of optimum harvest strategy estimates to alternative definitions of risk. *Can. J. Fish. Aquat. Sci.* 51(12):2695-2704.
- Megrey, B. A., A. B. Hollowed, S. R. Hare, S. A. Macklin, P. J. Stabeno. 1996. Contributions of FOCI research to forecasts of year-class strength of walleye pollock in Shelikof Strait, Alaska. *Fisheries Oceanography* 5(Suppl. 1):1989-203
- Methot, R.D. 1986. Synthetic estimates of historical abundance and mortality for northern anchovy, *Engraulis mordax*. U.S. National Marine Fisheries Service, Southwest Fisheries Center, Administrative Report LJ 86-29. La Jolla, California.
- Methot, R.D. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. In: (E.F. Edwards and B.A. Megrey, editors) *Mathematical Analysis of Fish Stock Dynamics: Reviews, Evaluations, and Current Applications*. American Fisheries Society Symposium Series No. 6:66-82.
- Methot, R.D.. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *INPFC Bull.* 50:259-277.
- Picquelle, S.J., and B.A. Megrey. 1993. A preliminary spawning biomass estimate of walleye pollock, *Theragra chalcogramma*, in Shelikof Strait, Gulf of Alaska, based on the annual egg production method. *Bulletin of Marine Science* 53(2):728:749.
- Quinn, T. J., R. Fagen, and J. Zheng. 1990. Threshold management policies for exploited populations. *Can. J. Fish. Aquatic Sci.* 47:2016-2029.
- Thompson, G.G. 1994. A proposal for a threshold stock size and maximum fishing mortality rate. In S.J. Smith (ed.) *Risk evaluation and biological reference points for fisheries management*. *Can. Spec. Pub. Fish. Aquat. Sci.*
- Urban, D. 1993. Bottom trawl survey of crab and groundfish: Kodiak Island and Alaska Peninsula areas. 1992. Alaska Department of Fish and Game, Technical Fisheries Report 93-17. 181p.
- Wespestad, V. G. Walleye pollock. In *Stock Assessment and Fishery Evaluation Report for the 1994 Bering Sea and Aleutian Islands Fishery*. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

- Wilson, C. 1994. Echo integration-trawl survey of pollock in Shelikof Strait, Alaska in 1994. In Stock Assessment and Fishery Evaluation Report for Gulf of Alaska As Projected for 1995. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.
- Wilson, C., M. Guttormsen and D. McKelvey. 1995. Echo integration-trawl survey of pollock in Shelikof Strait, Alaska in 1995. In Stock Assessment and Fishery Evaluation Report for Gulf of Alaska As Projected for 1996. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.
- Wilson, C., M. Guttormsen and S.K. DeBlois. 1996. Echo integration-trawl survey of pollock in Shelikof Strait, Alaska in 1995. In Stock Assessment and Fishery Evaluation Report for Gulf of Alaska As Projected for 1996. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Table 1.1--Landed catch including discard pollock (1000 t) in the Western and Central regions of the Gulf of Alaska 1977-94.

Year	Western Central Catch	Western Central TAC*	Yakutat S.E. Catch	Yakutat S.E. TAC
1977	112.3	118.0*	-	-
1978	95.8	168.0*	3.5	-
1979	99.8	168.0*	5.4	-
1980	110.4	168.0*	4.6	-
1981	139.2	168.0*	8.6	-
1982	165.1	168.0*	3.6	-
1983	215.5	256.6*	T	-
1984	306.7	400.0	0.0	16.6
1985	284.8	305.0	0.0	16.6
1986	93.6	150.0	0.0	16.6
1987	69.5	104.0		4.0
1988	65.6	90.0		3.0
1989	78.2	72.0		0.2
1990	90.5	70.0		3.4
1991	107.5	100.0		3.4
1992	93.9	84.0		3.4
1993	107.4	111.0	0.7	3.4
1994	104.0	102.0	6.9	7.3
1995	69.9	62.0	3.4	3.6
1996	23.7 *	29.7 *		
Average	126.8			

*: Gulfwide TAC from 1977 - 1983.

* Based on mid-season data updated July 1996.

Sources: Foreign and joint venture catches 1977-84--Berger et al. (1986); 1985-88--Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission.

Domestic catches 1973-80--Rigby (1984); 1981-90--PacFIN, 1991-93 NMFS Alaska Regional Office.

Table 1.2. 1995 Retained and discarded walleye pollock catch in the Gulf of Alaska by area and quarter.

Area	Data	1	2	3	4	Grand Total
610-Shumagin	Discard	1,130	360	119	349	1,958
	Retained	9,732	7,979	3,874	7,416	29,000
	Total	10,862	8,339	3,993	7,765	30,958
620-Chirikof	Discard	983	300	300	475	2,058
	Retained	4,110	1,897	4,813	212	11,032
	Total	5,093	2,197	5,113	687	13,090
630-Kodiak	Discard	631	620	1,204	1,363	3,818
	Retained	3,890	3,029	4,136	10,933	21,989
	Total	4,521	3,649	5,340	12,297	25,808
640-Yakutat	Discard	3	T	42	7	53
	Retained	480	0	0	0	480
	Total	483	T	42	7	533
649-Prince William Sound	Discard	74	T	0	0	75
	Retained	2,737	2	0	0	2,739
	Total	2,811	2	0	0	2,813
650-Southeast	Discard	0	T	T	T	0
	Retained	0	0	46	0	46
	Total	0	T	46	T	47
659-S.E. Inside	Discard	T	T	T	T	T
	Retained	0	0	0	0	0
	Total	T	T	T	T	T
Total Discard		2,822	1,280	1,666	2,194	7,962
Total Retained		20,948	12,907	12,869	18,561	65,286

Table 1.3. Estimated catch (1000's) in numbers of pollock by foreign trawl, joint venture, and domestic fisheries in the North Pacific Fishery Management Council Western and Central Regulatory Areas of the Gulf of Alaska, by age, 1976-1995.

Age	Year													
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	
2	1,909	2,774	12,189	2,532	19,259	2,729	10,677	3,639	2,705	12,786				
3	24,207	7,062	48,316	48,833	26,499	31,549	55,545	20,654	33,002	5,527				
4	108,694	23,830	18,263	76,367	58,311	73,907	100,774	110,031	38,798	33,215				
5	39,077	89,681	26,394	14,150	36,630	47,967	71,728	137,312	120,800	42,219				
6	16,372	30,348	51,857	10,131	11,310	20,292	54,248	67,414	170,722	86,016				
7	3,517	8,330	12,832	16,702	8,611	4,874	10,463	42,013	62,546	128,946				
8	2,249	2,131	4,179	5,022	7,995	4,831	1,329	7,377	19,312	41,191				
9	1,914	1,785	1,360	1,268	3,888	2,730	926	1,241	5,417	10,843				
10+	310	1,227	1,413	805	1,919	313	622	408	235	2,900				
Total	198,248	167,168	176,802	175,811	176,424	189,193	306,312	390,089	453,536	363,643				

Table 1.3, continued.--Estimated catch (1000's) in numbers of pollock by foreign trawl, joint venture, and domestic fisheries in the North Pacific Fishery Management Council Western and Central Regulatory Areas of the Gulf of Alaska, by age, 1976-1995.

Age	Year									
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
2	8,625	8,826	3,048	271	2,766	585	3,251	1,970	1,255	63
3	20,355	14,026	20,800	1,470	2,396	9,681	5,574	9,427	4,491	1,007
4	10,116	7,998	26,947	19,393	2,993	5,447	50,609	21,828	9,625	5,110
5	19,131	6,894	11,927	28,888	9,490	2,853	14,129	47,464	35,916	11,523
6	7,316	6,435	5,102	16,955	40,389	5,333	4,024	15,720	31,323	25,829
7	8,701	7,180	3,447	8,094	13,057	26,669	8,769	6,548	12,202	12,086
8	9,782	4,194	1,623	4,757	4,898	3,124	19,552	6,293	4,838	2,989
9	2,133	9,951	339	1,694	1,078	16,101	1,020	8,520	4,596	1,821
10+	800	1,935	3,209	5,164	1,125	10,101	2,427	5,459	9,063	656
Total	86,959	67,439	76,442	86,686	78,192	79,894	109,355	123,229	133,366	61,084

Table 1.4. Estimated number at age in 1981, 1983-1986 and 1988-1991 derived from the NMFS hydroacoustic surveys.

	----- POPULATION NUMBERS (MILLIONS) -----									
AGE	81	83	84	85	86	88	89	90	91	
1	78	1	62	2091	573	17		49	22	
2	3481	902	58	544	2115	110	89.5	1210	174	
3	1511	380	324	123	183	694	90.0	72	549	
4	769	1297	142	315	45	322	222.0	63	48	
5	2786	1171	635	180	75	78	248.7	116	65	
6	1052	698	988	347	49	17	39.4	180	70	
7	210	599	449	439	86	6	11.8	46	116	
8	129	132	224	167	149	6	3.8	22	24	
9	79	14	41	43	60	4	1.9	8	29	
10	25	12	2	6	11	9	0.6	8	2	
11	2	4	0	2	1	2	10.7	1	4	
12	0	2	1	1	0	0	1.4	3	1	
Total	10121	5211	2928	4259	3352	1266	719.8	1782	1109	

Table 1.5. Walleye pollock weight-at-age.

Age	First Trimester (kg.)	Second Trimester (kg.)	Third Trimester (kg.)	Bering Sea (kg.)
1	0.017	0.043	0.081	0.12
2	0.130	0.186	0.247	0.23
3	0.313	0.380	0.447	0.37
4	0.514	0.579	0.642	0.52
5	0.703	0.760	0.813	0.66
6	0.864	0.911	0.955	0.78
7	0.995	1.033	1.068	0.89
8	1.100	1.129	1.156	0.98
9	1.181	1.204	1.225	1.06
10	1.244	1.261	1.277	1.13
11	1.291	1.305	1.317	1.16
12	1.328	1.338	1.347	1.16

Age	Hydroacoustic Survey	Bottom Trawl Survey
1	-	-
2	0.085	0.187
3	0.211	0.407
4	0.367	0.622
5	0.528	0.800
6	0.679	0.936
7	0.812	1.034
8	0.925	1.103
9	1.018	1.151
10	1.093	1.184
11	1.153	1.206
12	1.201	1.221

Table 1.6. Walleye pollock biomass estimates from echo integration trawl surveys of Shelikof Strait. Gulfwide bottom trawl surveys, estimates of spawner stock biomass from egg production surveys of Shelikof Strait, and biomass estimates from ADF&G trawl surveys. Previous and revised biomass estimates from the EIT survey since 1992 were adjusted to compare with the earlier EIT survey (see text for explanation).

	Shelikof St. Previous EIT Survey (tons)	Shelikof St. Revised EIT Survey (tons)	Western- Central to 144.30° Bottom Trawl (tons)	Shelikof St. Egg Production Spawner Biomass (tons)	Coastal Kodiak ADF&G Trawl Survey (tons)
1975	-	-	825,042*	-	-
1976	-	-	-	-	-
1977	-	-	-	-	-
1978	-	-	-	-	-
1979	-	-	-	-	-
1980	-	-	-	-	-
1981	3,765,300	2,785,755	-	1,788,908	-
1982	-	-	-	-	-
1983	2,433,000	2,278,172	-	-	-
1984	1,838,100	1,757,168	730,431	-	-
1985	704,900	1,175,823	-	768,419	-
1986	623,600	585,755	-	375,907	-
1987	-	-	846,976	484,455	92,222
1988	324,800	301,709	-	504,418	185,873
1989	290,461	-	-	433,894	127,919
1990	381,594	374,731	799,154	381,475	70,460
1991	382,397	380,331	-	370,000	80,088
1992	580,000	-	-	616,000	69,766
1993	295,785	-	760,788	-	46,331
1994	366,800	-	-	-	40,146
1995	572,900	-	-	-	57,605
1996	588,800	-	653,905	-	-

* Estimate expanded from bottom trawl survey estimate of the Chirikof area using 400 mesh eastern trawl.

Table 1.7. 1996 triennial bottom trawl haul distribution, percent occurrence with pollock, pollock biomass, pollock abundance, average weight of pollock and average length of pollock by area and depth strata.

Area	Depth	Hauls	Number		CPUE	Biomass	Number	Weight	Length
			w poll	% Occ.					
Shumagin	0-100	102	82	80.39	2,856	117,532	250,909,344	0.47	32.46
	101-200	60	55	91.67	2,852	41,856	41,905,165	1.00	50.71
	201-300	22	22	100.00	845	2,357	4,388,346	0.54	36.57
	301-500	16	11	68.75	119	300	336,150	0.89	49.85
	All Depths	200	170	85.00		162,045	297,539,005	0.54	35.11
Chirikof	0-100	69	52	75.36	6,288	163,714	177,749,286	0.92	45.52
	101-200	68	61	89.71	4,221	100,675	118,708,820	0.85	45.17
	201-300	31	29	93.55	809	9,338	37,913,570	0.25	27.40
	301-500	13	12	92.31	169	271	1,316,111	0.21	26.24
	All Depths	181	154	85.08		273,998	335,687,787	0.82	43.27
Kodiak	0-100	59	44	74.58	1,876	72,279	77,377,172	0.93	42.78
	101-200	109	89	81.65	3,018	130,763	146,437,045	0.89	43.70
	201-300	31	30	96.77	724	8,325	16,351,848	0.51	33.90
	301-500	11	8	72.73	277	805	748,524	1.08	52.56
	All Depths	210	171	81.43		212,172	240,914,589	0.88	42.77
Yakutat	0-100	33	29	87.88	389	6,428	123,845,277	0.05	17.44
	101-200	50	45	90.00	294	8,548	77,554,264	0.11	20.92
	201-300	27	25	92.59	757	3,913	9,313,427	0.42	35.57
	301-500	6	4	66.67	228	598	1,133,891	0.53	37.75
	All Depths	116	103	88.79		19,587	211,946,859	0.09	19.62
Southeast	0-100	7	3	42.86	3,848	25,193	164,446,114	0.15	25.48
	101-200	50	37	74.00	797	8,787	71,325,113	0.12	23.23
	201-300	28	24	85.71	1,095	5,531	8,024,372	0.69	43.52
	301-500	12	3	25.00	39	121	133,667	0.91	47.80
	All Depths	97	67	69.07		39,632	243,929,266	0.16	25.43
All areas	0-100	270	210	77.78		385,146	794,327,193	0.48	32.60
	101-200	337	287	85.16		290,729	456,030,407	0.64	37.65
	201-300	139	130	93.53		29,464	75,991,563	0.39	32.03
	301-500	58	38	65.52		2,095	3,668,343	0.57	38.12
	All Depths	804	665	82.71		707,434	1,330,017,506	0.53	34.31

Table 1.8 Comparison of stock synthesis model fits for Models A - F.

	<i>POP LN</i>	<i>For AC</i>	<i>Dom.AC</i>	<i>EIT Bio</i>	<i>EIT AC</i>	<i>EIT LN</i>	<i>BT Bio</i>	<i>BT AC</i>	<i>EPI Bio</i>	<i>Tot. Like.</i>
Model A	-139	-207	-421	-95	-379	-356	-28	-245	-13	-1885.17
Model B	-135	-192	-378	-58	-282	-382	-5	-249	-15	-1694.54
Model C	-137	-196	-387	-58	-287	-392	-8	-288	-2	-1754.41
Model D	-141	-234	-391	-60	-291	-395	-16	-269	-3	-1800.59
Model E	-135	-199	-295	-84	-734	-646	-8	-185	-7	-2291.69
Model F	-134	-203	-321	-84	-734	-646	-8	-185	-7	-2320.34

POP LN = Pollock length frequency from the Pacific ocean perch fishery.

For AC = Foreign fishery age composition

Dom AC = Domestic fishery age composition

EIT Bio = Echo Integration Trawl survey biomass

EIT LN = Echo Integration Trawl survey length frequency

BT AC = Bottom trawl survey age composition

BT Bio = Bottom trawl biomass

EPI Bio = Egg production index spawner biomass

Table 1.9. Estimates of selectivity at age based on the 1996 stock assessment model runs.

Survey	Selectivity at Age								
	2	3	4	5	6	7	8	9	10
EIT	1.00	0.99	0.99	0.99	0.99	0.99	0.95	0.60	0.10
Bottom Trawl	0.17	0.28	0.43	0.63	0.86	1.00	0.84	0.47	0.19
Fishery 75-84	0.03	0.27	0.83	1.00	0.89	0.64	0.35	0.14	0.05
Fishery 85	0.05	0.16	0.39	0.73	1.00	0.86	0.45	0.17	0.10
Fishery 86	0.08	0.25	0.60	0.99	1.00	0.57	0.23	0.08	0.06
Fishery 87-88	0.04	0.14	0.35	0.67	0.98	1.00	0.60	0.25	0.03
Fishery 89-90	0.03	0.10	0.25	0.48	0.77	1.00	0.85	0.44	0.17
Fishery 91	0.01	0.04	0.09	0.19	0.32	0.50	0.75	1.00	0.97
Fishery 92	0.05	0.17	0.42	0.76	1.00	0.79	0.38	0.14	0.05
Fishery 93	0.04	0.14	0.35	0.67	0.98	1.00	0.60	0.25	0.09
Fishery 94	0.03	0.10	0.26	0.50	0.79	1.00	0.81	0.41	0.16
Fishery 95	0.12	0.38	0.82	1.00	0.63	0.27	0.10	0.03	0.01
Average 85-95	0.06	0.19	0.45	0.77	1.00	0.97	0.67	0.38	0.21
Average 92-95	0.07	0.23	0.54	0.86	1.00	0.91	0.56	0.24	0.09

Table 1.10. Estimates of total biomass, female spawning biomass, age 2 recruitment and fishing mortality from Model B (1996) and the 1995 stock assessment.

Year	1996				Year	1995			
	2+ Total Biomass (1000 t)	Female Spawner Biomass (1000 t)	Recruitment at age 2 (millions)	Fishing Mortality		2+ Total Biomass (1000 t)	Female Spawner Biomass (1000 t)	Recruitment at age 2 (millions)	Fishing Mortality
69	758	288	625	0.167	69	677	279	567	0.174
70	739	255	394	0.101	70	679	245	381	0.108
71	754	236	572	0.068	71	704	225	508	0.071
72	866	235	1224	0.305	72	821	226	1,088	0.331
73	957	248	534	0.119	73	887	235	475	0.15
74	1254	278	2583	0.157	74	1,211	260	2,355	0.173
75	1453	337	508	0.079	75	1,352	309	467	0.089
76	1522	416	325	0.101	76	1,334	381	302	0.113
77	1588	481	1720	0.109	77	1,419	441	1,628	0.121
78	1789	497	2357	0.107	78	1,690	455	2,307	0.118
79	2083	516	2043	0.096	79	2,034	473	2,133	0.104
80	2562	593	3486	0.085	80	2,595	554	3,487	0.09
81	2961	724	1950	0.085	81	2,967	695	1,959	0.087
82	3051	872	375	0.087	82	2,932	858	357	0.088
83	2864	971	590	0.117	83	2,655	978	610	0.115
84	2454	944	192	0.227	84	2,158	972	176	0.222
85	1941	773	595	0.329	85	1,681	808	614	0.301
86	1668	590	2024	0.214	86	1,630	606	2,094	0.166
87	1703	508	1319	0.148	87	1,746	522	1,433	0.121
88	1693	497	208	0.128	88	1,716	512	223	0.095
89	1590	530	291	0.141	89	1,574	557	293	0.125
90	1605	534	1986	0.139	90	1,629	571	1,908	0.121
91	1583	498	491	0.196	91	1,555	539	382	0.201
92	1491	469	326	0.156	92	1,387	499	110	0.131
93	1339	473	175	0.182	93	1,163	494	132	0.159
94	1120	441	93	0.222	94	910	447	51	0.215
95	896	369	243	0.266	95	746	353	414	0.195
96	1326	301	5393	0.201					

Table 1.11. Estimated number of pollock at age by INPFC area from the 1993 NMFS bottom trawl survey in the Gulf of Alaska.

Age	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
1	18,746,825	8,330,783	51,230,124	42,993,647	18,011,136	139,312,515
2	31,605,882	10,900,771	5,116,109	15,759,801	7,762,957	71,145,520
3	23,171,415	14,053,672	7,673,547	5,679,632	356,277	50,934,543
4	97,995,026	41,353,110	31,684,034	11,164,421	759,517	182,956,108
5	133,677,343	62,420,406	54,319,859	15,593,994	1,109,694	267,121,296
6	41,068,304	22,343,261	23,107,224	4,665,332	326,817	91,510,938
7	13,534,167	9,265,282	9,243,788	998,340	78,441	33,120,018
8	28,362,131	16,877,271	21,769,339	1,817,776	151,662	68,978,179
9	34,145,970	16,387,155	24,154,942	1,777,091	154,263	76,619,421
10	10,992,415	6,608,391	7,896,679	797,261	63,400	26,358,146
11	5,774,114	2,129,271	3,682,929	235,919	25,036	11,847,269
12	2,939,556	1,164,288	2,085,032	95,554	8,560	6,292,990
13	1,463,772	936,241	1,272,723	136,784	8,975	3,818,495
14	975,813	348,828	467,976	23,361	3,221	1,819,199
15	519,897	120,483	200,751	7,181	335	848,647
16	2,026,697	672,217	833,617	24,838	4,667	3,562,036
Total	446,999,327	213,911,430	244,738,673	101,770,932	28,824,958	1,036,245,320
Total + out of range	447,038,668	213,920,929	246,906,558	102,800,852		1,039,491,965

Table 1.12. Estimated number of age 2 pollock in the EIT survey 1981 - 1991 based on age determinations. Number of age 2 pollock (16 cm - 26 cm) in the EIT survey.

<u>Year</u>	<u>Age 2 (millions)</u>
81	3,481
83	902
84	58
85	544
86	2,115
88	110
89	90
90	1,210
91	174
96	3196

Table 1.13. 1995 age composition by area and time period for the Western-Central Gulf of Alaska.

Age	Shumagin	Kodiak-Chirikof	Kodiak-Chirikof	Kodiak-Chirikof	Total
		Jan - Apr	May - Aug	Sep. - Dec	Western/Central
1	0	0	0	0	0
2	0	55,561	7,388	0	62,949
3	503,200	258,697	195,081	49,598	1,006,576
4	2,761,843	502,384	1,407,077	438,385	5,109,689
5	7,215,070	891,027	2,185,775	1,230,683	11,522,555
6	16,919,110	2,156,916	4,124,272	2,628,645	25,828,943
7	5,200,134	1,707,348	2,659,457	2,518,757	12,085,696
8	336,761	468,784	967,933	1,215,687	2,989,164
9	129,408	185,624	608,814	598,981	1,522,828
10	587,964	265,697	689,742	456,693	2,000,095
11	217,786	276,578	1,002,230	324,104	1,820,698
12	25,575	26,403	124,842	17,173	193,993
13	17,128	35,802	83,889	147,099	283,918
14	4,115	2,691	15,242	7,386	29,434
15	6,177	13,376	17,544	88,482	125,579
16	0	0	0	0	0
17	1,777	19,076	615	1,956	23,423
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

Table 1.14. 1994 and 1995 age composition from the Yakutat region.

Age	1994	1995
	Yakutat Jan - Apr	Yakutat Jan - Apr
1	233	0
2	8,645	0
3	54,219	41,373
4	262,385	72,593
5	1,487,762	220,389
6	4,026,182	775,243
7	1,302,445	898,345
8	311,091	396,106
9	198,745	148,803
10	475,042	72,692
11	12,651	114,484
12	8,679	47,514
13	1,609	3,030
14	7,817	104
15	397	770
16	0	0
17	0	229
18	0	0
19	0	0
20	0	0

Table 1.15. Estimates of fishing mortality values.

I. Based on average selectivity pattern 85 - 96.

Strategy	F	Female Equilibrium Spawner Biomass (million t)
$F_{40\%}$	0.329	289,689
$F_{35\%}$	0.390	245,603
$F_{30\%}$	0.468	210,517

F= Full Recruitment Fishing Mortality

Table 1.16. Summary statistics from realizations where the threshold spawner stock biomass equals 382,000 t (males and females combined) and the coefficient of variation on estimates of numbers at age was held constant for all ages at 0.30. Values in parenthesis are the coefficients of variation.

Fishing Mortality	True Yield (1000 t)	Perceived Biomass (1000 t)	True Biomass (1000 t)	M&F	M&F	True Probability	Perceived Probability	Mean Square Difference
				Perceived Spawner Biomass (1000 t)	True Spawner Biomass SPAWNER			
0.00	0	1,644	1,621	1,273	1,252	0.000	0.000	341
0.02	12	1,595	1,607	1,226	1,236	0.000	0.000	345
0.04	23	1,568	1,569	1,197	1,198	0.000	0.000	360
0.06	34	1,487	1,492	1,115	1,118	0.000	0.000	423
0.08	45	1,459	1,478	1,073	1,093	0.000	0.000	335
0.10	53	1,359	1,392	999	1,030	0.000	0.003	536
0.12	62	1,301	1,354	944	992	0.007	0.004	259
0.14	68	1,257	1,272	902	917	0.020	0.004	395
0.16	77	1,226	1,255	875	899	0.019	0.005	281
0.18	77	1,106	1,129	777	802	0.063	0.022	274
0.20	90	1,164	1,177	806	819	0.047	0.014	249
0.22	94	1,069	1,130	731	786	0.073	0.016	257
0.24	101	1,050	1,115	705	767	0.091	0.024	384
0.26	88	865	960	575	663	0.230	0.065	332
0.28	104	956	1,018	629	686	0.137	0.050	314
0.30	100	933	935	624	629	0.161	0.051	258
0.32	104	907	935	593	621	0.182	0.073	294
0.34	114	923	948	597	622	0.155	0.054	225
0.36	102	862	865	565	567	0.211	0.087	261
0.38	99	835	826	545	539	0.270	0.126	368
0.40	107	826	844	533	550	0.299	0.132	265
0.42	103	770	807	489	522	0.352	0.158	270
0.44	94	726	762	468	500	0.400	0.216	275
0.46	101	764	780	488	502	0.356	0.186	231
0.48	112	845	808	543	509	0.228	0.154	214
0.50	104	781	767	499	486	0.317	0.190	285
0.52	108	760	773	484	493	0.365	0.205	242
0.54	106	711	753	446	478	0.401	0.237	276
0.56	101	701	731	443	465	0.410	0.237	232
0.58	108	726	746	452	469	0.405	0.243	245
0.60	96	695	712	443	456	0.412	0.280	202

Table 1.17. Estimated population numbers (thousands) at age at the beginning of the year through 1997.

Year	Age									
	2	3	4	5	6	7	8	9	10	
64	103,734	586,261	1,158,396	160,536	2	10	10	6	28	
65	417,408	76,848	434,261	856,539	118,533	1	7	7	25	
66	1,000	3,09,222	56,920	320,834	631,509	87,394	1	5	24	
67	240,423	741	228,945	41,783	233,882	460,394	64,123	1	22	
68	151,760	178,107	548	168,013	30,444	170,425	337,701	47,460	17	
69	625,055	112,422	131,779	398	120,180	21,781	123,637	249,694	35,169	
70	394,193	462,968	82,786	88,764	250	75,373	14,599	90,754	210,958	
71	571,864	291,993	341,730	57,894	59,417	167	52,554	10,755	223,497	
72	1,223,620	423,616	215,785	243,523	40,059	41,126	119	38,787	173,536	
73	534,498	906,429	313,641	158,924	171,132	23,198	22,454	74	151,675	
74	2,583,281	395,792	668,526	224,230	105,676	112,525	15,734	15,852	111,585	
75	507,660	1,912,631	291,498	472,538	144,037	66,885	74,192	10,938	93,289	
76	324,764	375,090	1,387,030	202,206	323,585	99,463	47,094	53,463	76,824	
77	1,719,668	239,776	270,381	944,453	135,425	219,057	69,035	33,672	95,619	
78	2,356,861	1,269,304	172,467	182,883	627,510	91,027	151,260	49,221	94,964	
79	2,042,804	1,739,729	913,441	116,832	121,731	422,470	62,928	107,915	105,831	
80	3,485,983	1,508,465	1,255,718	624,502	78,627	82,766	294,145	45,070	156,807	
81	1,950,373	2,575,069	1,091,932	866,165	424,771	53,969	58,022	211,458	148,596	
82	375,307	1,440,744	1,864,206	753,428	589,367	291,656	37,844	41,717	264,261	
83	589,731	277,218	1,042,367	1,283,818	511,477	403,839	204,210	27,187	225,350	
84	192,256	435,172	198,977	700,452	846,340	341,399	277,447	145,198	185,684	
85	594,840	141,343	303,150	121,931	413,533	511,883	218,412	189,761	239,872	
86	2,024,103	433,258	99,223	197,023	71,009	220,484	284,881	139,352	306,495	
87	1,318,546	1,473,639	303,848	64,585	118,009	42,452	144,347	200,612	326,919	
88	207,515	970,192	1,068,394	213,531	43,337	75,603	27,136	97,810	382,039	
89	290,643	152,829	705,422	756,128	145,188	28,308	49,287	18,607	349,819	
90	1,986,191	214,330	111,581	504,214	522,997	96,401	18,211	32,353	265,719	
91	490,963	1,464,804	156,524	79,806	349,187	347,944	62,175	11,980	214,620	
92	325,997	362,818	1,076,664	113,734	56,942	242,868	233,518	39,764	138,574	
93	175,070	239,429	261,525	746,437	74,728	36,095	158,991	162,871	130,590	
94	92,892	128,612	172,709	181,524	489,351	46,266	22,283	105,487	210,313	
95	242,755	68,305	93,045	120,708	120,294	303,854	27,450	13,764	221,669	
96	5,392,547	173,873	45,631	55,350	68,543	75,178	209,305	19,795	173,766	
97	--	3,892,676	118,970	28,559	33,426	44,556	52,665	151,883	142,954	

Table 1.18. Summary of 1997 - 2001 short term projections of Gulf of Alaska pollock biomass (tons), female spawning biomass (March), fishing mortality rate and yield.

Year	F	Begin Year		Female Spawner Biomass	2+ Yield (tons)	3+ Yield (tons)	Selectivity SPR	Selectivity Projection	F 40 %	Recruitment Option
		2+ Biomass	3+ Biomass							
1997	0.267	1,200,498	1,097,826	230,836	77,113	75,770	Avg 85-95	Avg 85-95	0.329	A
1998	0.280	1,165,034	1,137,878	240,957	103,991	103,619	Avg 85-95	Avg 85-95	0.329	A
1999	0.314	1,013,382	986,226	268,603	144,125	143,708	Avg 85-95	Avg 85-95	0.329	A
2000	0.286	787,939	760,782	245,915	122,736	122,357	Avg 85-95	Avg 85-95	0.329	A
2001	0.222	595,713	568,557	193,810	71,919	71,624	Avg 85-95	Avg 85-95	0.329	A
1997	0.275	1,208,092	1,105,420	237,258	76,079	74,386	Avg 85-95	Avg 92-95	0.329	A
1998	0.287	1,167,405	1,140,249	246,682	111,484	111,017	Avg 85-95	Avg 92-95	0.329	A
1999	0.314	1,001,655	974,499	269,004	145,886	145,375	Avg 85-95	Avg 92-95	0.329	A
2000	0.283	771,521	744,365	243,296	113,944	113,484	Avg 85-95	Avg 92-95	0.329	A
2001	0.221	587,415	560,258	193,324	64,439	64,079	Avg 85-95	Avg 92-95	0.329	A
1997	0.267	1,208,092	1,105,420	256,180	74,064	72,418	Avg 92-95	Avg 92-95	0.319	A
1998	0.279	1,169,653	1,142,497	264,858	109,101	108,546	Avg 92-95	Avg 92-95	0.319	A
1999	0.307	1,006,277	979,121	296,038	143,792	143,292	Avg 92-95	Avg 92-95	0.319	A
2000	0.278	777,679	750,523	274,547	113,248	112,796	Avg 92-95	Avg 92-95	0.319	A
2001	0.218	593,255	566,099	219,789	64,364	64,010	Avg 92-95	Avg 92-95	0.319	A
1997	0.266	1,124,982	1,097,826	229,807	75,784	75,430	Avg 85-95	Avg 85-95	0.329	B
1998	0.273	1,052,832	1,025,676	235,800	96,950	96,587	Avg 85-95	Avg 85-95	0.329	B
1999	0.295	895,312	868,156	253,473	123,821	123,429	Avg 85-95	Avg 85-95	0.329	B
2000	0.257	694,840	667,684	222,856	97,343	97,001	Avg 85-95	Avg 85-95	0.329	B
2001	0.198	538,096	510,940	174,359	55,475	55,212	Avg 85-95	Avg 85-95	0.329	B
1997	0.274	1,132,576	1,105,420	236,230	74,509	74,063	Avg 85-95	Avg 92-95	0.329	B
1998	0.280	1,055,651	1,028,495	241,555	103,184	102,728	Avg 85-95	Avg 92-95	0.329	B
1999	0.296	885,773	858,616	254,276	123,515	123,133	Avg 85-95	Avg 92-95	0.329	B
2000	0.256	682,858	655,702	221,513	89,093	88,577	Avg 85-95	Avg 92-95	0.329	B
2001	0.198	533,362	506,206	175,032	49,561	49,237	Avg 85-95	Avg 92-95	0.329	B
1997	0.266	1,132,576	1,105,420	236,439	72,536	72,103	Avg 92-95	Avg 92-95	0.319	B
1998	0.273	1,057,829	1,030,673	242,358	100,995	100,550	Avg 92-95	Avg 92-95	0.319	B
1999	0.290	890,077	862,921	255,966	121,386	121,415	Avg 92-95	Avg 92-95	0.319	B
2000	0.251	688,313	661,157	223,877	88,566	88,157	Avg 92-95	Avg 92-95	0.319	B
2001	0.195	538,413	511,257	177,308	49,468	49,149	Avg 92-95	Avg 92-95	0.319	B
1997	0.267	1,200,498	1,097,826	230,836	77,113	75,770	Avg 85-95	Avg 85-95	0.329	C
1998	0.281	1,240,550	1,137,878	241,987	105,471	104,060	Avg 85-95	Avg 85-95	0.329	C
1999	0.321	1,200,901	1,098,228	274,754	154,042	152,430	Avg 85-95	Avg 85-95	0.329	C
2000	0.311	1,091,710	989,038	266,747	151,848	150,285	Avg 85-95	Avg 85-95	0.329	C
2001	0.275	952,422	889,749	237,423	120,061	118,677	Avg 85-95	Avg 85-95	0.329	C
1997	0.275	1,208,092	1,105,420	237,258	76,079	74,386	Avg 85-95	Avg 92-95	0.329	C
1998	0.288	1,242,921	1,140,249	247,709	113,244	111,472	Avg 85-95	Avg 92-95	0.329	C
1999	0.322	1,188,685	1,086,013	275,110	157,260	155,284	Avg 85-95	Avg 92-95	0.329	C
2000	0.308	1,072,686	970,014	263,687	145,681	143,790	Avg 85-95	Avg 92-95	0.329	C
2001	0.273	978,024	875,351	235,460	114,704	113,025	Avg 85-95	Avg 92-95	0.329	C
1997	0.267	1,208,092	1,105,420	237,467	74,064	72,418	Avg 92-95	Avg 92-95	0.319	C
1998	0.281	1,245,169	1,142,497	248,521	110,817	109,091	Avg 92-95	Avg 92-95	0.319	C
1999	0.315	1,193,376	1,090,704	276,882	154,939	153,006	Avg 92-95	Avg 92-95	0.319	C
2000	0.302	1,079,215	976,543	266,371	144,536	142,680	Avg 92-95	Avg 92-95	0.319	C
2001	0.268	984,755	882,083	238,345	114,118	112,466	Avg 92-95	Avg 92-95	0.319	C

Table 1.19. Percentage of times the stock fell below the threshold spawner stock biomass (384,000 t, males and females combined) in short term stochastic stock projections.

Recruitment Scenario 1. 1994 year class is strong, and all others random.

Year	F = 0.2	F=0.25	F=0.3
1996	0.0	0.0	0.0
1997	0.0	0.0	0.0
1998	0.0	0.0	0.0
1999	0.0	0.0	0.0
2000	0.0	0.0	6.3

Recruitment Scenario 2. All recruitment random.

Year	F = 0.2	F=0.25	F=0.3
1996	0.0	0.0	0.0
1997	0.0	0.0	37.0
1998	62.7	76.8	75.4
1999	51.4	60.3	62.5
2000	44.9	49.0	54.3

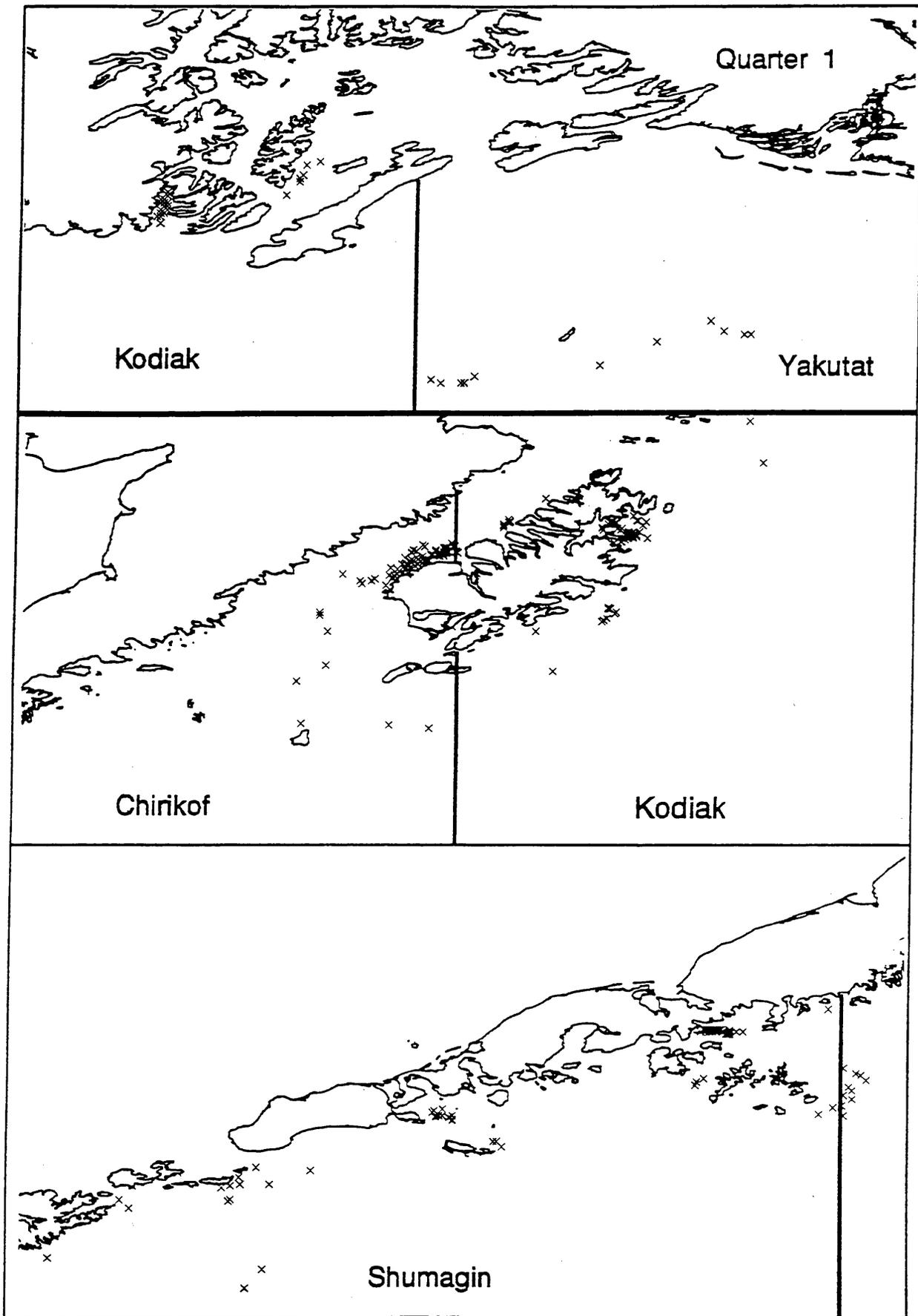


Figure 1. 1995 quarterly distribution of domestic trawl locations where pollock was the target species (Quarter 1).

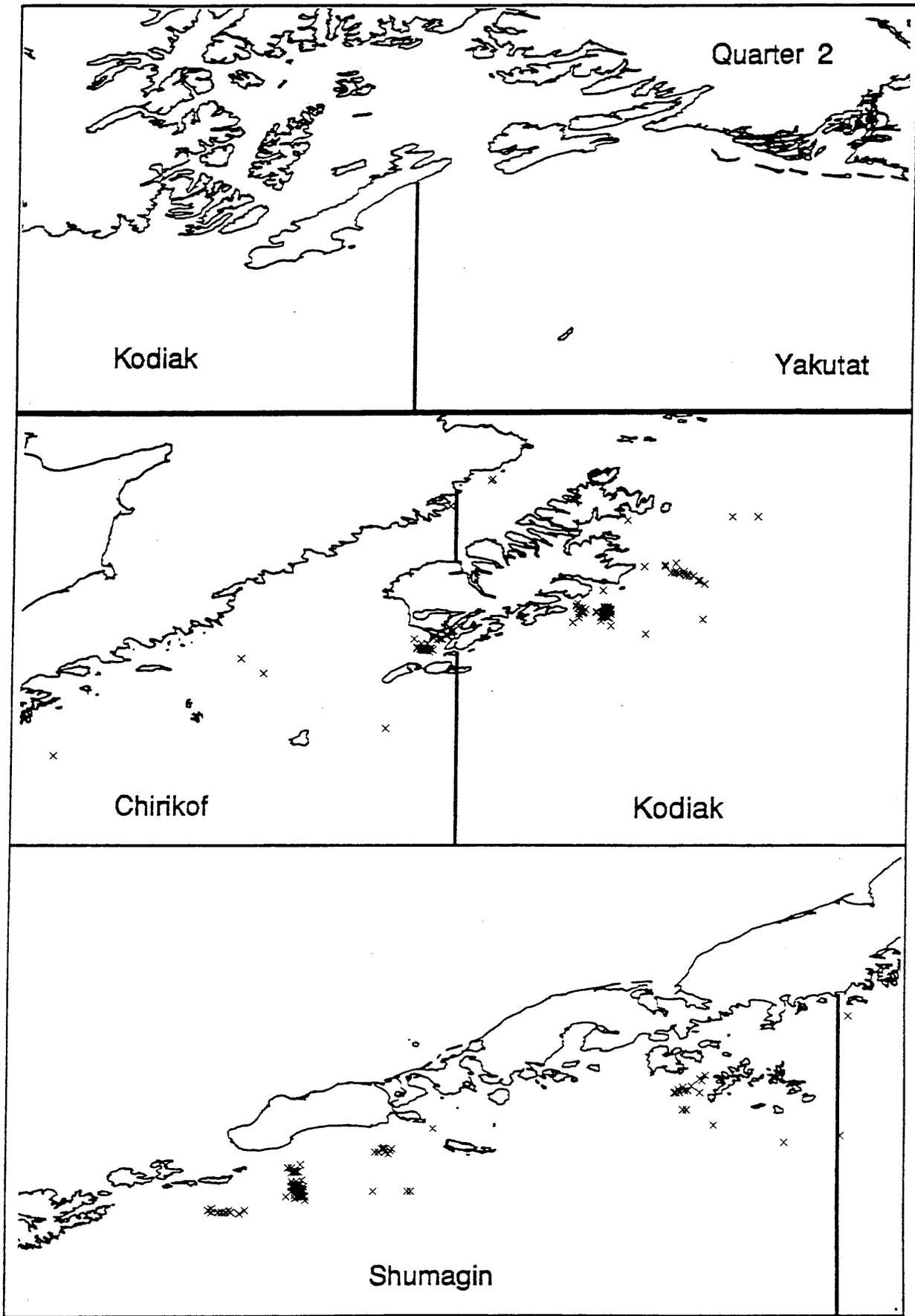


Figure 1. cont. 1995 quarterly distribution of domestic trawl locations where pollock was the target species (Quarter 2).

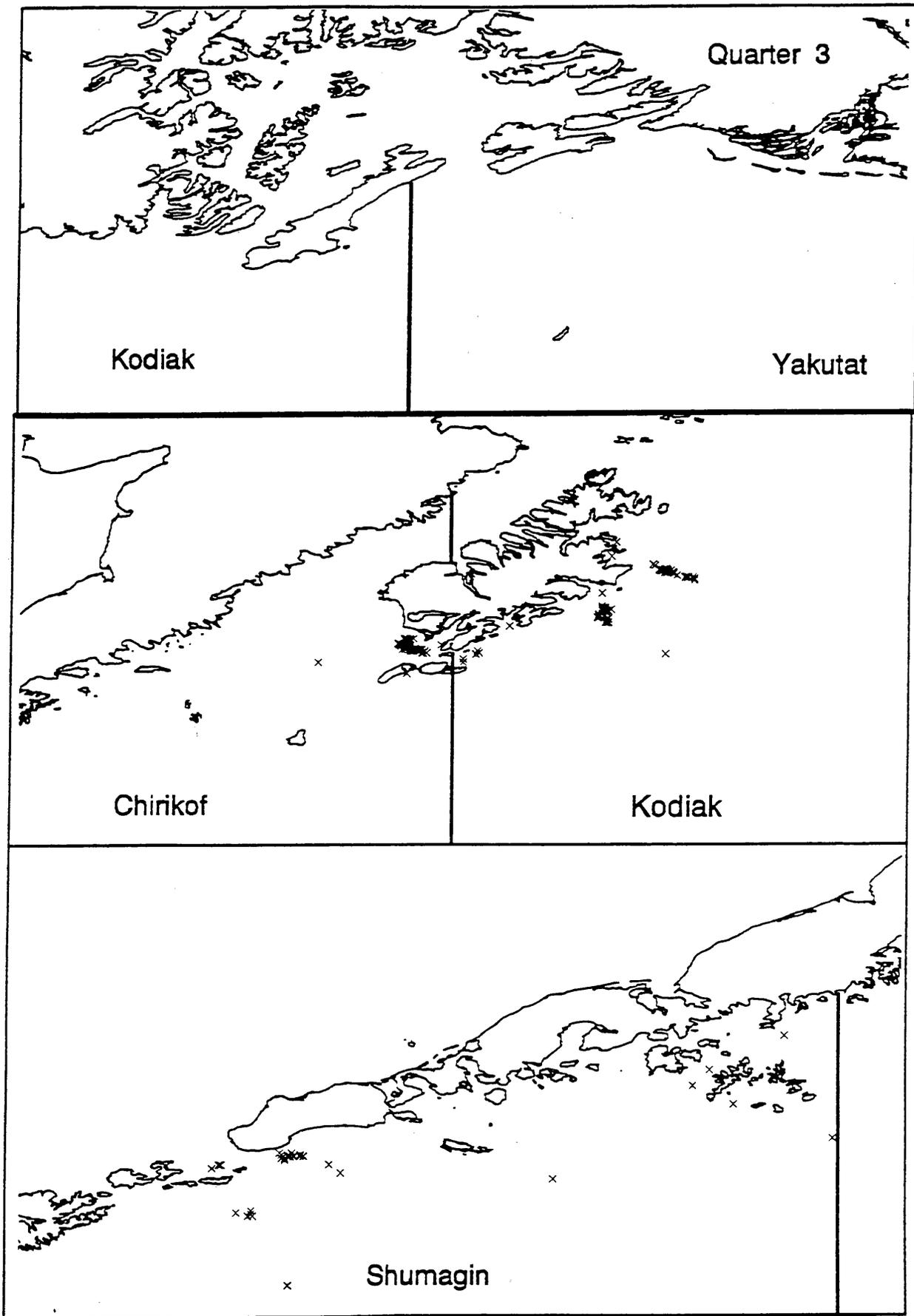


Figure 1. cont. 1995 quarterly distribution of domestic trawl locations where pollock was the target species (Quarter 3).

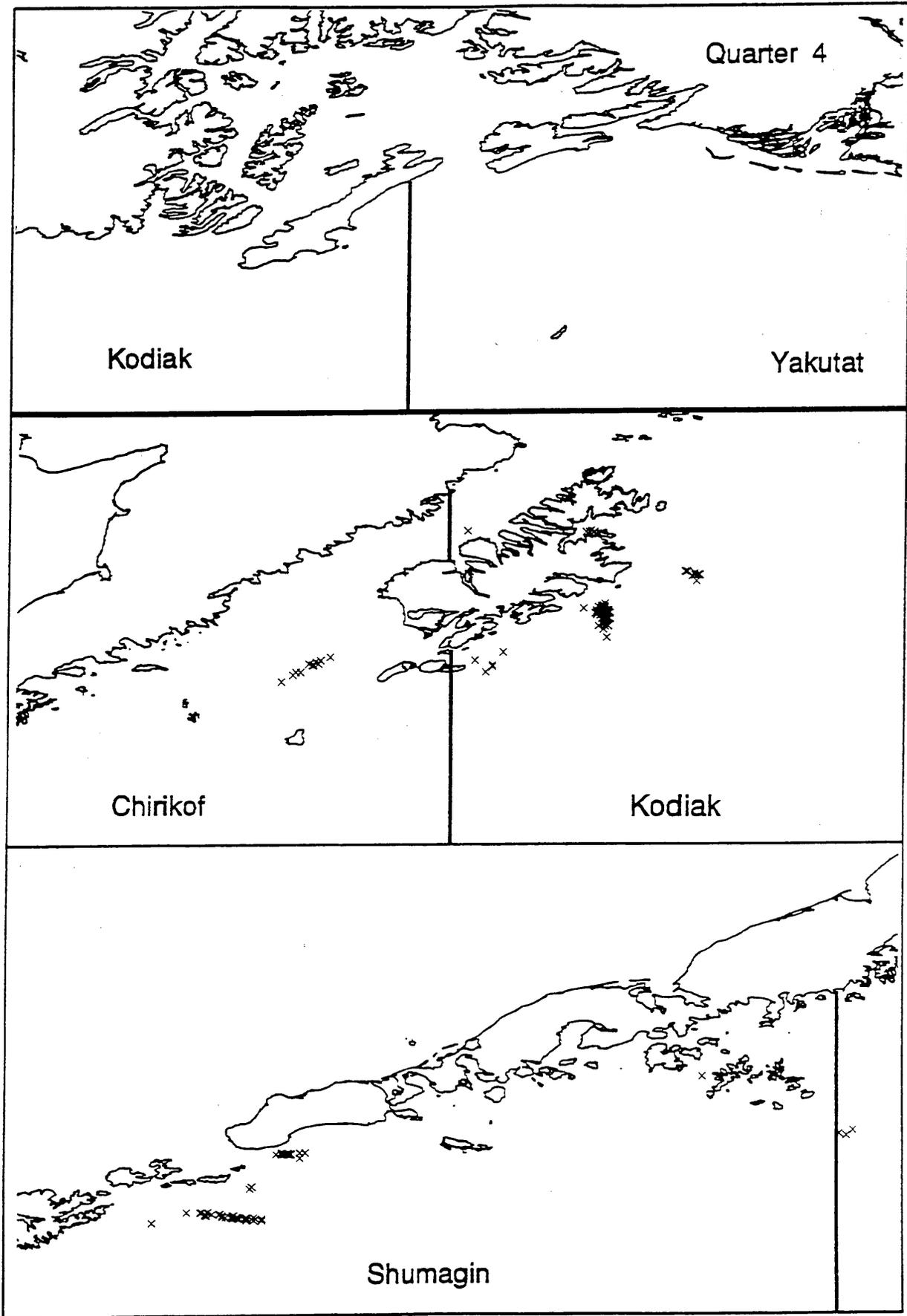


Figure 1. cont. 1995 quarterly distribution of domestic trawl locations where pollock was the target species (Quarter 4).

Pollock Survey CPUE (wt) 1996

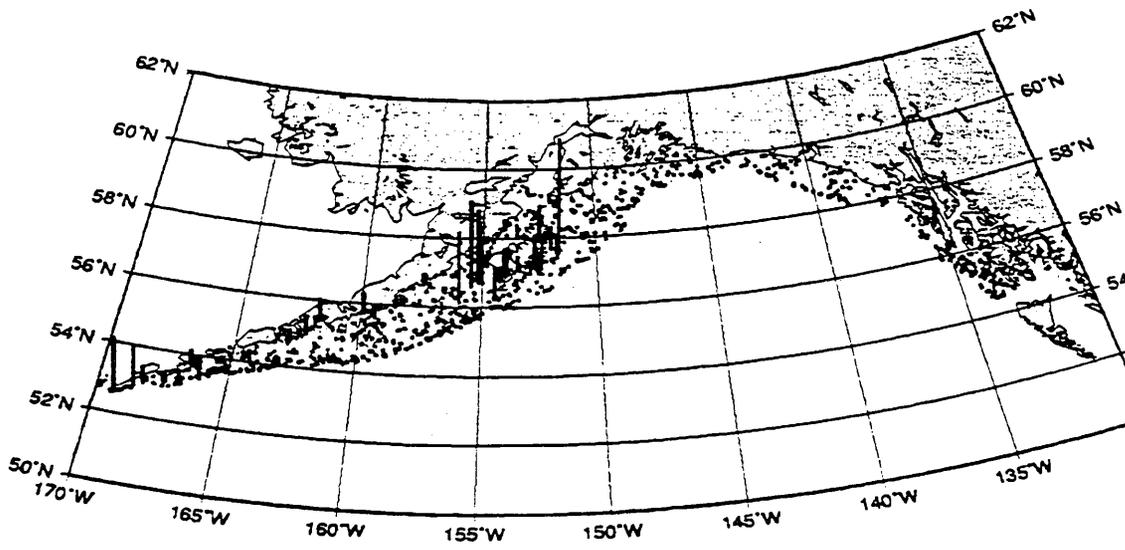


Figure 2. Distribution of survey catch per unit area (CPUE) during NMFS' 1996 triennial survey. Height of vertical bars is proportional to CPUE.

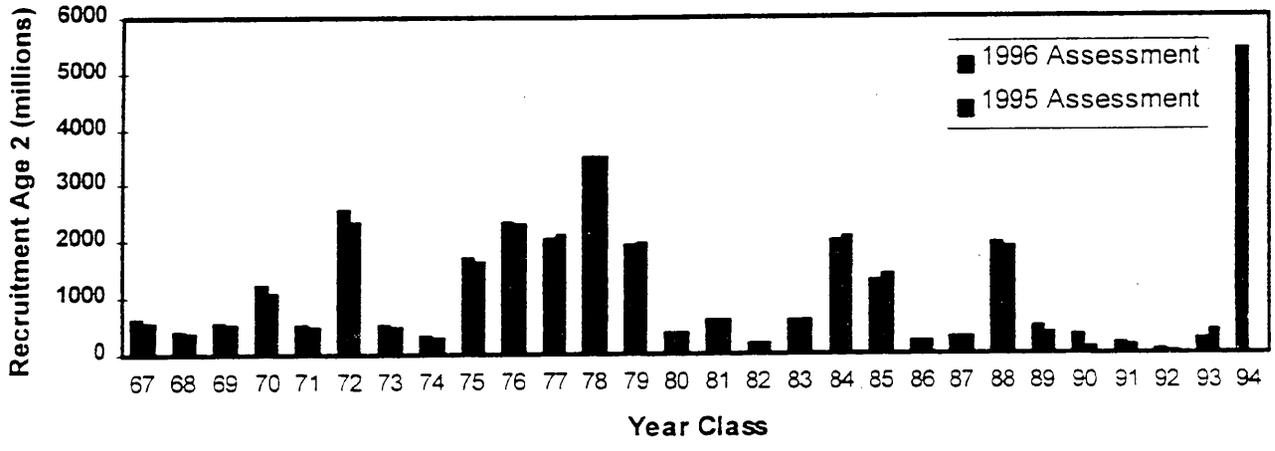
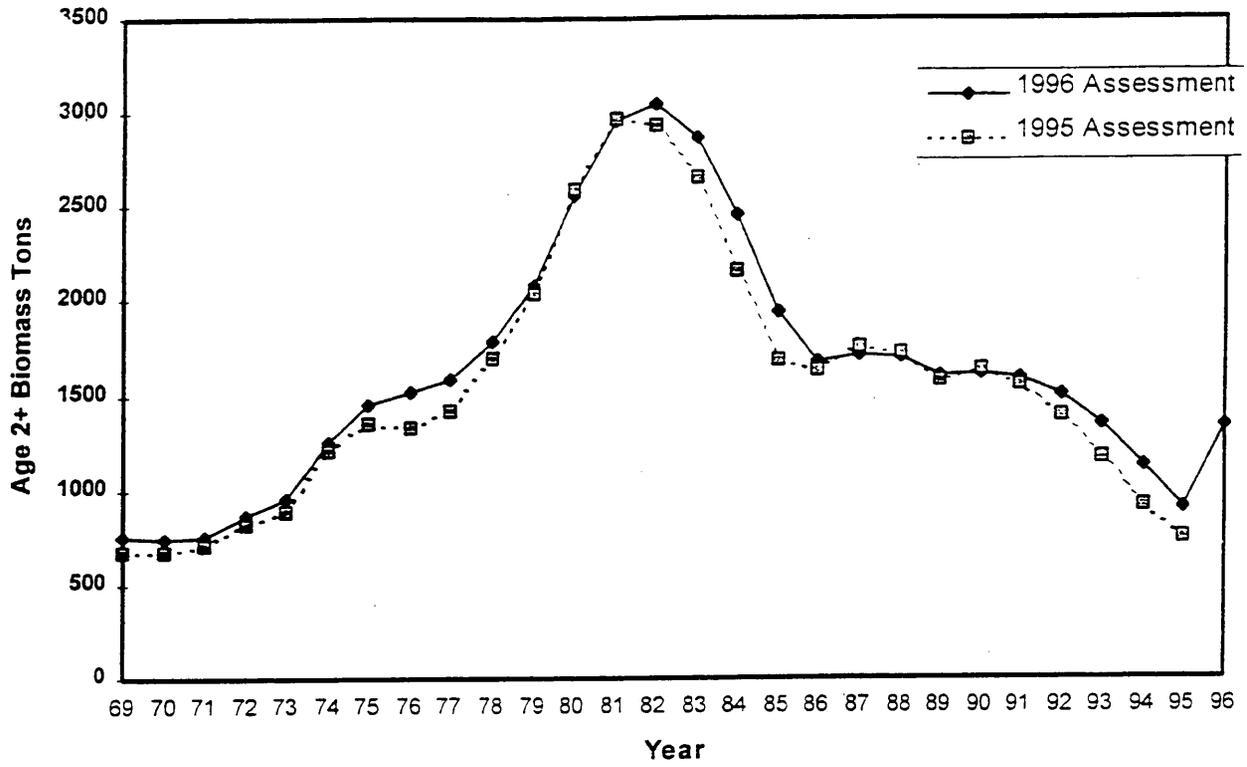


Figure 1.3. Time series of biomass (top) and age 2 recruitment (bottom) estimated from the 1995 and 1996 Stock Synthesis models.

EIT Survey

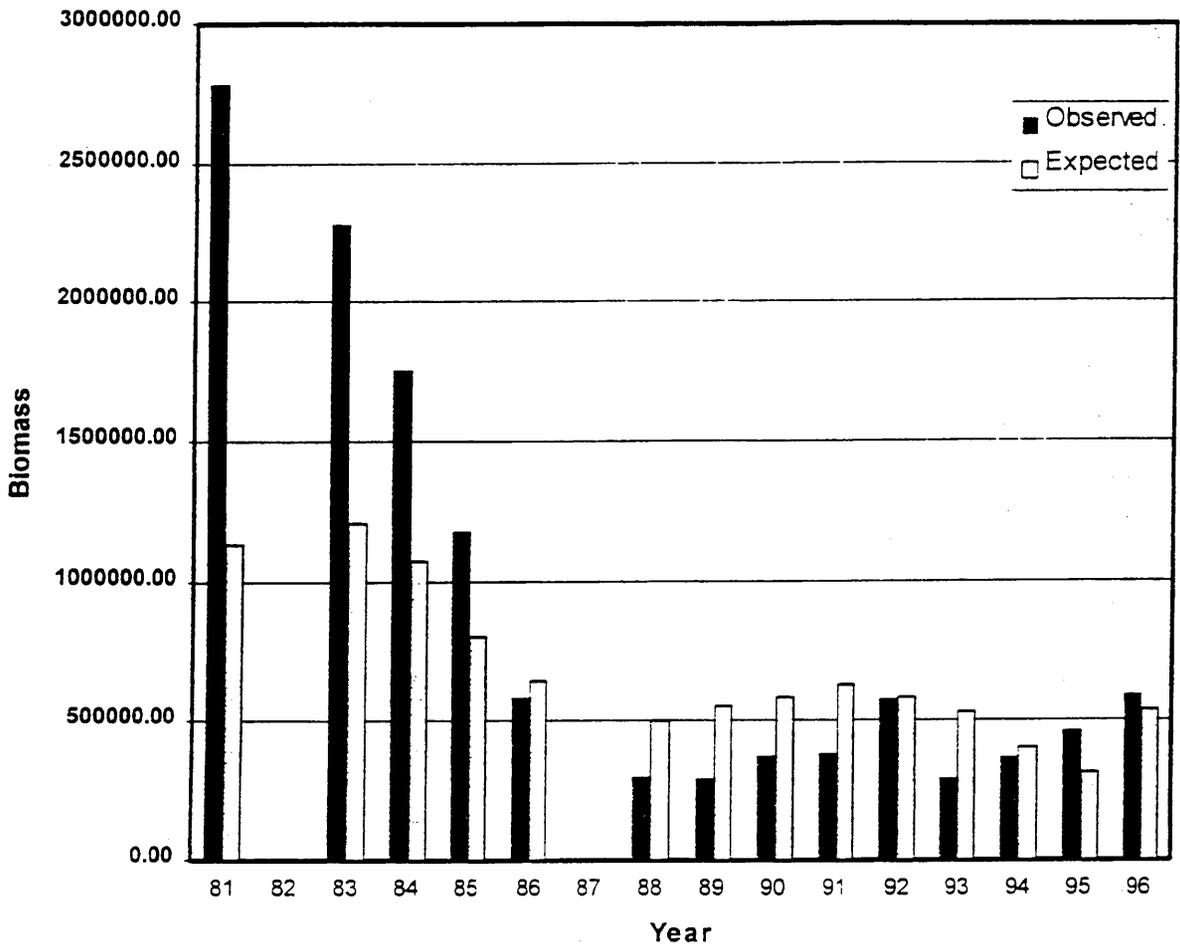


Figure 1.4. Estimates of pollock in Shelikof Strait from echo integration trawl (EIT) surveys (observed), and estimated EIT survey biomass from the 1996 Stock Synthesis model.

Bottom Trawl Survey

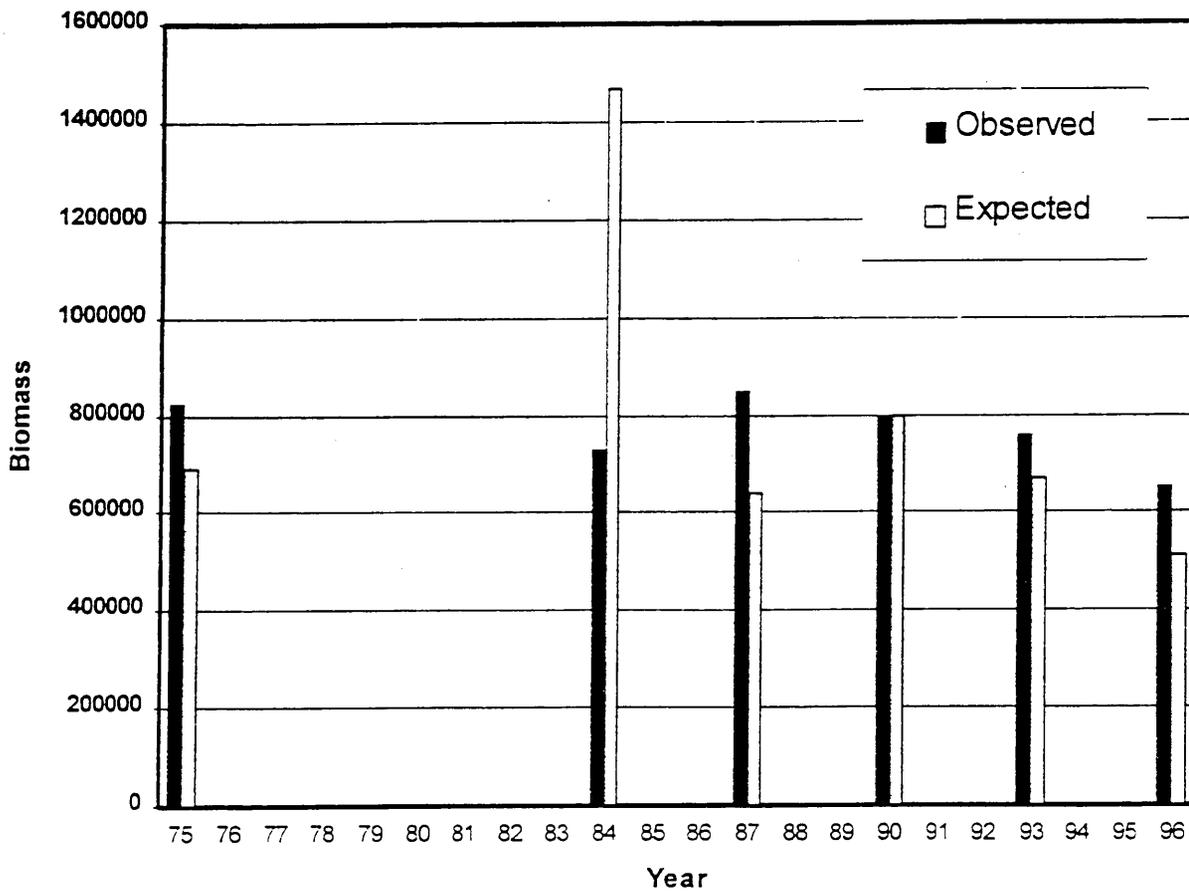


Figure 1.5 . Estimates of pollock biomass west of 144 degrees west longitude in the Gulf of Alaska from NMFS bottom trawl surveys (observed) and estimates of bottom trawl biomass from the 1996 Stock Synthesis model.

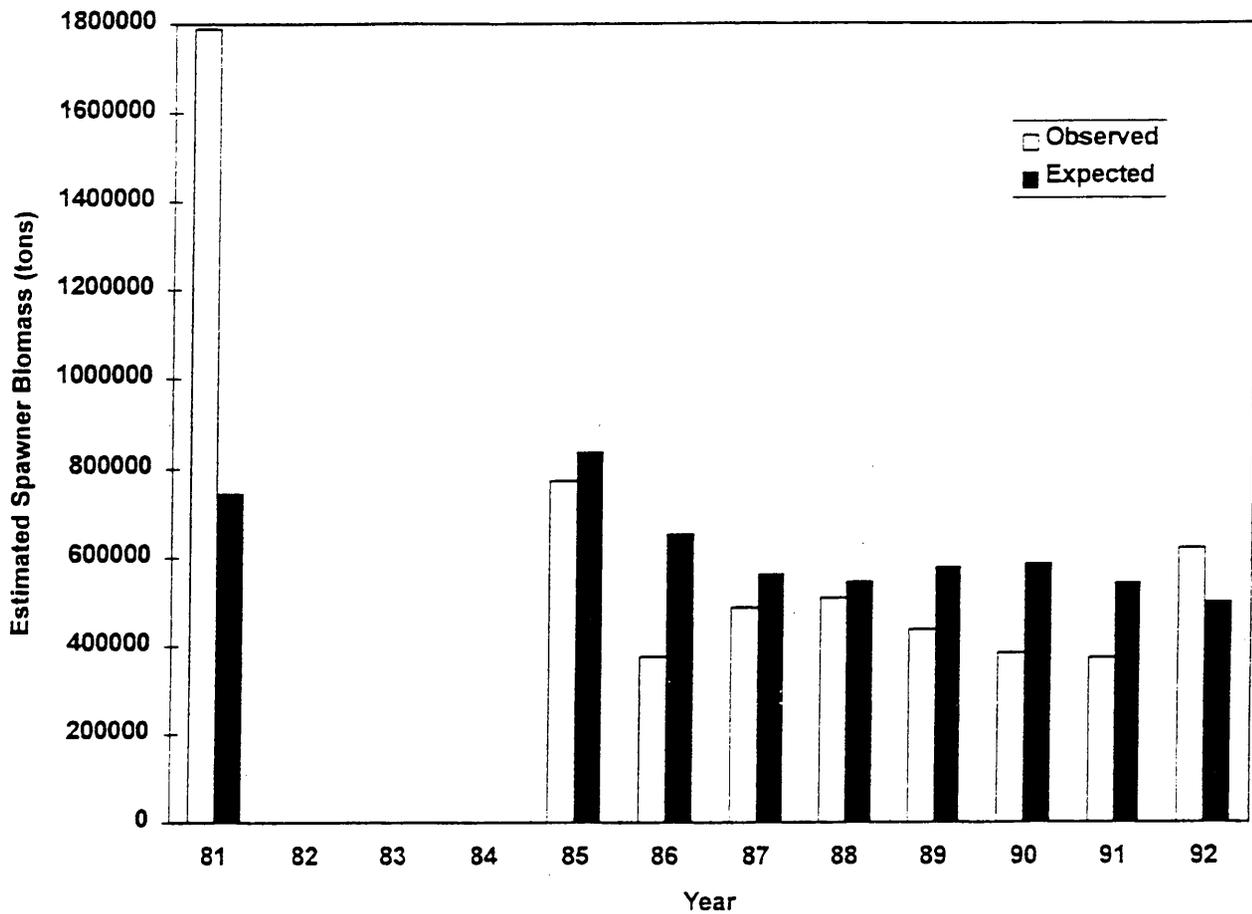


Figure 1.6. Estimates of pollock spawning biomass in Shelikof Strait derived from the egg production method (Observed) and the estimated spawning stock biomass from the Stock Synthesis model.

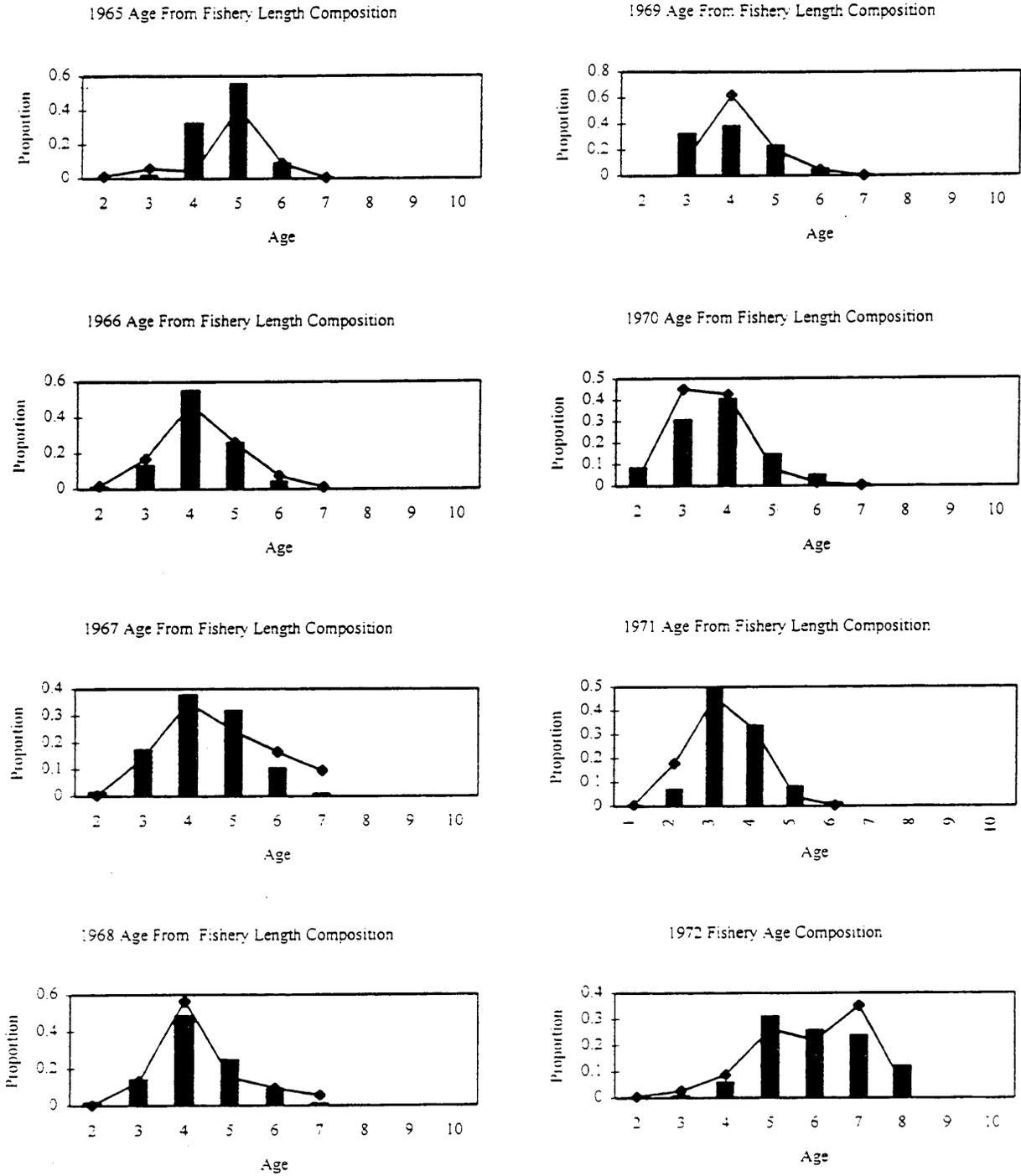
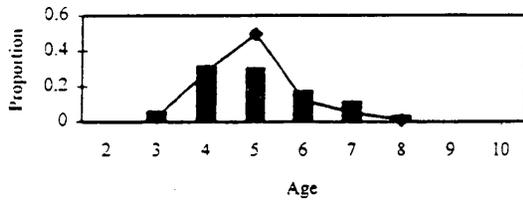
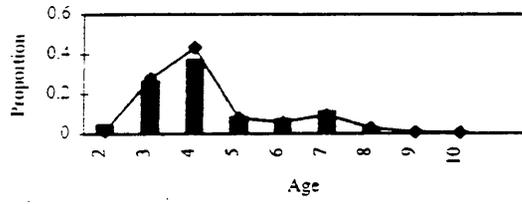


Figure 1.7. Fit to the fishery and survey age composition data expected (bars) and observed (line).

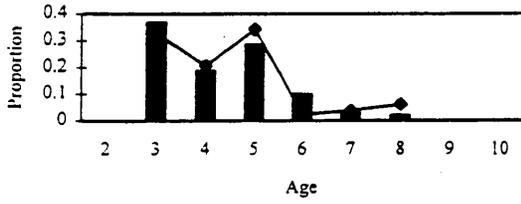
1974 Fishery Age Composition



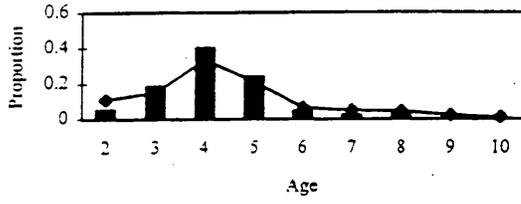
1979 Fishery Age Composition



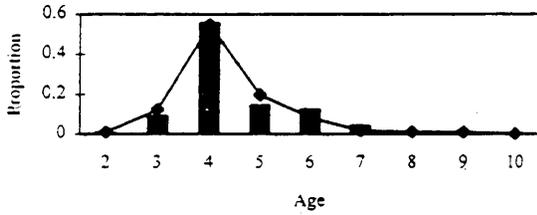
1975 Fishery Age Composition



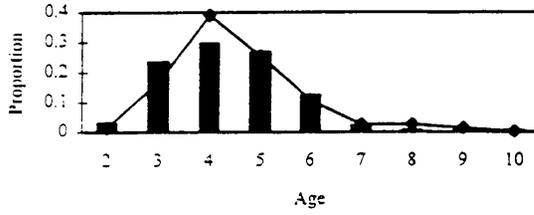
1980 Fishery Age Composition



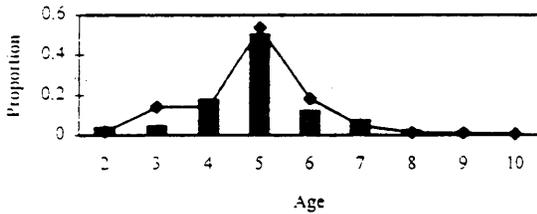
1976 Fishery Age Composition



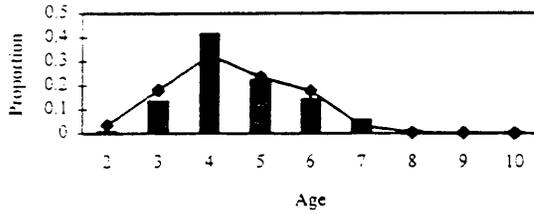
1981 Fishery Age Composition



1977 Fishery Age Composition



1982 Fishery Age Composition



1978 Fishery Age Composition

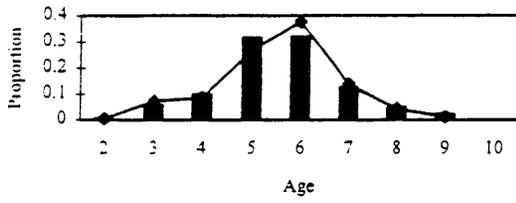


1983 Fishery Composition

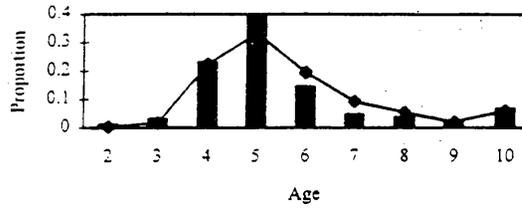


Figure 1.7 cont.. Fit to the fishery and survey age composition expected (bars) and observed (line).

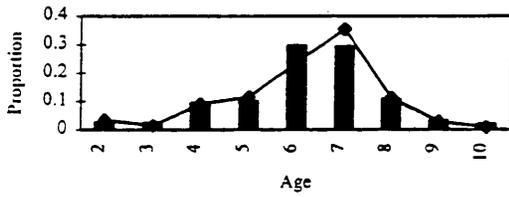
1984 Fishery Age Composition



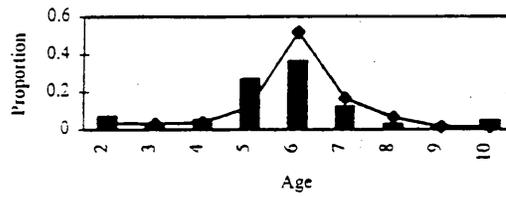
1989 Fishery Age Composition



1985 Fishery Age Composition



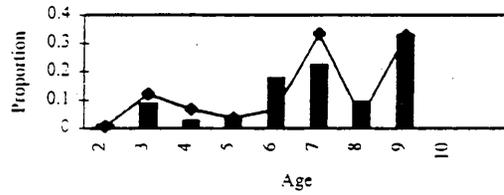
1990 Fishery Age Composition



1986 Fishery Age Composition



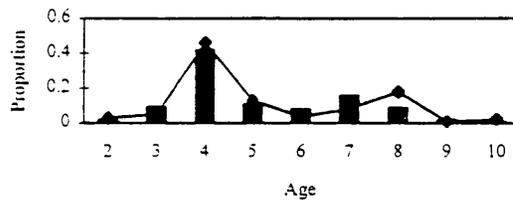
1991 Fishery Age Composition



1987 Fishery Age Composition



1992 Fishery Age Composition



1988 Fishery Age Composition



1993 Fishery Age Composition

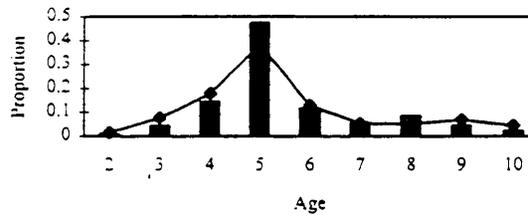
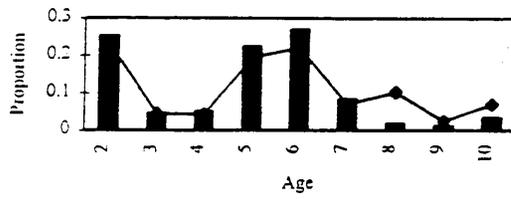


Figure 1.7 Cont.. Fits to fishery and survey age composition expected (bars) and observed (lines).

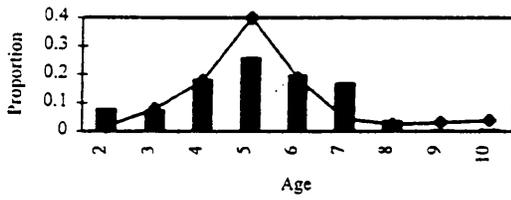
1994 Fishery Age Composition



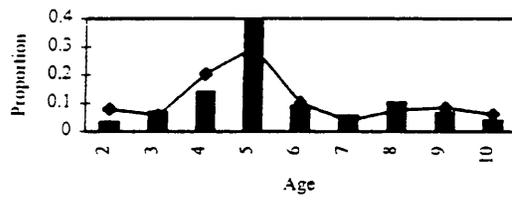
1990 Bottom Trawl Survey Age Composition



1995 Fishery Age Composition



1993 Bottom Trawl Survey Age Composition



1973 Bottom Trawl Survey Age Composition



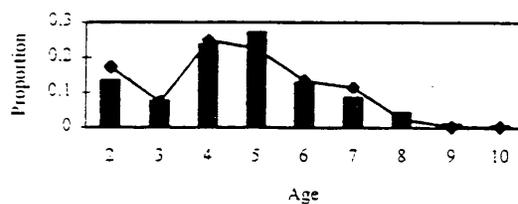
1981 EIT Survey Age Composition



1984 Bottom Trawl Survey Age Composition



1985 EIT Survey Age Composition



1987 Bottom Trawl Survey



1984 EIT Survey Age Composition

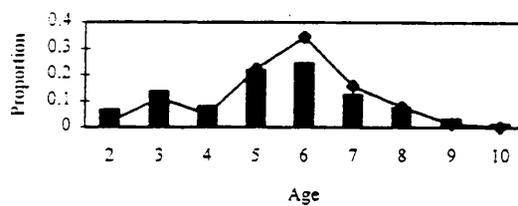


Figure 1.7 Cont.. Fits to fishery and survey age composition expected (bars) and observed (lines).

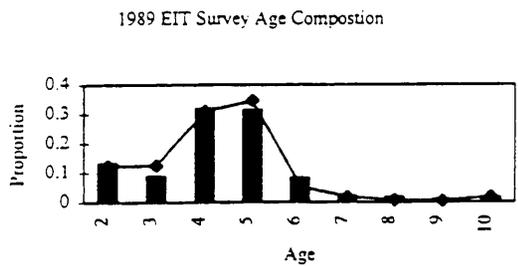
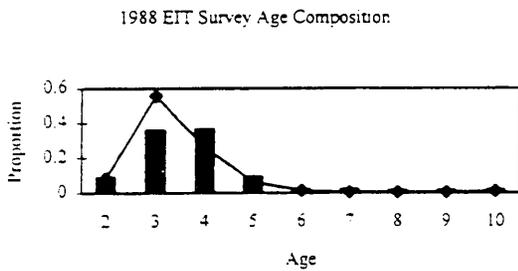
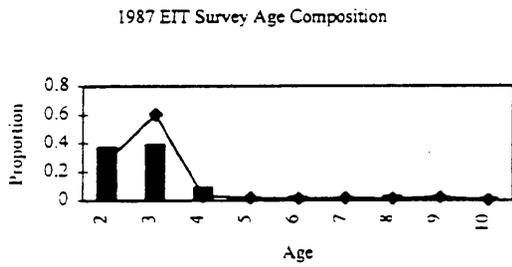
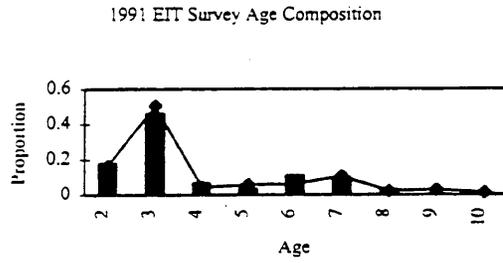
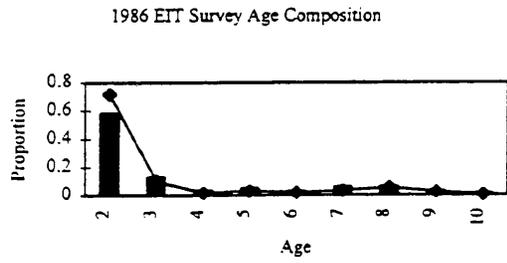
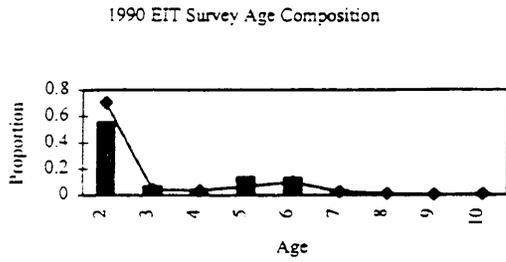
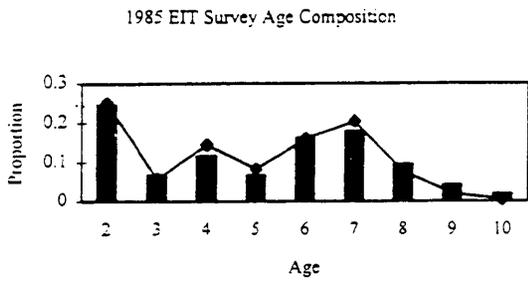


Figure 1.7 Cont.. Fits to fishery and survey age composition expected (bars) and observed (lines).

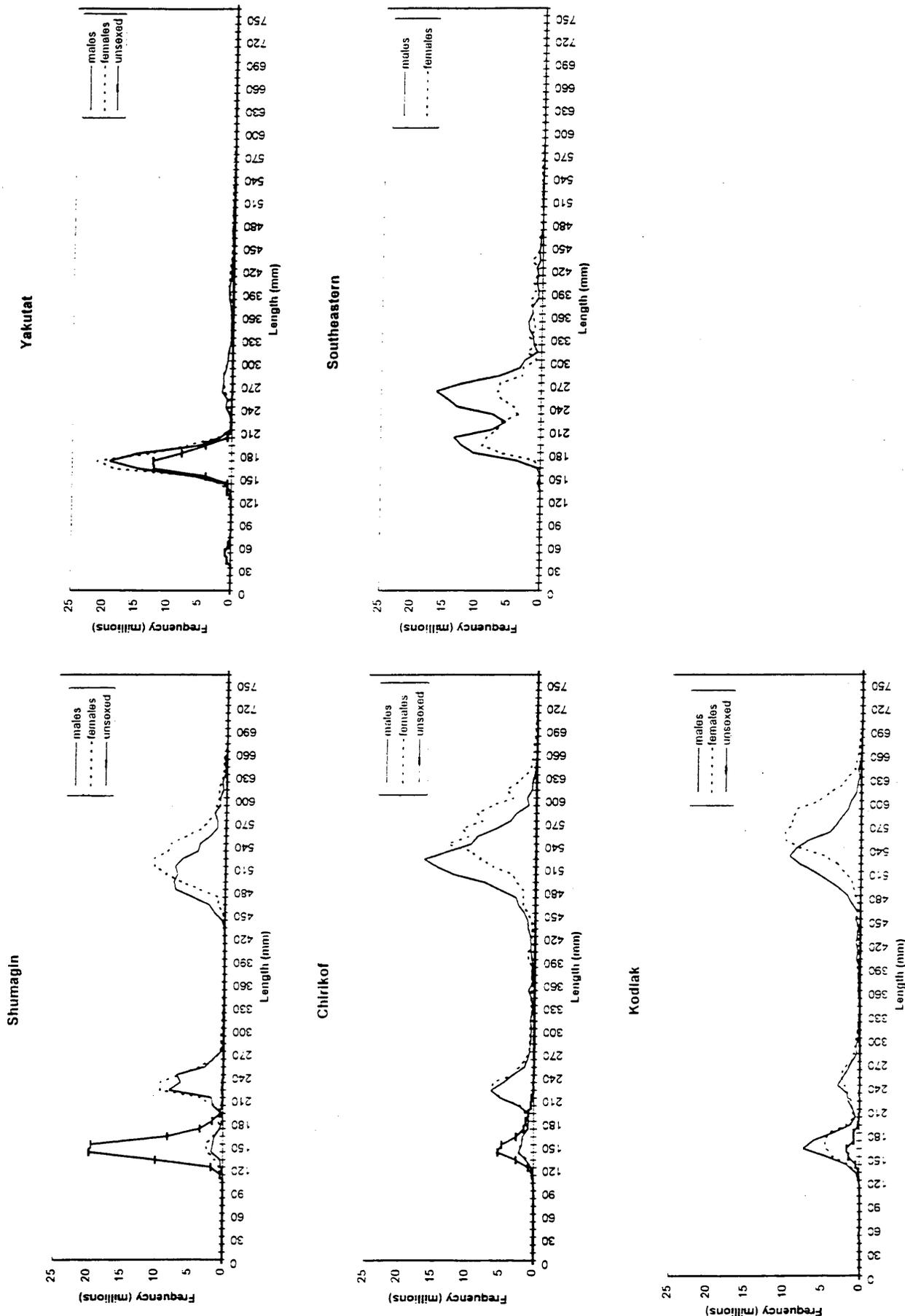


Figure 1.8. Length frequency from the 1996 NMFS triennial bottom trawl survey by INPFC statistica. area.

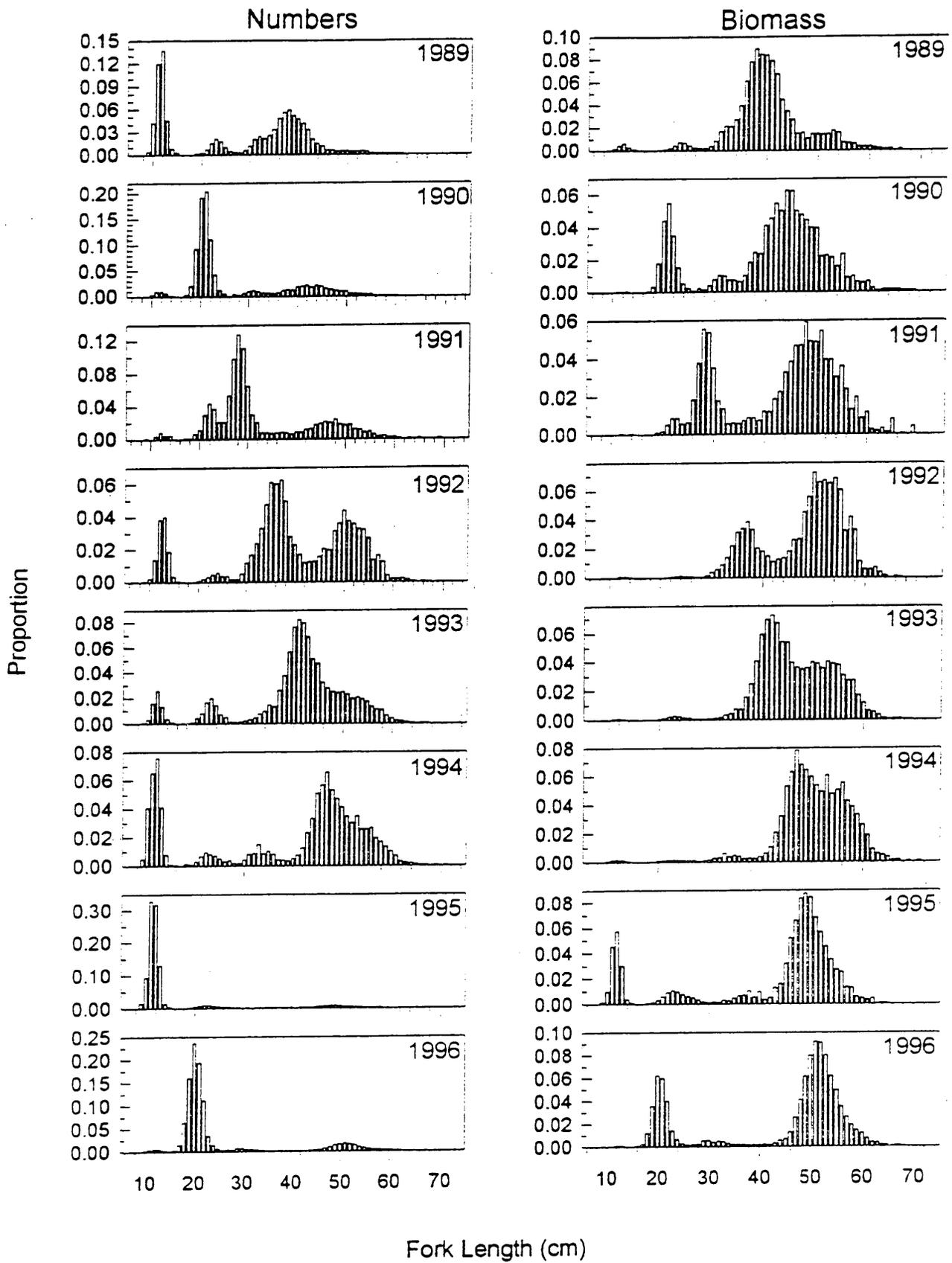


Figure 1.9. Annual pollock size composition estimates for the Shelikof Strait area based on echo integration-trawl surveys during 1989-1996.

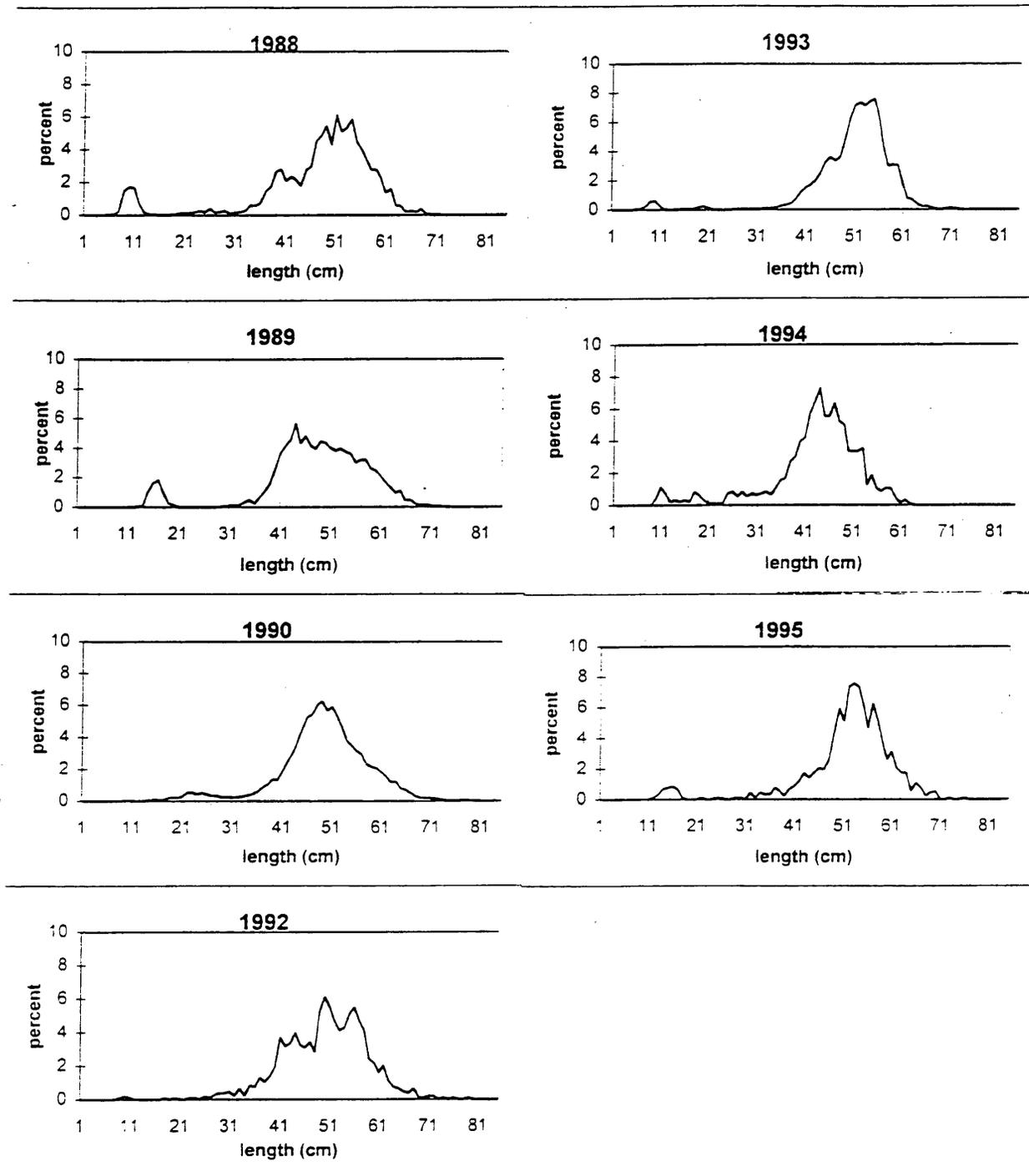


Figure 1.10 Proportional population size composition of walleye pollock from ADF&G bottom trawl surveys (Kodiak management area).

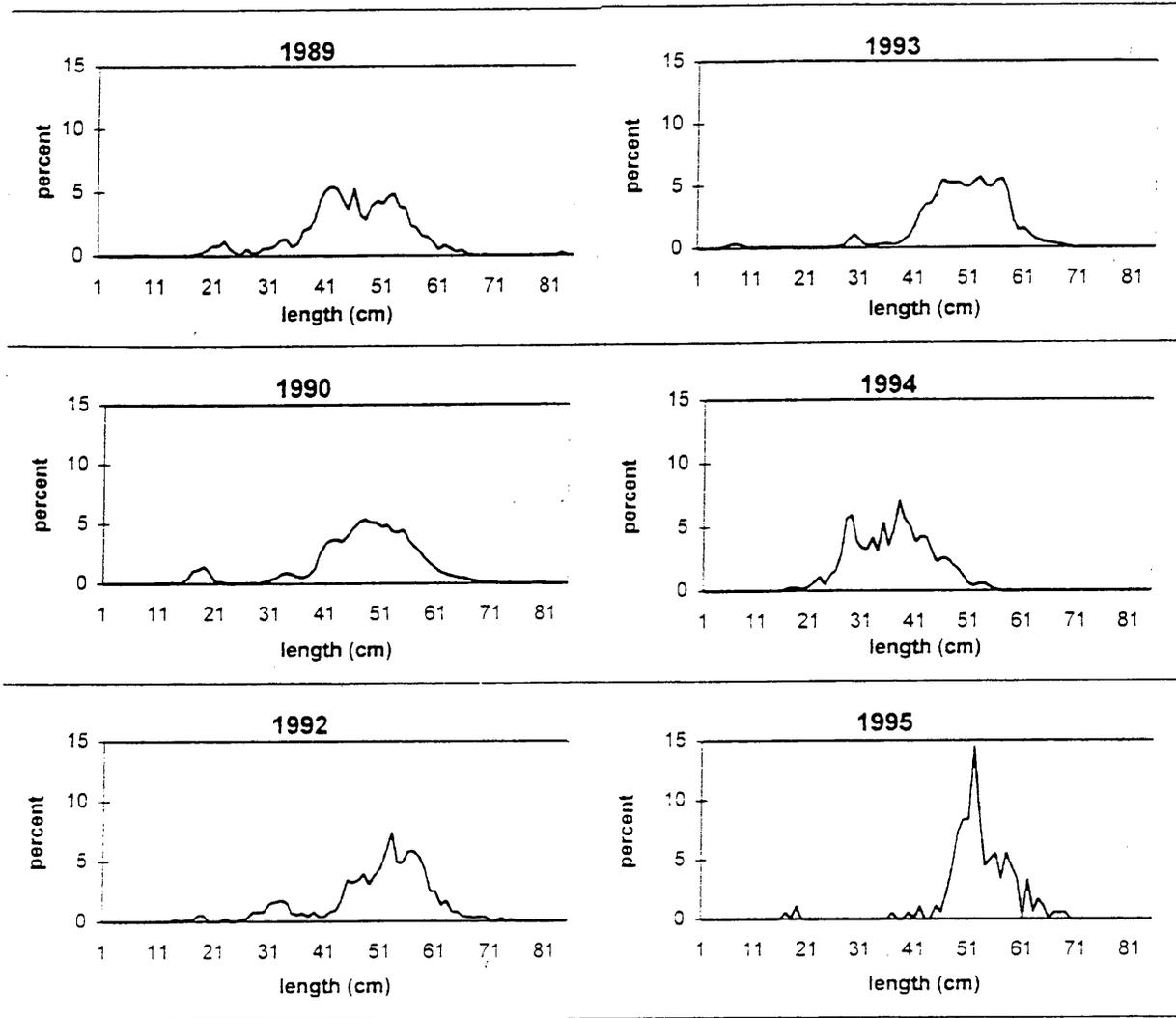
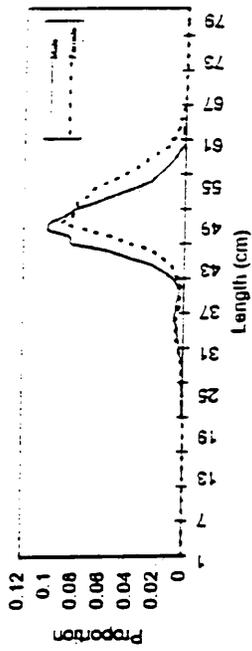
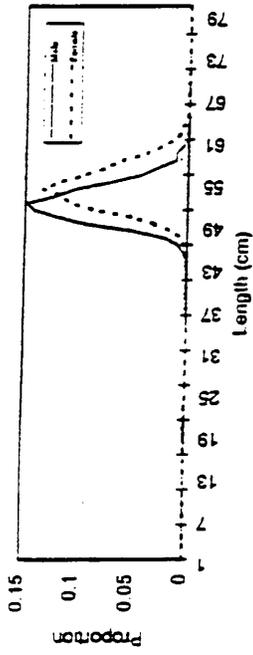


Figure 1.11 Proportional population size composition of walleye pollock from ADF&G bottom trawl surveys (Chignik and South Peninsula management areas).

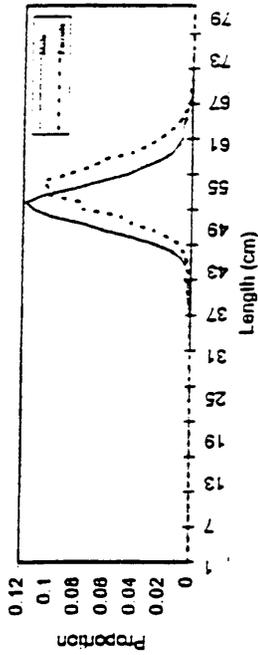
Kodiak - Chirikof, Jan - Apr



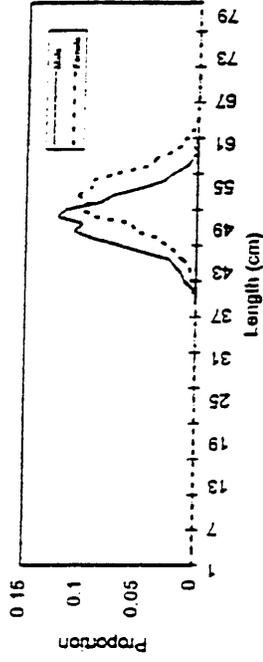
Kodiak - Chirikof, Sep - Dec



Kodiak - Chirikof, May - Aug



Yakutat



Shumagin

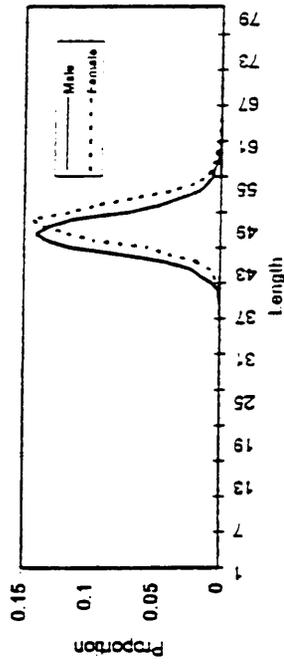


Figure 1.12 1995 length proportions from commercial fishery data obtained from the Shumagin, Kodiak and Yakutat regions.

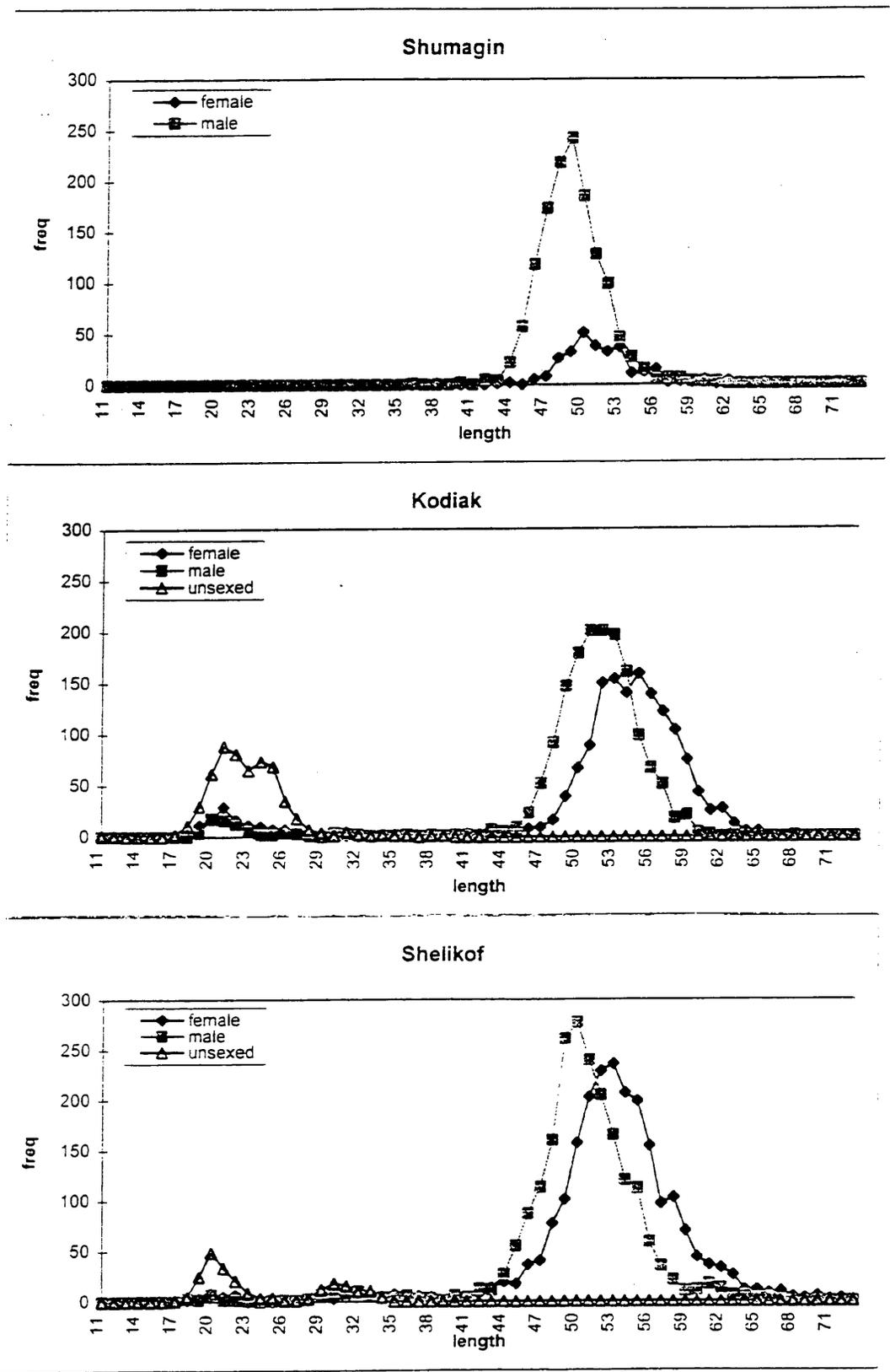


Fig. 1.13 1996 length frequency data for the first trimester port samples from the commercial fishery. Areas 621 and 631 are the Shelikof regions.

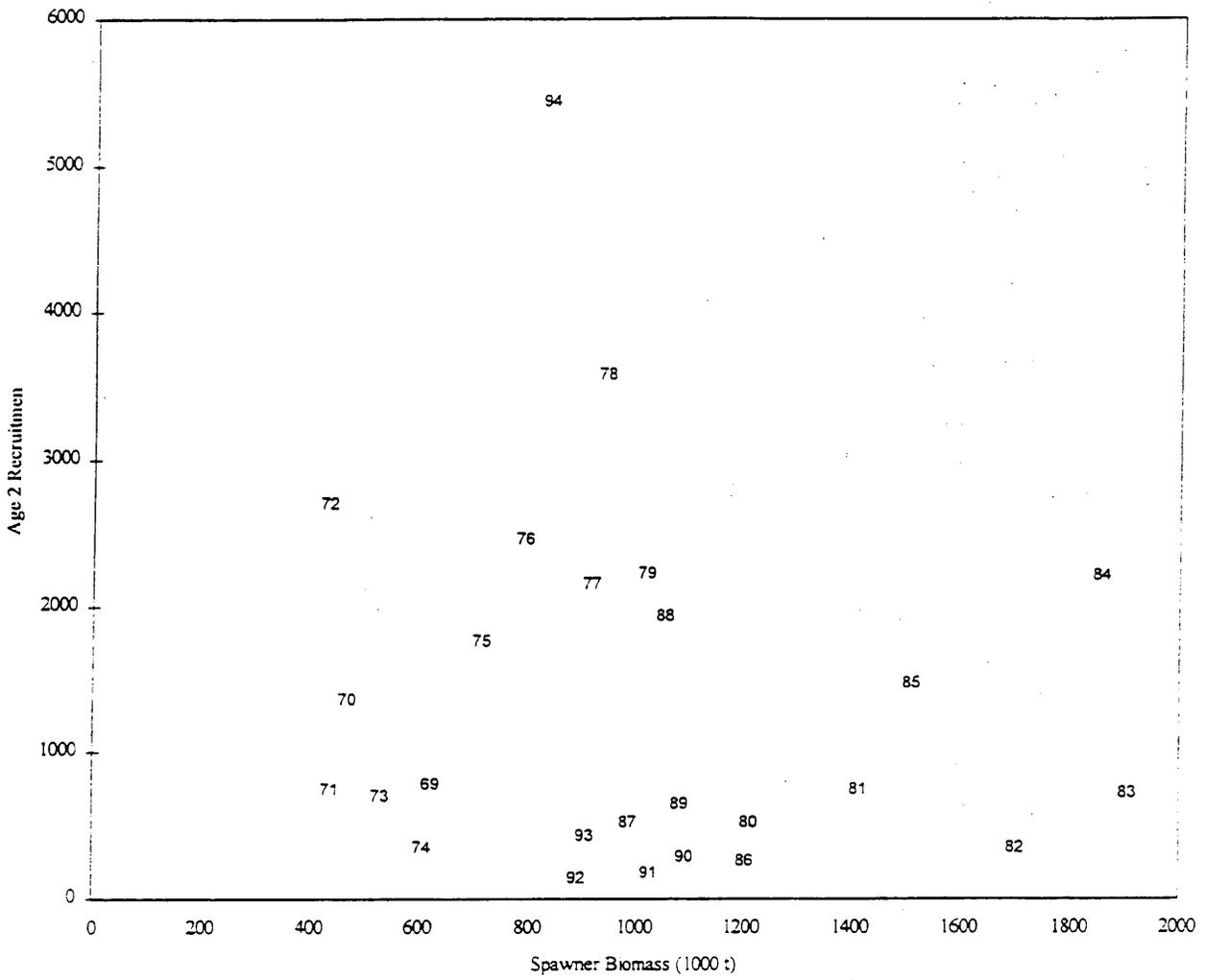


Figure 1.14 - Spawning stock (males and females combined) and age 2 recruitment for Gulf of Alaska walleye pollock based on the 1996 Stock Synthesis model.

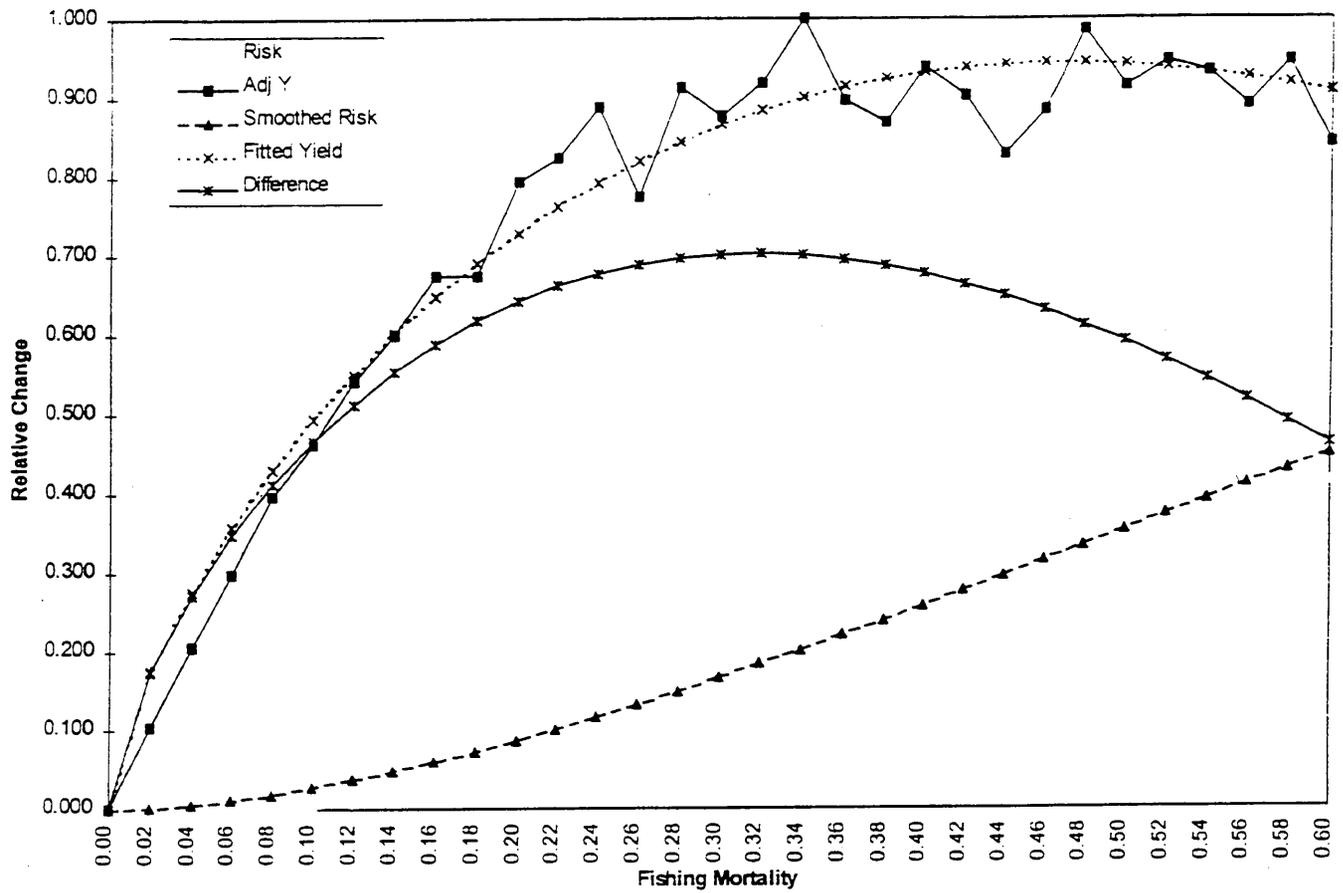


Figure 1.15. Relative changes in the risk of spawner biomass falling below a threshold of 381,000 t and yield in relation to fishing mortality.

Appendix 1. Sensitivity Analysis of the Stock Synthesis Model.

Introduction:

The stock synthesis model provides a flexible modeling framework that allows the analyst to explore the impact of a variety of assumptions concerning stock conditions and the relative consistency of different data sources through sensitivity analysis. The first sensitivity analysis of the stock synthesis model was conducted in 1989 (Megrey et al 1990). Megrey et al (1990) documented several inconsistencies in the assessment data sets used for Gulf of Alaska pollock. The analysis presented here is a reconsideration of the sensitivity of the stock synthesis model to a variety of assumptions. This analysis is not an exhaustive study of all of the possible combinations of model assumptions, however, it does provide a useful guide for selecting model configurations for assessing the Gulf of Alaska pollock resource.

Analysis Methods:

Eight model configurations were explored in this analysis. Models A - H are described in Table A.1. These models were designed to address the following questions.

1. What is the impact of decreasing emphasis on the egg production biomass index?
2. Could the number of length bins be reduced from 10 to 7 without altering the estimated trends in stock abundance?
3. Would inclusion of the 1984 bottom trawl biomass estimate change the model results?
4. What is the impact of forcing the EIT survey selectivity to be asymptotic?
5. If natural mortality is increased from 0.3 to 0.4, does the fit to the data sources change?
6. If natural mortality for age 2 fish is increased from 0.3 to 0.6 and natural mortality for age 3+ fish is increased from 0.3 to 0.4, does the fit to the data sources change?
7. Is there sufficient contrast in the data to estimate bottom trawl survey catchability using the stock synthesis model?

Subsequently, the impact of increasing the emphasis on a single biomass index was explored.

Results:

Decreasing the emphasis on the egg production spawner biomass index (EPI) resulted in a better fit to the EIT biomass time series and a degraded fit to the EPI time series. The relative fit to the other data sources was approximately the same between models A and B (Table A.1). The later finding supports published findings that the EPI index generally follows the trend observed in the EIT survey (Picquelle and Megrey 1989, Models A and B).

As expected, reduction of the number of length bins improved the fit to the POP length and EIT length data. This apparent improvement is simply a result of fewer bins in the model fit. The relative fit to the other data sources was not changed substantially (likelihood change ≤ 5) (Table A.1, Models A and C).

The selectivity pattern of the EIT survey indicates that pollock are fully recruited to this survey until they reach older age groups. The selectivity pattern shows a steep decline between age 7 and 10. This steep pattern of decline is consistent with the hypothesis that older age pollock do not spawn in Shelikof Strait, or that older age pollock tend to reside in the near bottom habitat where they can not be differentiated from the bottom or captured

with mid-water trawl gear. Forcing the selectivity pattern of the EIT survey to be asymptotic results in a reduction of fit (Table A.1, Models C and D).

The 1984 bottom trawl survey biomass estimate has been excluded from the stock synthesis model since 19--. The rationale used to justify excluding this estimate was that the 1984 data point was inconsistent with the biomass trend observed in Shelikof Strait. The Shelikof Strait time series indicated that the pollock stock declined rapidly between 1981 and 1986, while the bottom trawl surveys in 1984 and 1987 showed a stable biomass level. Inclusion of the 1984 biomass did not influence the relative fit to data sources other than the bottom trawl time series (Table A.1, Models A and E, or Models C and F).

Hollowed et al (1995) introduced a stock synthesis model that incorporated predation mortality from other fish predators and marine mammals. This model indicated that natural mortality for age 3 + fish should 0.4 rather than 0.3. The predation model also indicated that mortality of age 2 fish could be as high as 0.6. Models G and H explore these possibilities (Table A.1). Model G explores the impact of increasing natural mortality from 0.3 to 0.4, and Model H explores the impact of increasing age 2 natural mortality to 0.6. Model fits to the available information sources show a substantial improvement to the fit of the EIT biomass time series and a degradation of the fit to the bottom trawl biomass time series (Table A.1, Models F, G, and H).

Changing Q for the bottom trawl survey had little impact on the relative fit of the model to the information sources (Table A.1, Models C2 - C10). However, the ending biomass level ranged from 1.9 million t to 1.3 million t. The best over all fit to the model was produced from model C10 where the catchability for the bottom trawl survey was assumed to be 1.2. These results indicate that Q must be estimated independently from the model.

Summary

The exploratory runs demonstrated the need for additional process oriented field research to verify assumptions made in the stock assessment. The analysis indicated that the inclusion of the EPI data did not negatively impact the over all fit of the model. The analysis also indicated that decreasing the length bins from 10 to 7 is recommended. The results suggest that the EIT survey selectivity should not be constrained to be asymptotic. Questions regarding natural mortality and the catchability of the bottom trawl survey are less conclusive. Model H and Models C2 - C10 indicated that the model would fit the data better if the number of older fish was reduced. Additional research is required to select the "correct" model configuration. Approximately 4,000 stomachs were collected during the 1995 bottom trawl survey. Analysis of an additional year of gut content data should improve our ability estimate natural mortality from fish predation. Likewise, NMFS is exploring alternative acoustic methods to improve our understanding of the behavior of pollock to bottom trawl gear. In the absence of new information from auxiliary studies designed to independently estimate model parameters, the recommended model configuration for 1996 is Model F.

Table A. 1. Summary models A - H based on maximum likelihood fitting algorithms.

Model	Len Bins	EPI	BTQ	EFT	N	POP	Len	EFT	AC	BT	84	M	POP	Len	For	AC	Dom	AC	EFT	Biom	EFT	AC	EFT	Len	BT	BIOM	BT	AC	EPI	Total
A	10	1	1	1	1	300	Free	0	0.3	180	-195	-432	-62	-298	-482	6	-238	-20	-1900											
B	10	0.001	1	1	1	300	Free	0	0.3	-181	-194	-428	-55	-299	-488	6	-234	-42	-1914											
C	7	1	1	1	1	200	Free	0	0.3	-135	-193	-430	-60	-297	-373	5	-236	19	-1739											
D	7	1	1	1	1	200	Asymptotic	0	0.3	-140	-208	-417	-88	-380	-355	-30	-248	-10	-1876											
E	10	1	1	1	1	300	Free	1	0.3	-182	-194	-432	-64	-297	-482	-6	-241	-15	-1912											
F	7	1	1	1	1	200	Free	1	0.3	-135	-193	-429	-61	-297	-372	-6	-239	-14	-1746											
G	7	1	1	1	1	300	Free	1	0.4	-134	-195	-433	-56	-290	-380	-15	-240	-6	-1750											
H	7	1	1	1	1	300	Free	1	0.6/0.4	-134	-194	-444	-55	-285	-370	-10	-234	-9	-1737											
C2	7	1	0.75	1	1	200	Free	0	0.3	-135	-192	-433	-64	-297	-372	4	-235	-23	-1746											
C3	7	1	0.8	1	1	200	Free	0	0.3	-134	-193	-432	-63	-297	-373	4	-235	-22	-1744											
C4	7	1	0.9	1	1	200	Free	0	0.3	-135	-193	-431	-61	-297	-373	5	-236	-20	-1741											
C5	7	1	0.95	1	1	200	Free	0	0.3	-136	-192	-430	-61	-297	-373	5	-236	-19	-1740											
C6	7	1	1	1	1	200	Free	0	0.3	-135	-193	-430	-60	-297	-373	5	-236	-19	-1739											
C7	7	1	1.05	1	1	200	Free	0	0.3	-137	-192	-430	-60	-297	-373	5	-236	-18	-1738											
C8	7	1	1.1	1	1	200	Free	0	0.3	-135	-193	-429	-60	-297	-374	6	-236	-18	-1737											
C9	7	1	1.15	1	1	200	Free	0	0.3	-135	-194	-429	-59	-297	-375	6	-236	-18	-1736											
C10	7	1	1.2	1	1	200	Free	0	0.3	-136	-193	-428	-59	-297	-374	6	-237	-16	-1735											

POP Len = Length frequency data from incidental catch of pollock in Japanese Pacific Ocean Trawl fishery.

For AC = Age composition data from the foreign fishery.

Dom AC = Age composition data from the domestic fishery.

EFT Biom. = Echo Integration Trawl survey biomass estimates

EFT AC = Echo Integration Trawl survey age composition data.

EFT Len = Echo Integration Trawl survey length frequency data.

Walleye Pollock (*Theragra chalcogramma*) abundance in the Southeastern Aleutian Basin near Bogoslof Island during February-March, 1997

by Taina Honkalehto and Neal Williamson
Alaska Fisheries Science Center
7600 Sand Point Way NE, Bldg. #4
Seattle WA 98115

INTRODUCTION

Since 1988, with the exception of 1990, the distribution and abundance of spawning walleye pollock (*Theragra chalcogramma*) in the southeastern Aleutian Basin near Bogoslof Island have been investigated using echo integration-trawl (EIT) survey techniques. In the late 1980's, a directed domestic fishery on Bogoslof pollock existed, but it was halted in 1991 due to declining catches in the Donut Hole (central Aleutian Basin) and a drop in biomass in the Bogoslof area (Honkalehto and Williamson 1996). Tracking the abundance of pollock that spawn near Bogoslof remains important for management of the U. S. pollock fishing industry and to Central Bering Sea Convention member nations. Results presented here are from the pollock survey carried out 28 February-11 March 1997 between Akutan Island and the Islands of Four Mountains, Alaska. Scientists from the United States, China, Poland and South Korea participated.

METHODS

Acoustic data were collected with a Simrad EK 500¹ quantitative echo-sounding system (Bodholt et al. 1989) on the NOAA ship *Miller Freeman*, a 66-m stern trawler equipped for fisheries and oceanographic research. Two split-beam transducers (38 kHz and 120 kHz) were mounted on the bottom of the vessel's centerboard extending 9 m below the water surface. System electronics were housed inside the vessel in a new permanent acoustics laboratory that replaced the portable laboratory used on previous cruises. Data from the echo sounder/receiver were processed using Simrad BI500 echo integration and target strength analysis software (Foote et al. 1991) on a SUN workstation. Results presented here were based on the 38 kHz data. Midwater echo sign was sampled using an Aleutian Wing 30/26 trawl and 5 m² "Fishbuster" doors (1,250 kg).

Between 1 and 10 March, two EIT survey passes were run through the Bogoslof spawning area (Fig. 1). Pass 1 (1-8 March) covered about 1400 nautical miles (nmi) of transects. The trackline consisted of 27 north-south parallel transects beginning at about 165° 44'W and ending near 170° 20'W. Transects 1-6 were spaced 10 nmi apart and transects 7-17 were 5 nmi apart. Pass 2 (9-10 March, transects 21-38) covered 525 nmi, and was run from west to east between 170° W and 167° 30'W at 5 nmi spacing. Pass 2 transects were positioned mid-way between pass

¹ Reference to trade names or commercial firms does not constitute U.S. Government endorsement.

1 transects. Echo integration data collected continuously at about 11.5 kts vessel speed were examined for pollock and stored at a SV threshold of -69 decibels (dB). Estimates of pollock backscattering strength in the area represented by each transect were generated. These values were then summed and scaled using a previously derived relationship between target strength and fish length ($TS = 20 \text{ Log FL} - 66$; Traynor 1996) to estimate the numbers and weight of pollock for each length category using pollock size compositions and a length-weight relationship derived from trawl catch information. Although trawl hauls sampled a higher percentage of females than males on average as they have in the past several years' surveys, we assumed a 50:50 sex ratio for population size composition and computed length-weight relationships. This is because we cannot easily obtain a representative sex ratio, as Bogoslof spawning pollock are highly aggregated and stratified by sex (Honkalehto and Williamson 1995; 1996). Size compositions used to scale the acoustic data in each area were obtained using a weighting procedure described in Honkalehto and Williamson (1996). Separate male and female length-weight relationships obtained by pooling trawl data were averaged together into one regression by minimizing the sum of squares between the two curves using an iterative non-linear approach. Age data are not yet available.

Numbers and biomass of pollock were estimated for the entire geographic area covered by the survey (Fig. 1), using data from all trawl hauls (Fig. 2). Separate estimates were made for the area covered by pass 1 and pass 2. Assuming little or no migration to or from the area covered in pass 2, "pass 1 and 2 combined" numbers and biomass were estimated by averaging pass 1 and 2 data in this area and adding it to an estimate for the remaining geographic area. Echo sign characteristics as well as pollock length and maturity data from trawl catches led to classification of echo integration and trawl data into three strata: "transect 1" (haul 1), "east Bogoslof" (transects 2-5, hauls 2, 15, and 16) and "west Bogoslof" (transects 6-17 and 21-38, hauls 3-14). Estimates were made for pollock inside North Pacific Fisheries management area 518, which is equivalent to the "Specific Area" as it is defined in the Central Bering Sea Convention² and will thus be referred to as "area 518/CBS convention area". This area corresponds to "west Bogoslof" area estimates minus portions of transects 6 and 16 and excluding all of 16.5 and 17 (Fig. 1). EIT survey and biomass estimation methods are discussed in detail in Honkalehto and Williamson (1996).

Error bounds on the acoustic data were derived using the one-dimensional (1D) geostatistical approach described in Petitgas (1993) and Williamson and Traynor (1996). The 1D method requires equal spacing between transects and no fewer than 10 transects (Petitgas, pers. comm.). For this reason, transects 2-5 were treated separately from transects 6-17, 21-38. For transects 2-5 ($n=4$), a conservative error bound can be calculated using the sample variance of the transect cumulates - i.e. $\text{error} = \pm 2 \sqrt{(\text{var}/n)/\text{mean}}$. For the remaining area (west of transect 5),

²The "specific area" is defined in the Annex to the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea as "the area south of a straight line between a point at 55° 46' N lat. and 170° W long. and a point at 54° 30' N lat., 167° W long. and between the meridian 167° W long. and the meridian 170° W long. and the north of the Aleutian Islands and straight lines between the islands connecting the following coordinates in the order listed: 52° 49.2 N 169° 40.4 W, 52° 49.8 N 169° 06.3 W, 53° 23.8 N 167° 50.1 W, 53° 18.7 N 167° 51.4 W.

95% of the total acoustic return (S_m) is contained in the region covered at 2.5 nmi spacing. We calculated the error (± 2 relative estimation error) using the 1D approach and all data from transects 7-16, 21-38 and assuming 2.5 nmi spacing. These acoustic data error bounds can be used to provide error bounds on the point estimate of biomass. These error bounds only quantify acoustic data sampling variability; other sources of error (e.g. target strength, trawl sampling) are not included. This treatment of error - though not statistically rigorous - provides a general idea of the acoustic sampling variability of the survey.

RESULTS

Pollock were observed throughout the survey area, either as dense spawning layers or aggregations or as faint layers of single fish. They dominated the 16 midwater trawl catches in both weight and numbers. Low to moderately dense pollock aggregations were distributed in the eastern portion of the survey area north of Akutan Island and along the shelf edge north of Umnak Island (Figs. 3 and 4). Most pollock (about 60% of the biomass from pass 1) were observed in extremely dense aggregations 1-10 nmi in horizontal extent and 200-400 m in vertical extent between 200-700 m in the water column in the Samalga Pass area northeast of the Islands of Four Mountains (between approximately 169° 00' - 169° 45' W long., and 52° 50' - 53° 30' N lat.). Temperature profiles in the surveyed region were similar to those from previous years in March; the water column was well-mixed with an average temperature of 3.9° C between the surface and 500 m.

Walleye pollock caught during the survey had lengths ranging from 33 to 66 cm and average lengths increased from east to west (Fig. 5). At the eastern edge of the survey area near transect 1, fish lengths from a single haul averaged 41.9 cm (males) and 44.0 cm (females). Hauls in the east Bogoslof area caught pollock with average lengths of 46.8 cm (males) and 50.0 cm (females). West Bogoslof hauls caught pollock with the largest average lengths; 51.8 cm (males) and 55.4 cm (females). The sex ratio by haul ranged from 29% to 96% female and averaged 62% female.

Maturity composition data revealed differences between pollock in haul 1 and those from hauls 2-16 (Fig. 6). Among 38 females from haul 1 only 34% were pre-spawning/spawning/post-spawning, whereas 66% were immature/developing. Conversely, females in hauls 2-16 ($n=609$) were >99% pre-spawning/spawning/post-spawning and < 1% immature/developing. Males in haul 1 ($n=40$) were less mature as well, 55% pre-spawning (none was spawning or post-spawning), and 45% immature/developing, whereas in hauls 2-16 ($n=534$) they were 98% pre-spawning/spawning/post-spawning and only 2% immature/developing. The mean gonadosomatic index (GSI), defined as the ratio of gonad weight to total body weight for pre-spawning females, was 0.20. However, most females from haul 1 had a much lower GSI than the average (Fig. 7). Because haul 1 fish were caught in shallower water (<400 m bottom depth), had smaller mean lengths, and were less mature than those from all other hauls, they were classified as non-Bogoslof fish and not included in the overall Bogoslof spawning biomass estimate.

Abundance and biomass estimates were generated for pass 1 east and west, pass 2 (entirely in the west area) and a combination of data from the two passes (Table 1, and Fig. 1). Using the combined estimate, the biomass of pollock for the entire Bogoslof survey area in winter 1997 was 392 thousand tons; 50 thousand tons in the east area, and 342 thousand tons in the west (Table 1). The biomass error bound for the east area was 4-96 thousand tons and for the west area was 301-383 thousand tons. Pollock totaled 337 million--57 million in the east and 280 million in the west. Inside the area 518/CBS convention area, pollock biomass was 342 thousand tons and pollock numbered 279 million. Transect 1 pollock, considered to be non-Bogoslof fish, numbered 23 million and totaled about 14 thousand tons. Pollock otoliths collected during this cruise have not yet been aged and thus estimates of age composition are not available.

Bogoslof pollock have experienced a gradual decline in abundance from their 1988 and 1989 levels of over 2 million tons (Fig. 8). In recent years the geographic distribution of the main spawning aggregations has shifted westward, from deeper basin waters near Bogoslof Island to slope waters in Samalga Pass near the Islands of Four Mountains. From 1988 through 1993, increasing average fish length indicated an aging population with little recruitment (Table 2, Fig. 9). In 1994 a relatively strong 1989 year class began to recruit to the population (Table 3, Fig. 10). In 1995, recruitment from the 1989 year class continued, and we estimated a larger biomass than in 1994--1.1 million tons--that appeared to reverse the declining trend (Honkalehto and Williamson 1996, Fig. 8). However this reversal was short-lived. Abundance declined in 1996 and again in 1997 and is currently at its lowest level yet observed--0.39 million tons.

REFERENCES

- Bodholt, H., H. Nes, and H. Solli. 1989. A new echo sounder system. Proceedings of the Institute of Acoustics 11(3):123-130.
- Foote, K.G., H. P. Knudsen, R. J. Korneliussen, P. E. Nordbo, and K. Roang. 1991. Postprocessing system for echo sounder data. J. Acoust. Soc. Am. 90:37-47.
- Honkalehto, T. and N. Williamson. 1995. Echo integration-trawl survey of walleye pollock (*Theragra chalcogramma*) in the southeast Aleutian Basin during February and March, 1994. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-52, 39 p.
- Honkalehto, T. and N. Williamson. 1996. Echo integration-trawl survey of walleye pollock (*Theragra chalcogramma*) in the southeastern Aleutian Basin during February and March, 1995. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-65, 57 p.
- Petitgas, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. ICES Journal of Marine Science, 50: 285-298.
- Traynor, J. J. 1996. Target strength measurements of walleye pollock (*Theragra chalcogramma*) and pacific whiting (*Merluccius productus*). ICES Journal of Marine Science, 53: 253-258.

Williamson, N and J. Traynor. 1996. Application of a one-dimensional geostatistical procedure to fisheries acoustic surveys of Alaskan pollock. ICES Journal of Marine Science, 53: 423-428.

Table 1. Estimates of numbers, biomass and acoustic return of spawning pollock near Bogoslof Island from the 1997 echo integration-trawl survey.

Estimate	Biomass thousand tons)	Numbers (millions)	Acoustic return (Sm) ¹ (1000 m ²)	Transects	Hauls	
1. Pass 1						
East	50	57	425	2-5	2,15,16	
West	271	221	2023	6-17	3-14	
Total	321	278	2448	2-17	2-16	
Area 518	270	221	2018	6-16	3-14	
2. Pass 2						
	397	325	2970	21-38	3-14	
3. Pass 1 & 2 combined						
		<u>Biomass Error Bounds</u>		<u>Acoustic Error Bounds</u>		
East	50	(4-96)	57	425 (+/-91%)	2-5	2,15,16
West	342	(301-383)	280	2560 (+/-12%)	6-17,21-38	3-14
Total	392		337	2985	2-17,21-38	2-16
Area 518	342		279	2555	6-16,21-38	3-14

¹ $Sm = \sum_{i=1}^n Sa * A_n$, where n is the number of 0.5 nmi intervals along the transect, Sa is meters² of pollock backscattering cross section per nmi² and $A_n = 0.5 * w$, where w is the width assigned to the interval and varies depending on transect spacing.

Table 2. Population at length estimates (millions of fish) from February-March echo integration-trawl surveys of spawning pollock in the Bogoslof Island area. No survey was conducted in 1990.

Length	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
10	0	0	-	0	0	0	0	<1	0	0
11	0	0	-	0	0	0	0	<1	0	0
12	0	0	-	0	0	0	0	1	0	0
13	0	0	-	0	0	0	0	<1	0	0
14	0	0	-	0	0	0	0	<1	0	0
15	0	0	-	0	0	0	0	0	0	0
16	0	0	-	0	0	0	0	0	0	0
17	0	0	-	0	0	0	0	0	0	0
18	0	0	-	0	0	0	0	0	0	0
19	0	0	-	0	0	0	0	0	0	0
20	0	0	-	0	0	0	0	0	0	0
21	0	0	-	0	0	0	0	0	0	0
22	0	0	-	<1	0	0	0	0	0	0
23	0	0	-	2	0	0	0	0	0	0
24	0	0	-	1	0	0	0	0	0	0
25	0	0	-	0	0	0	0	0	0	0
26	0	0	-	<1	0	0	0	0	0	0
27	0	0	-	0	0	0	0	0	0	0
28	0	0	-	0	0	0	0	0	0	0
29	0	0	-	0	0	0	0	0	0	0
30	0	0	-	0	0	0	0	0	0	0
31	0	0	-	0	<1	0	0	0	0	0
32	0	0	-	0	<1	0	0	0	0	0
33	0	0	-	0	<1	0	0	0	0	0
34	0	0	-	0	0	0	0	<1	<1	0
35	0	0	-	0	0	0	0	<1	0	<1
36	0	0	-	0	<1	0	0	<1	<1	<1
37	9	3	-	0	0	0	0	<1	<1	<1
38	6	0	-	2	0	1	0	1	1	<1
39	16	4	-	5	0	2	0	4	1	1
40	24	3	-	7	1	4	3	12	4	1
41	27	4	-	19	3	5	6	20	8	2
42	48	23	-	23	7	7	9	40	14	3
43	118	33	-	31	14	6	14	40	17	4
44	179	54	-	36	18	7	21	41	21	5
45	329	159	-	46	28	8	21	50	23	7
46	488	177	-	55	32	13	21	53	31	10
47	547	389	-	79	42	22	18	40	36	14
48	476	434	-	130	68	28	17	55	36	15
49	389	431	-	168	102	46	16	47	37	18
50	248	366	-	205	129	69	39	52	40	21
51	162	279	-	189	144	76	46	58	45	24
52	80	168	-	160	118	73	52	78	52	26
53	48	85	-	122	106	73	49	81	52	26

Table 2. continued.

Length	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
54	19	50	—	63	67	66	43	88	53	31
55	12	13	—	40	41	50	37	81	48	28
56	4	5	—	17	27	29	26	69	40	24
57	3	8	—	8	13	14	17	58	37	22
58	1	1	—	4	6	9	10	47	28	17
59	0	0	—	1	5	3	6	31	19	13
60	0	0	—	1	1	1	3	17	12	12
61	2	0	—	1	<1	1	2	7	6	6
62	0	0	—	<1	<1	<1	1	4	2	3
63	0	0	—	0	0	0	<1	2	1	1
64	0	0	—	0	1	<1	0	1	<1	1
65	0	0	—	<1	0	0	0	<1	<1	<1
66	0	0	—	0	0	0	0	<1	0	<1
67	0	0	—	0	0	0	0	0	0	0
68	0	0	—	0	0	0	0	1	0	0
Totals	3236	2687	—	1419	975	613	478	1081	666	337

Table 3. Bogoslof spawning pollock population estimates (millions of fish) from February-March echo integration-trawl surveys. No survey was conducted in 1990. Numbers for 1991-1995 were reanalyzed and may vary slightly from those in previous reports.

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996*	1997*
0	0	0	-	0	0	0	0	0	-	-
1	0	0	-	0	0	0	0	1	-	-
2	0	0	-	4	0	0	0	0	-	-
3	0	0	-	0	1	1	0	2	-	-
4	0	6	-	2	2	33	21	6	-	-
5	28	15	-	12	27	17	86	75	-	-
6	327	58	-	46	54	44	26	278	-	-
7	247	363	-	213	97	46	38	105	-	-
8	164	147	-	93	74	48	36	68	-	-
9	350	194	-	160	71	42	36	80	-	-
10	1201	91	-	44	55	28	17	53	-	-
11	288	1105	-	92	57	51	27	54	-	-
12	287	222	-	60	33	25	23	19	-	-
13	202	223	-	373	34	27	13	59	-	-
14	89	82	-	119	142	42	9	32	-	-
15	27	90	-	41	164	92	45	12	-	-
16	17	30	-	38	59	47	36	31	-	-
17	7	60	-	29	8	25	28	103	-	-
18	3	0	-	32	15	11	16	60	-	-
19	0	0	-	56	22	11	4	18	-	-
20	0	0	-	4	42	11	4	5	-	-
21	0	0	-	2	13	10	8	5	-	-
22	0	0	-	0	3	1	2	6	-	-
23	0	0	-	0	1	1	2	6	-	-
24	0	0	-	0	0	0	1	2	-	-
25	0	0	-	0	0	0	0	0	-	-
Totals	3236	2687	-	1419	975	613	478	1081	*Not yet available	

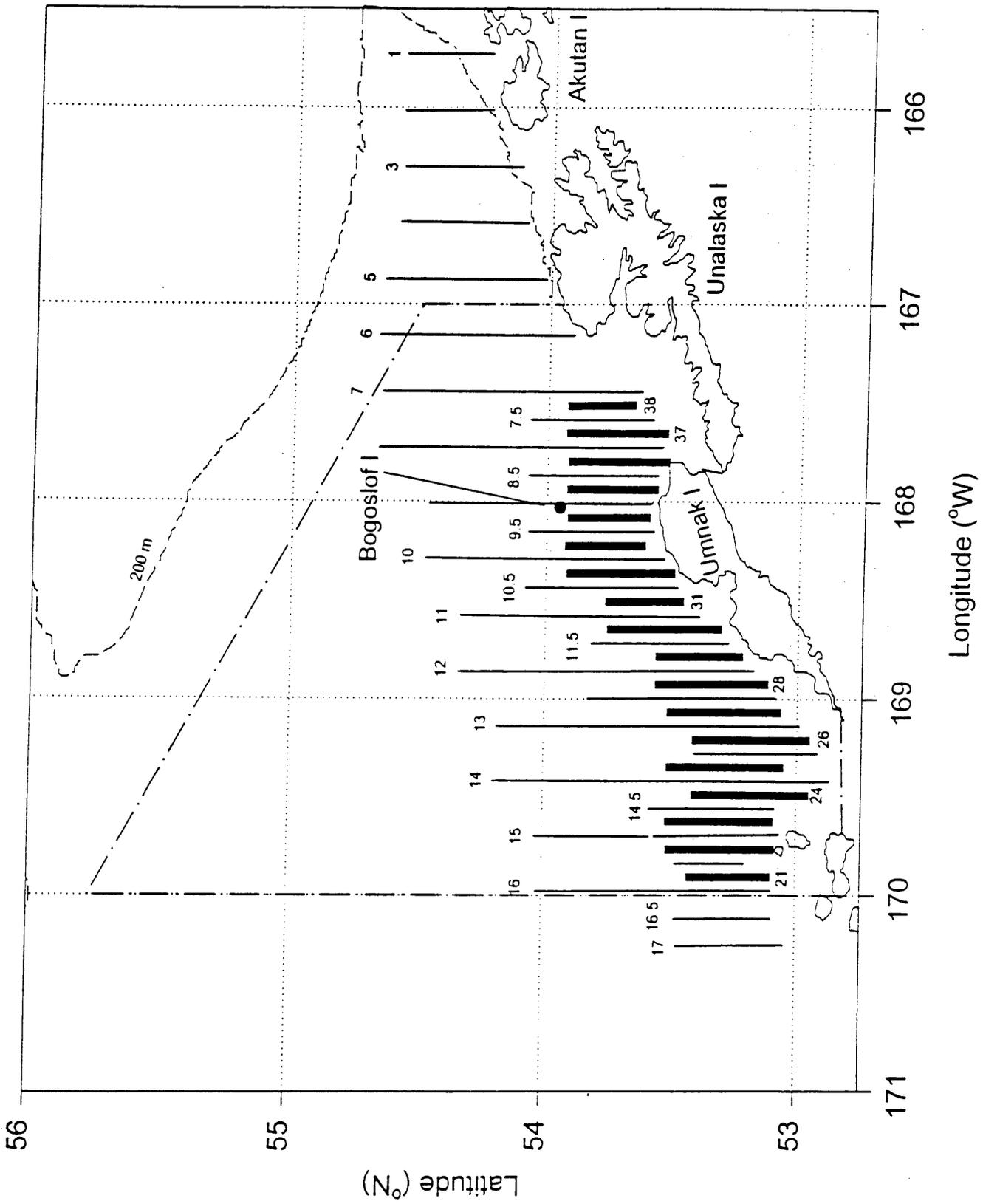


Figure 1. Echo sign sample points along north-south transects from the winter 1997 echo integration-trawl survey of the Bogoslof Island area. Thin solid lines are pass 1, thick solid lines are pass 2. Transect numbers are indicated. Dash-dotted line is boundary of U.S. fisheries management area 518/CBS convention area

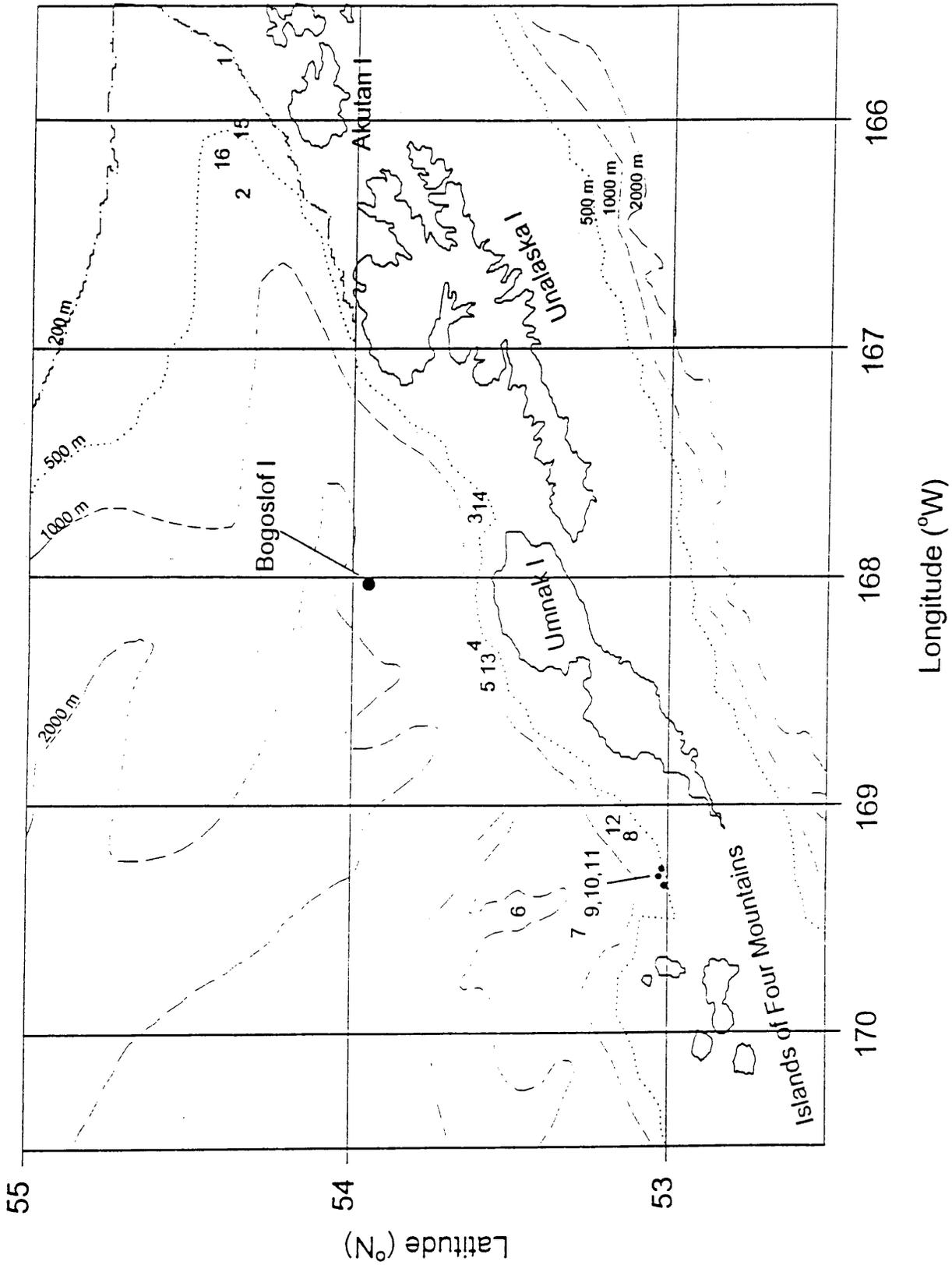


Figure 2. Haul locations (1-16) from the winter 1997 echo integration-trawl survey of the Bogoslof Island area.

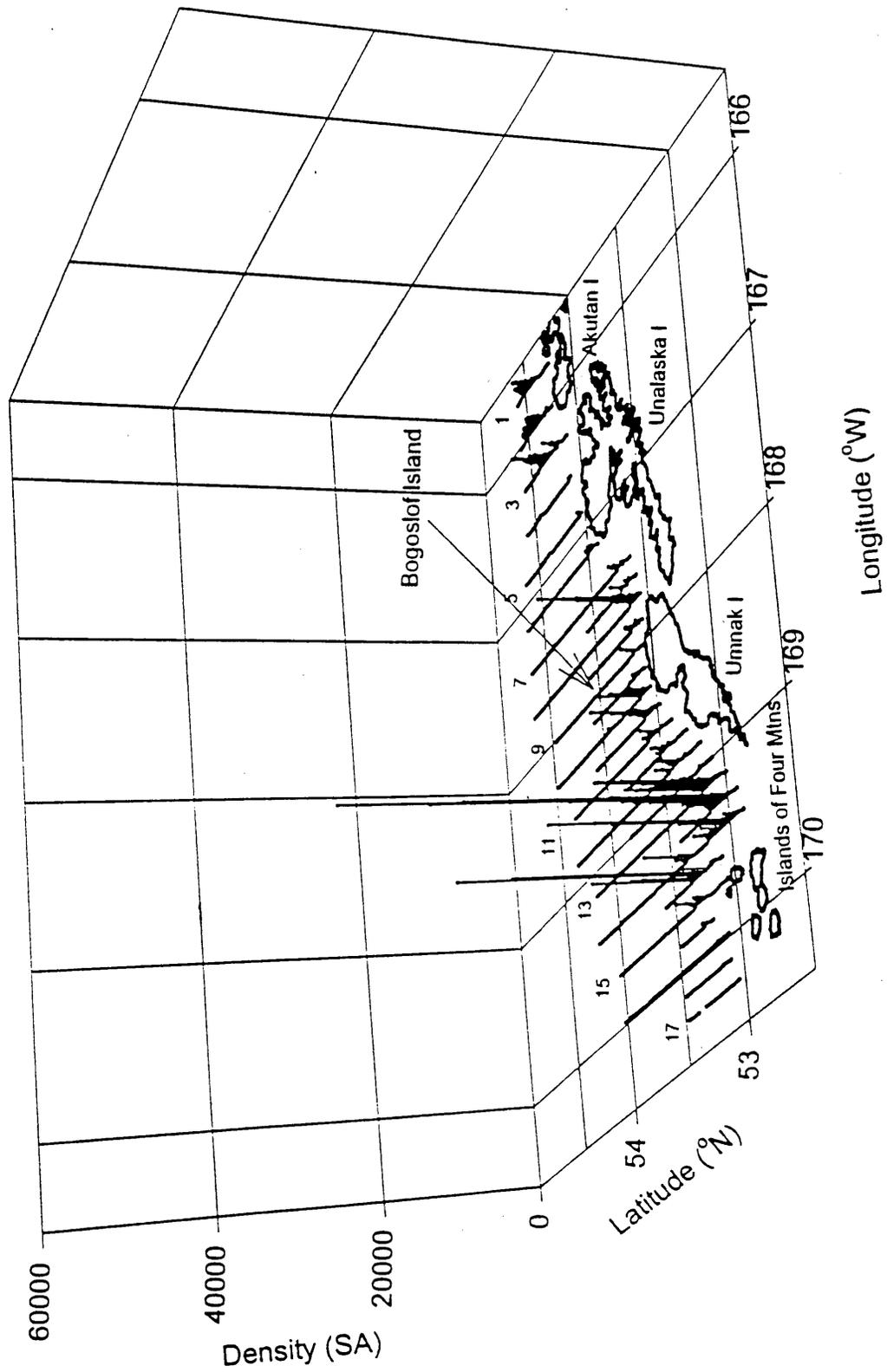


Figure 3. Relative pollock density along trackline from pass 1 of the winter 1997 echo integration-trawl survey of the Bogoslof Island area. Transect numbers are indicated.

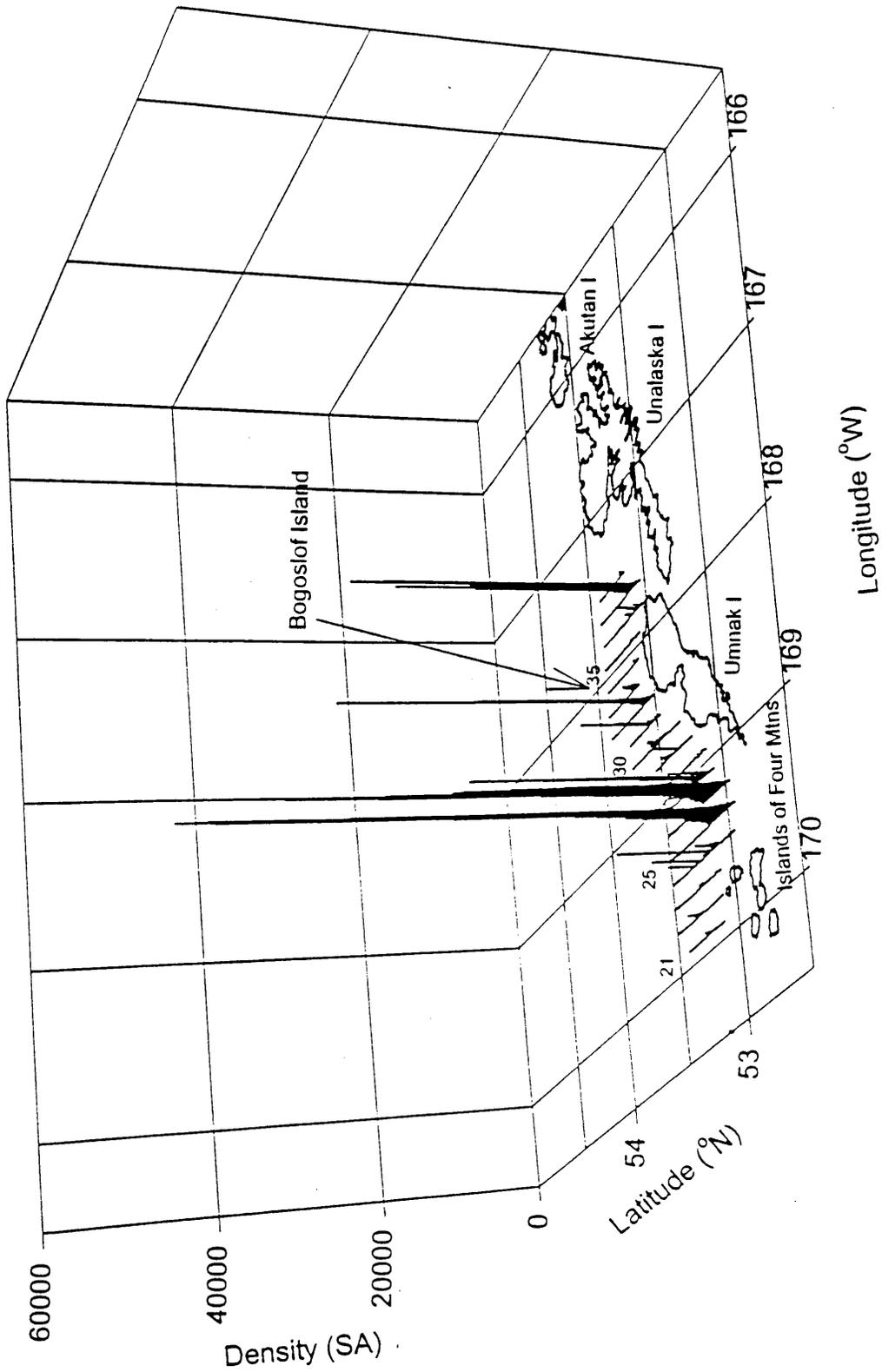


Figure 4. Relative pollock density along trackline from pass 2 of the winter 1997 echo integration-trawl survey of the Bogoslof Island area. Transect numbers are indicated.

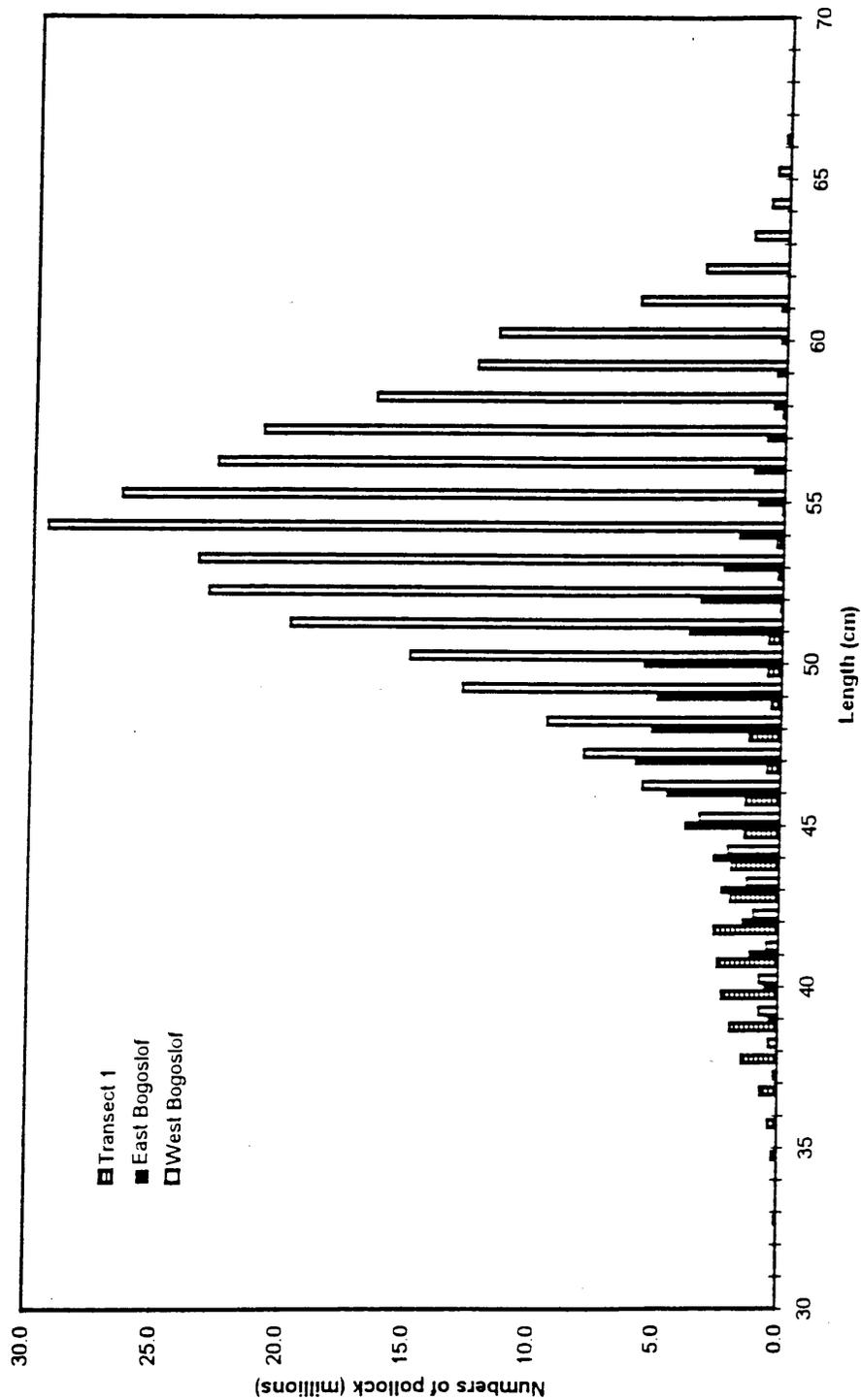


Figure. 5 Pollock numbers at length from the 1997 winter echo integration-trawl survey of the southeastern Aleutian Basin near Bogoslof Island. Transect 1 is east of 166 deg. W, outside the Bogoslof spawning area as defined here. East Bogoslof is between approximately 166 deg. W and 167 deg. W (transects 2-5); West Bogoslof is west of 167 deg. to the western boundary of the survey area (transects 6-17,21-38).

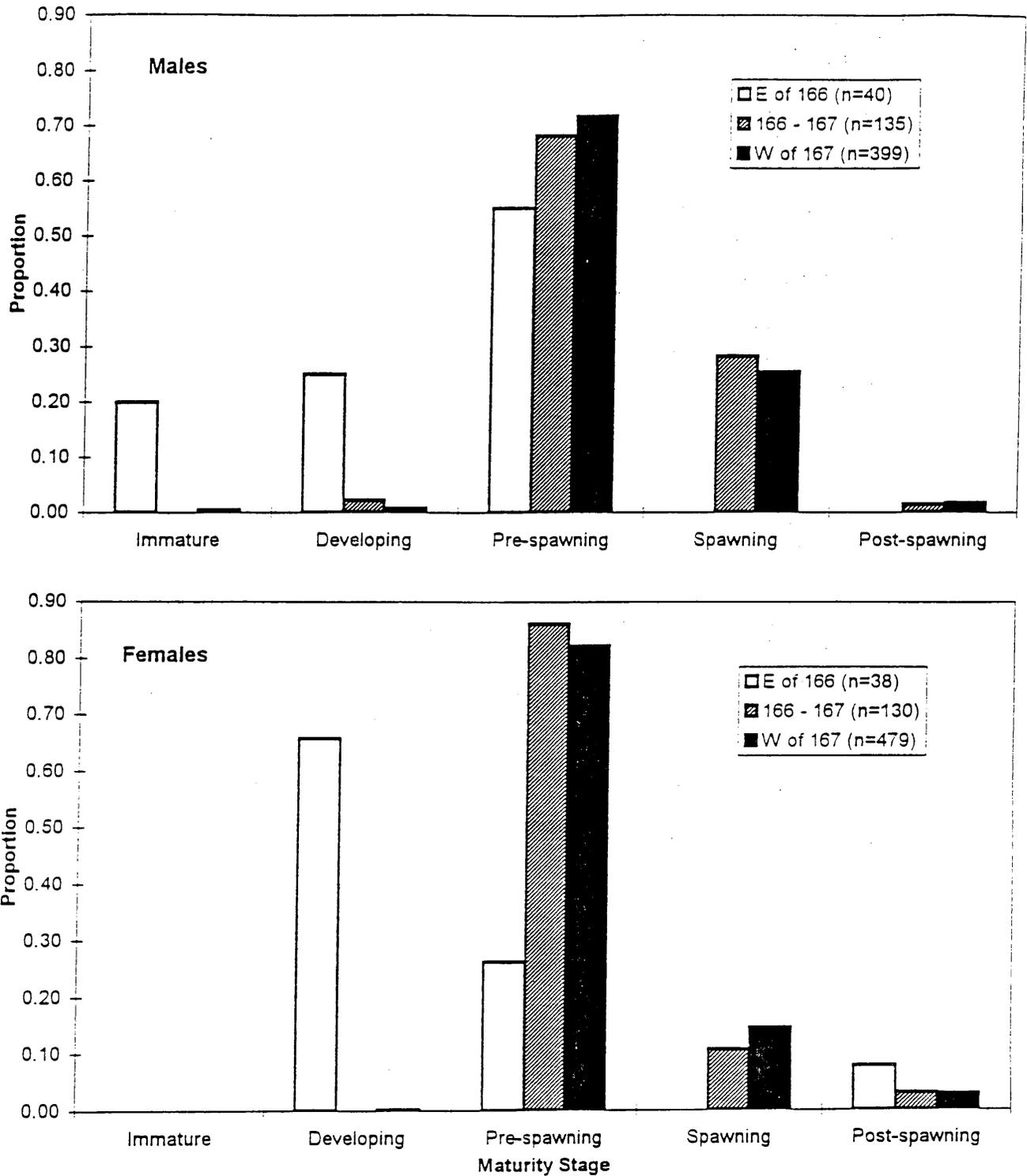


Figure 6. Maturity stages of pollock observed during the winter 1997 echo integration-trawl survey of the Bogoslof Island area. Haul 1 (E of 166° W) is contrasted with hauls 2, 15, and 16 (166 - 167° W), and hauls 3-14 (W of 167° W).

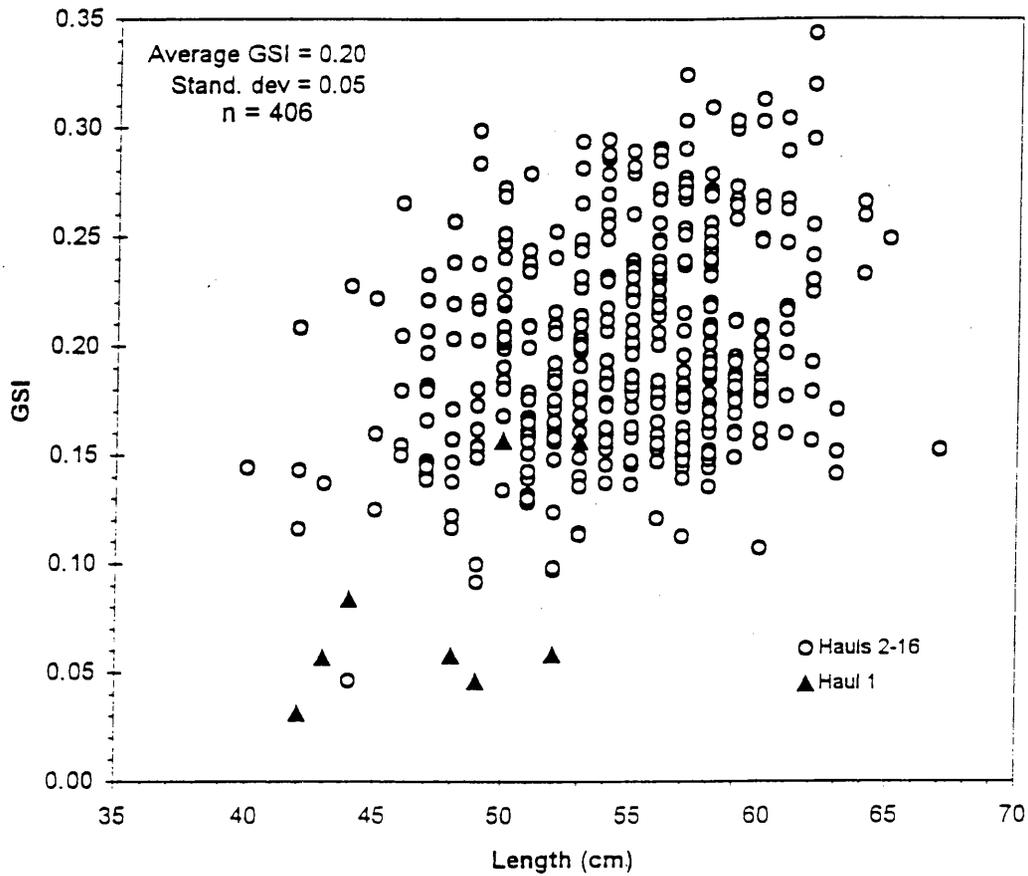


Figure 7. Pollock gonado-somatic indices for mature females plotted as a function of length from the winter 1997 echo integration-trawl survey of the Bogoslof Island area.

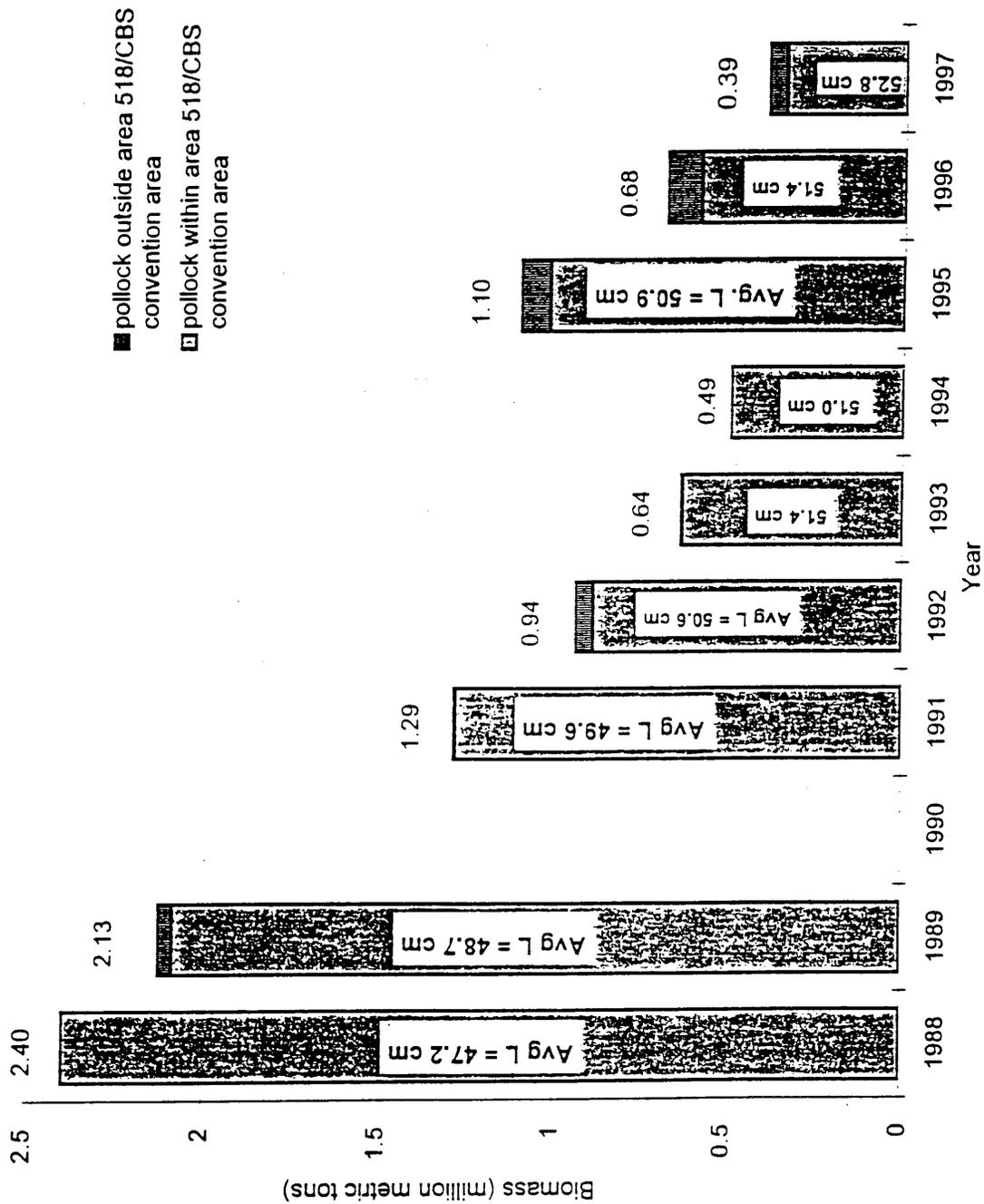
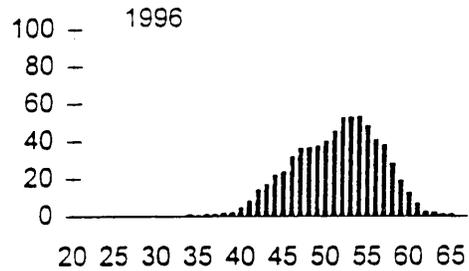
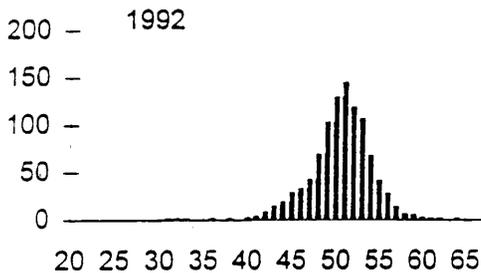
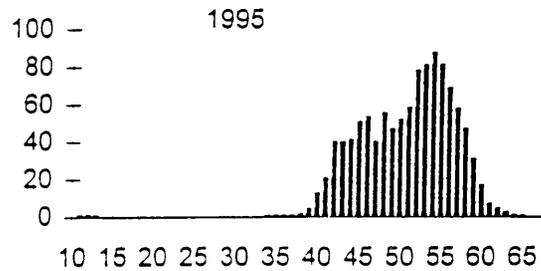
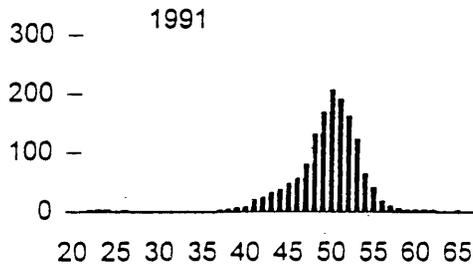
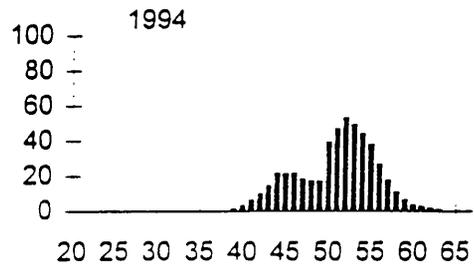
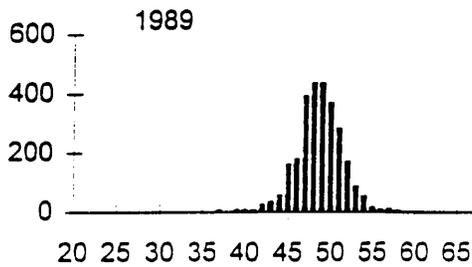
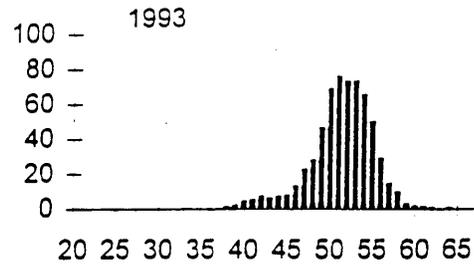
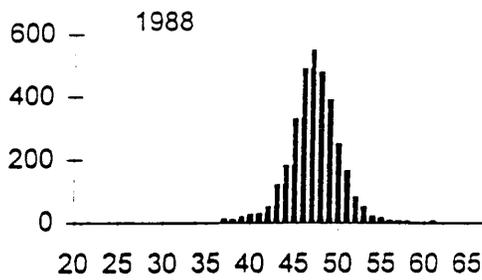


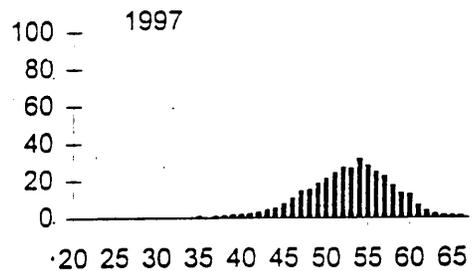
Figure 8. Biomass estimates and average fork lengths obtained during winter echo integration-trawl surveys for spawning walleye pollock near Bogoslof Island, 1988-97. There was no survey in 1990. Total pollock biomass for each survey year is indicated.

Millions of Fish



Length (cm)

Figure 9. Population-at-length estimates obtained during echo integration-trawl surveys of spawning walleye pollock near Bogoslof Island in winter 1988-97. Note y-axis scale differences. No survey was conducted in 1990.



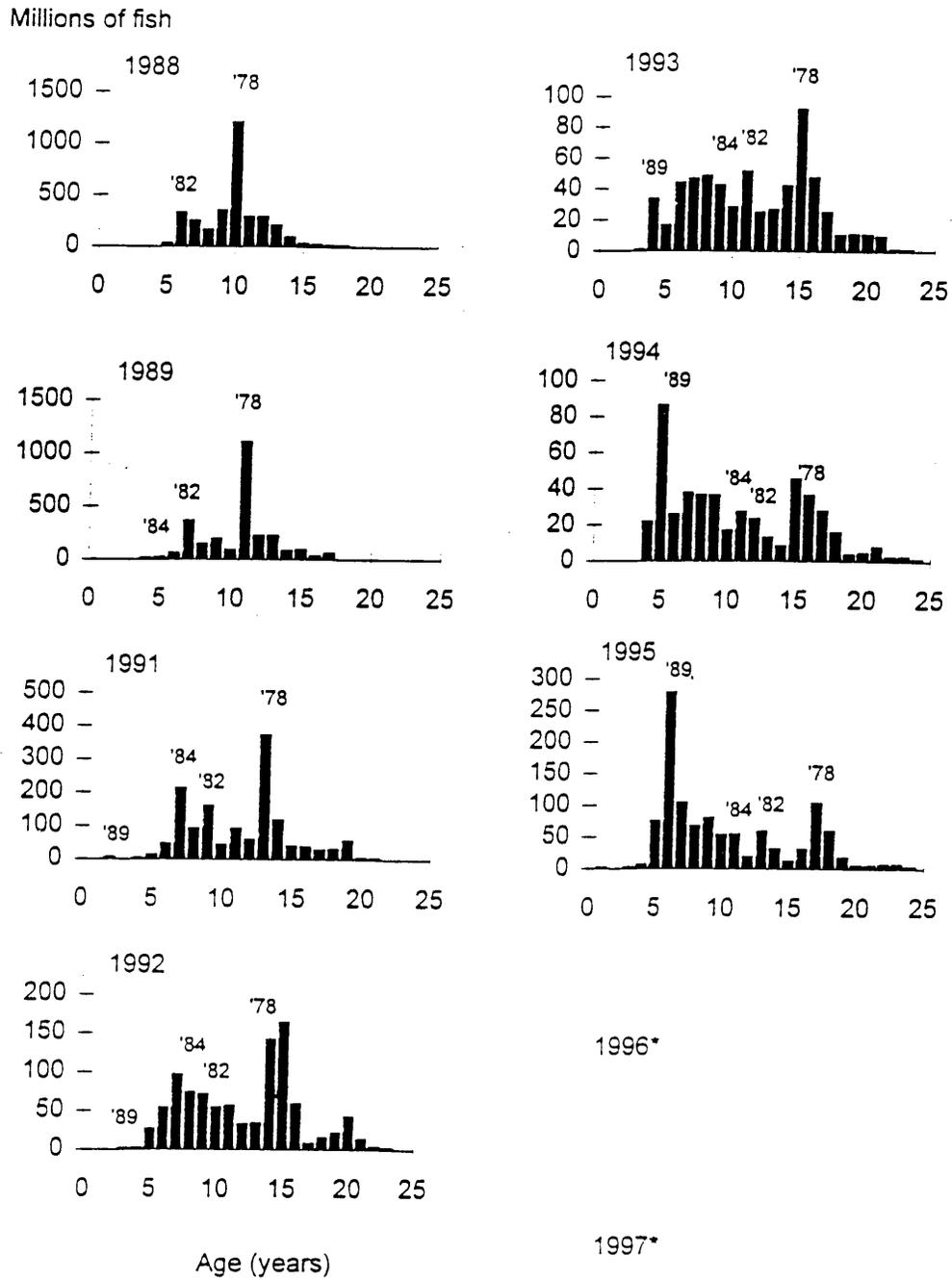


Figure 10. Population-at-age estimates obtained during echo integration-trawl surveys of spawning walleye pollock near Bogoslof Island in winter 1988-89, 1991-95. Major year classes are indicated. No survey was conducted in 1990. Note y-axis scale differences.

* Age data not yet available.

Proposed Assessment Procedures for Aleutian Basin Pollock utilizing biennial surveys in the Bogoslof Island area.

The estimated biomass and yield from the Aleutian Basin for the past several years has been based on an annual survey of spawning pollock in the southeastern Aleutian Basin in the area of Bogoslof Island. The Bogoslof Island survey, conducted since 1988, has shown a nearly steady decline in abundance since the inception of the survey.

Bogoslof Island survey biomass estimates, 1988-1997

Biomass (million t)									
1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
2.4	2.1	--	1.3	0.9	0.6	0.54	1.1	0.68	0.39

The current low abundance of pollock in the Bogoslof Island area, and the outlook for continued low abundance the Alaska Fisheries Science Center plans to change the frequency of biomass assessment surveys in the Bogoslof Island area from annual to biennial.

It is hoped that vessels from research agencies in China, Korea, Japan, Poland, or Russia can survey Aleutian Basin pollock in the years between the U. S. survey to maintain the annual data series. However, if a survey only occurs every other year, the U. S. proposes that population models be used to extrapolate the biomass in non-survey years.

There are various levels of sophistication that can be used to estimate Aleutian Basin pollock. The simplest is a biomass model of the form

$$B_{t+1} = R + B_t e^{-Z}$$

where: B_t = Survey Biomass in year t
 B_{t-1} = Biomass in the following year
 $e^{-(F+M)}$ = Instantaneous natural (M) and Fishing (F) mortality
 R = Recruitment

This type of model may be the most appropriate model for forecasting the Biomass in the Bogoslof Island area, since the survey biomass trend is the primary consistent information available. The other needed information needed are estimates of total mortality, Z , and recruitment, R .

Total mortality, Z , has consisted almost entirely, of natural mortality, M , since 1991 when the fishing moratorium began. The estimated Z values from Bogoslof Island area surveys are shown in the following table 1. Annual estimates of Z vary considerably, and average 0.197 for all years, and 0.32 excluding 1994-95 when biomass increased.

Table 1. Estimated total mortality of pollock in the Bogoslof Island area based on survey biomass (million t) estimates, 1988-1997.

Year	Biomass	Z
1988	2.4	
1989	2.1	-0.134
1990		
1991	1.3	-0.240
1992	0.9	-0.368
1993	0.6	-0.405
1994	0.54	-0.105
1995	1.1	0.711
1996	0.68	-0.481
1997	0.39	-0.556
Average Z		-0.197
Average Z ex 1995		-0.327

Estimates of mortality from biomass estimates are usually not reflective of actual mortality, since there is variable recruitment in each year. Numbers-at-age estimates were also used to estimate mortality as $\{\ln(N_{\text{fully recruited}}/N_{1995})/n \text{ years}\}$ for the year-classes shown in Table 2. Total mortality estimates obtained by this method are less variable than those in Table 1, and the average Z is 0.33.

Table 2. Estimated total mortality (Z) by year-class from fully recruited age to oldest age using Bogoslof Island area estimates of numbers-at-age (millions) from 1988-1995 surveys.

Year-class	1988	1989	1990	1991	1992	1993	1994	1995	Total Mortality
1985		5.8		44.2	97.0	48.0	17.0	53.0	-0.201
1984		15.2		222.8	74.0	42.0	27.0	54.0	-0.354
1983	27.9	58.4		101.1	71.0	28.0	23.0	19.0	-0.418
1982	326.7	362.8		163.8	55.0	51.0	13.0	59.0	-0.303
1981	246.8	147.0		46.6	57.0	25.0	9.0	32.0	-0.292
1980	163.7	194.3		89.6	33.0	27.0	45.0	12.0	-0.464
1979	350.1	90.7		60.2	34.2	42.0	36.0	31.0	-0.346
1978	1200.9	1105.4		367.2	142.0	92.0	28.0	103.0	-0.351
1977	287.8	222.3		120.2	164.0	47.0	16.0	60.0	-0.224
1976	287.3	223.1		38.2	59.0	25.0	4.0	18.0	-0.396
1975	201.9	81.8		33.6	8.0	11.0	4.0	5.0	-0.529
1974	89.2	90.4		26.3	15.0	11.0	8.0	5.0	-0.412
1973	27.3	30.1		31.3	22.0	11.0	2.0	6.0	-0.216
1972	16.6	59.8		51.1	42.0	10.0	2.0	6.0	-0.145
Average									-0.332

The most difficult aspect of forecasting abundance is obtaining an estimate of recruitment. Bogoslof Island survey number-at-age estimates indicate that pollock appear to fully recruit at ages 6 or 7 and then numbers decline with age (Table 3).

Table 3. Average and median numbers-at-age (millions) and average and median tonnes of pollock in the Bogoslof Island survey, 1988-1996.

Age	Numbers at Age		Tonnes	
	Average	Median	Average	Median
2				
3	5.0	1.0		
4	25.8	6.0		
5	31.4	26.0		
6	91.6	44.2	80,785	39,100
7	101.4	97.0	75,110	67,027
8	65.4	68.0		
9	74.8	71.0		
10	41.9	46.6		
11	54.9	54.0		
12	30.0	25.0		
13	99.3	34.2		
14	76.2	45.0		

If age 7 is the age of full recruitment, then on average 90% of the fish will have recruited to the Bogoslof Island population by age 6. If age 6 is the age of full recruitment, then a much lower percentage of a year-class will be present at age 5 (Table 4).

Table 4. Percentage of recruitment at age in the Bogoslof Island area relative to age 6 and 7 based on 1988-1995 survey numbers at age.

Age	Percent recruited relative to age 6	Percent recruited relative to age 7
3	5%	5%
4	28%	25%
5	34%	31%
6	100%	90%
7		100%

Two methods are used to forecast the abundance of pollock in the Bogoslof area (Table 5). The first method (column B) estimates the next year's biomass as the survey biomass estimate (column A) decreased by Z and the recruitment of the estimated average recruitment of age 7 (Table 3). The second method (Column C) differs from the first in the treatment of recruitment. Rather than assume constant recruitment, it is assumed that age 7 is the age of full recruitment, and at age 6 a year-class is 90% recruited, on average. The biomass of age 6 is projected forward to age 7 based on the 90% rate of partial recruitment.

Table 5. Forecast biomass (million t) of Bogoslof area pollock based on the previous year's survey data, and survey based estimates of average recruitment and total mortality.

Year	Survey Biomass	Predicted Biomass $B_{t+1}=Be^{-z+}$ Age 7 _{average}	Predicted Biomass $B_{t+1}=Be^{-z+}$ Age 7 _{Predicted}	Age 7 Survey Estimate	Age 7 Predicted	Age 6 Survey Estimate
	A	B	C	D	E	F
1988	2.4					0.192
1989	2.1	1.818	1.956	0.241	0.214	0.041
1990		1.600	1.571		0.046	
1991	1.3	1.182		0.143		0.025
1992	0.9	1.019	0.972	0.067	0.028	0.038
1993	0.6	0.729	0.696	0.043	0.042	0.039
1994	0.54	0.511	0.479	0.040	0.043	0.022
1995	1.1	0.467	0.416	0.083	0.024	0.208
1996	0.68	0.874	1.030		0.232	
1997	0.39	0.569	0.569		(0.07511)	
Average Age 7 biomass (mill. t)		0.07511				
Z		0.32				
Age 6:Age 7		0.9				

The model projections of biomass are similar to the survey estimates, except for 1995 and following years (Table 5, Figure 1). The primary reason for the great difference was that survey abundance increased for all ages between 1994 and 1995, contrary to expectations of a fully recruited population. The differences between the survey and model estimates continue in 1996 with model results much greater than the survey. In 1997 the forecast of 1996 survey with constant recruitment was 46% higher than the survey estimate (Figure 2). A forecast of 1997 biomass with projected age 7 recruitment could not be made, because 1996 survey age samples have not been analyzed.

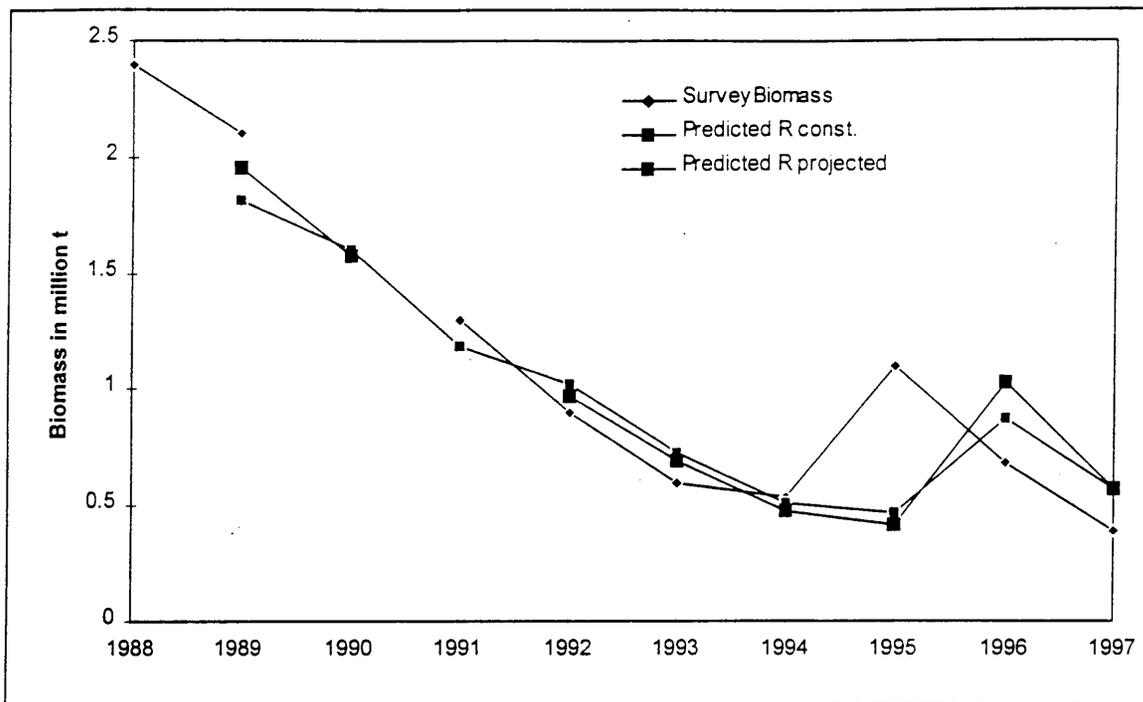


Figure 1. Trend of estimated pollock biomass in the Bogoslof Island area from survey and model predictions of biomass, 1988-1997.

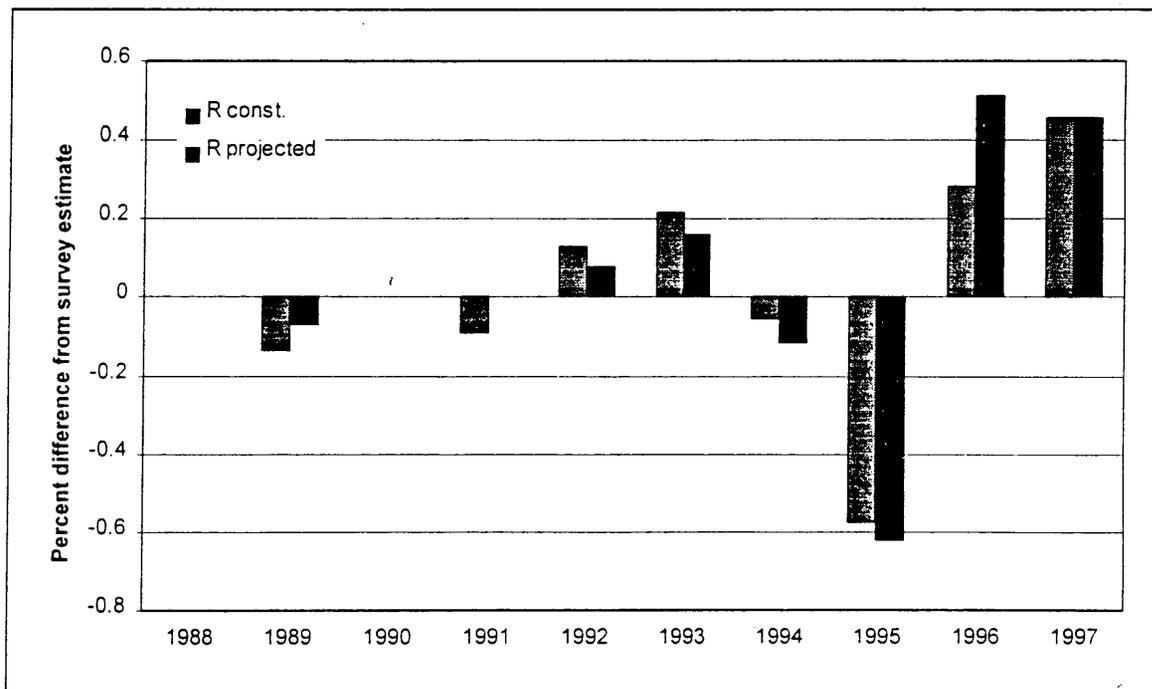


Figure 2. Percent difference between survey estimates of biomass and the estimates obtained from the two methods of modeling recruitment.

It is possible to model the Bogoslof Island area pollock abundance in greater detail by use of an age structured model, however, simple projections of survey numbers-at-age indicate a high degree of variability which may be due to sampling and/or data processing, such as aging errors.

Forecast Pollock number-at-age in the Bogoslof Island area in millions from previous years estimated number-at-age using $Z=0.32$

Age	1991		1992		1993		1994		1995	
	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted
6	44.2		54.0		44.0		38.0		278.0	
7	222.8		97.0	32.1	46.0	39.2	36.0	32.0	105.0	27.6
8	101.1	74.0	161.8		48.0	70.4	36.0	33.4	68.0	26.1
9	163.8		71.0	73.4	42.0	53.7	17.0	34.9	80.0	26.1
10	46.6	55.0	118.9		28.0	51.6	27.0	30.5	53.0	12.3
11	89.6		57.0	33.8	51.0	39.9	23.0	20.3	54.0	19.6
12	60.2		33.0	65.0	25.0	41.4	13.0	37.0	19.0	16.7
13	367.2		34.2	43.7	27.0	24.0	9.0	18.2	59.0	9.4
14	120.2	142.0	266.6		42.0	24.8	45.0	19.6	32.0	6.5
15	38.2		164.0	87.3	92.0	103.1	36.0	30.5	12.0	32.7
16	33.6		59.0	27.7	47.0	119.1	28.0	66.8	31.0	26.1
17	26.3		8.0	24.4	25.0	42.8	16.0	34.1	103.0	20.3
18	31.3		15.0	19.1	11.0	5.8	4.0	18.2	60.0	11.6
19	51.1		22.0	22.7	11.0	10.9	4.0	8.0	18.0	2.9
20	3.4	42.0	37.1		11.0	16.0	8.0	8.0	5.0	2.9
21	1.7		13.0	2.5	10.0	30.5	2.0	8.0	5.0	5.8
22			3.0	1.2	1.0	9.4	2.0	7.3	6.0	1.5
23			1.0	0.0	1.0	2.2	1.0	0.7	6.0	1.5
24									2.0	0.7
sum	1401.3		944.2	1017.3	562	684.8	345	407.5	996	250.3

Shaded cells denote strong year-classes on the eastern Bering Sea shelf - 1972,1978,1982,1984,1989.

Alternative estimates of recruitment at Bogoslof Island

Another potential means of determining recruitment to Bogoslof is to assign a percentage of the eastern Bering Sea biomass as recruitment to Bogoslof. From 1988 to 1995 the biomass of recruiting year-classes in the Bogoslof Island area averaged 2%, 7.5, and 17.6% of the eastern Bering Sea biomass of ages 5, 6, and 7 respectively. These percentages of eastern Bering Sea biomass estimates could be an alternative means of estimating potential recruitment to the Bogoslof Island area.

Table . Estimated pollock biomass in tonnes on the eastern Bering Sea shelf and at Bogoslof Island for ages 5-7, and the percentage of Bogoslof Island pollock relative to eastern Bering Sea pollock, 1988-1995. Eastern Bering sea pollock biomass estimates from catch-age analysis, and Bogoslof Island estimates from the Bogoslof Islands area survey.

Year	Age 5			Age 6			age 7		
	Shelf	Bogoslof	% shelf	Shelf	Bogoslof	% shelf	Shelf	Bogoslof	% shelf
1988	1118633	14997	1.3%	2842269	192324	6.8%	951432	155569	16.4%
1989	2329739	7275	0.3%	857464	41140	4.8%	2055431	241301	11.7%
1990									
1991	421838	6067	1.4%	481210	24911	5.2%	1231766	143024	11.6%
1992	409126	21455	5.2%	294681	38081	12.9%	301380	67027	22.2%
1993	860890	11939	1.4%	310081	39100	12.6%	163684	43049	26.3%
1994	3972319	59938	1.5%	716761	21530	3.0%	220779	39768	18.0%
1995	1826620	48690	2.7%	2913398	208409	7.2%	487404	82680	17.0%
Average			2.0%			7.5%			17.6%

Some biological characteristics of walleye pollock in the Bogoslof spawning ground during February-March, 1997

Xianyong Zhao

Yellow Sea Fisheries Research Institute
106 Nanjing Road, 266071 Qingdao, P. R. China

INTRODUCTION

According to the spirit of the multi-literal agreement on the conservation and management of the walleye pollock resource in the Bering Sea, and with the kind invitation of US scientists, I participated in the acoustic survey of walleye pollock in the Bogoslof spawning ground aboard the US R/V "Miller Freeman" from February 28 to March 11, 1997. This exercise tries to summarize some of the biological data on walleye pollock obtained during the survey, with emphasis on a simple comparative analysis on some of the biological characteristics of walleye pollock in two subjectively defined strata.

MATERIALS AND METHODS

During the above mentioned survey, two acoustic passes and 16 midwater trawls were carried out from 1 March to 11 March. The data used in this exercise are from the 16 hauls made during the survey. Fig. 1 shows the locations of the hauls. The first 10 hauls (haul 1~10) were made during pass 1 from 1 March to 8 March; The last 6 hauls (haul 11~16) were made during or after pass 2 from 8 March to 11 March, but will referred to as from pass 2. For further information, please refer to Honkalehto and Williamson (1997) or its new version presented at this meeting.

For the interests of fisheries management, the surveyed area was divided into two subjectively (from a biological point of view) defined strata, the Central Bering Sea Convention area (167° W~ 170° W, haul 3~14) and the east of the convention area (east of 167° W, haul 1,2,15,16), and the biological data were treated separately where appropriate.

Length composition

The overall length compositions of walleye pollock were calculated according to the equation:

$$P_i = P_{ij} \times \frac{w_i}{\sum w_j} \quad (1)$$

where p_i is the percentage of length group i in the overall length composition,
 p_{ij} is the percentage of length group i in the length composition of haul j and
 w_j is the weighting factor for haul j .

The weighting factor w_j was calculated as:

$$w_j = \frac{S_{A,j}}{\ell_j^2} , \quad (2)$$

where $S_{A,j}$ is the 5 mile average acoustic backscattering coefficient at haul j , and
 ℓ_j is the RMS length of the fish from haul j .

Length-weight relationship

The length (L, mm)-weight (W, g) relationships of walleye pollock were obtained by means of simple linear regression on log-transformed length and weight data. No correction was made to take into account of the bias due to the transformation of the data.

Condition factor

The condition factor (K) of the fish was calculated according to the equation:

$$K = \frac{W}{L^3} \times 100, \quad (3)$$

where W is the round fish weight in g and
 L is the fish length in cm.

Maturity composition

For the construction of the overall maturity composition, the same weight was given to the samples from each haul, following the eight-stage classification used during the survey.

Gonado-Somatic Index (GSI)

Only females reached maturity stage 4 or above were included in the calculation of GSI. according to the equation:

$$GSI = \frac{W_g}{W} \times 100\% , \quad (4)$$

where W_g and W are the weights of the gonad and the round fish, respectively.

RESULTS

Length compositions

Fig. 2 shows the length compositions of walleye pollock in the two strata. In the east of the convention area (Fig. 2A), the fork length of walleye pollock, including both males and females, ranged from 33 to 63 cm and dominated by the length groups from 45 to 50 cm, with a mean of 47.1 cm. The length of the males ranged from 35 to 58 cm and dominated by the length groups from 45 to 47 cm, with a mean of 45.9 cm; While the corresponding statistics for females were 33 ~ 63, 48 ~ 52 and 48.7 cm, respectively.

The pollock individuals in the CBS convention area were relatively larger (Fig. 2B), its length ranged from 37 to 66 cm and dominated by the length groups from 54 to 56 cm, with a mean of 54.5 cm. The length of the males ranged from 37 to 65 cm and dominated by the length groups from 51 to 55 cm, with a mean of 52.1 cm; While the corresponding statistics for females were 39 ~ 66, 56 ~ 58, and 55.4 cm, respectively.

Length-weight relationships

Fig. 3 shows the length-weight relationships of walleye pollock by sex and stratum. Since the regression coefficients were not corrected for the transformation bias, the length-weight relationships given in Fig. 4 actually represent the median weight-at-length relationships (Hayes et al., 1995).

Condition factor

Table 1 shows the condition factors of walleye pollock by sex and stratum. Two sided Kolmogorov-Smirnov test showed that the condition factor of males and females were significantly different from each other in both strata ($p < 0.0005$); The condition factor of females were higher than that of males. No detectable difference was found between males in the two strata ($p = 0.492$); There existed, however, a significant difference between females ($p < 0.0005$), the condition factor of females in the CBS convention area was higher than that in the east of the convention area.

Sex ratio

As shown in Fig. 4, the sex ratio of walleye pollock varied widely between hauls. The maximum and minimum female to male ratio were 1:2.49 and 1:0.05 respectively, with a mean of 1:0.86. However, these may not represent the true sex structure of the pollock population, as the fish were highly aggregated and stratified by sex (Honkalehto and Williamson, 1996, 1997).

Maturity composition

Fig. 5 shows the maturity composition of walleye pollock during the survey. Except some immature individuals, the males matured earlier in both strata (Fig. 5, A, B). In the east of the convention area, 88.0% male individuals and 85.0% females individuals had reached maturity stage 4 or above, of which 22.8% of the males and

12.5% of the females were actively spawning or spent; About 10% individuals were probably not going to spawn this year. Whereas in the CBS convention area, about 99% of the pollock individuals had reached stage 4 or above, of which 27.1% of the males and 16.1% of the females were actively spawning or spent. These statistics indicated that pollock in the CBS convention area matured earlier than that in the east of the convention area (also seen Fig. 5, C, D).

Fig. 5 (E, F) also shows the maturity compositions of pollock caught in each of the two passes. During the first pass, the percentages of males and female which had maturity stage below 5 were 39.2% and 30.1%, respectively; 12.3% of the males and 9.8% of the females were actively spawning or spent. Whereas during the second pass, only 12.6% of the males and 14.9% of the females had maturity stage below 5, and the percentage of males and females that were actively spawning or spent had already reached 36.9% and 29.2%. In the two hauls made on March 11, about 40% of the males were actively spawning. March 11 was therefor within the peak spawning period of males in the east of the convention area.

Gonado-Somatic Index (GSI)

Fig. 6 shows the mean GSI of mature female pollock in each haul. In the east of the convention area (haul 1, 2, 15, 16), the GSI value of pollock ranged from 1.3 to 38.8%, with a mean of 17.2% and standard deviation of 5.8%; The corresponding statistics in the CBS convention area were 2.3 ~ 34.3%, 20.7% and 4.9%, respectively. Kolmogorov-Smirnov test revealed a significant difference ($p < 0.0005$) between the GSI distributions of pollock in the two strata. The GSI of pollock in the CBS convention area had a narrower range, smaller standard deviation and higher mean value. These are in accordance with the results shown in the maturity compositions.

No significant difference ($p = 0.282$) was found between the GSI distributions of pollock in the two passes, this was probably because that the effect of gonad development was counterbalanced by the effect of spawning.

Fig. 7 shows the scatter plot between the GSI value and the fork length of mature female pollock. Despite the large differences in the GSI values between pollock of the same length, the tendency that the GSI value increases with increasing fish length is clearly seen from the plot. However, the relationship between GSI and fork length was not simply a linear one, the locally weighted smoothing curve (Fig. 7) showed that the slope of the curve decreased as the length of the fish increased.

ACKNOWLEDGMENT

Dr. Neal J. Williamson at the Alaska Fisheries Science Center is thanked for providing the survey data.

REFERENCES

- Cleveland, W. S. 1979. Robust locally weighted regression and smoothing scatterplots. *Journal of the American Statistical Association*, 74: 829-36.
- Hayes, D. B., Brodziak, J. K. T., and O'Gorman, J. B. 1995. Efficiency and bias of estimators and sampling designs for determining length-weight relationships of fish. *Can J. Fish. Aquat. Sci.*, 52: 84-92.
- Honkalehto, T., and Williamson, N. 1996. Echo integration-trawl survey of walleye pollock (*Theragra chalcogramma*) in the southeastern Aleutian Basin during February and March, 1995. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-65, 57p.
- Honkalehto, T., and Williamson, N. 1997. Walleye pollock (*Theragra chalcogramma*) abundance in the Southeastern Aleutian Basin near Bogoslof Island during February-March, 1997. Draft Document--May 22, 1997.
- SYSTAT, Inc. 1992. *SYSTAT for windows: Graphics*, Version 5 edition. Evanston, IL: SYSTAT, Inc., 1992. 750pp.

Table 1 The condition factor of walleye pollock in the Bogoslof spawning ground (March 1-11, 1997).

	Male			Female		
	Mean	SD	n	Mean	SD	n
East of the convention area	0.718	0.066	175	0.772	0.090	168
CBS convention area	0.724	0.073	361	0.820	0.097	404

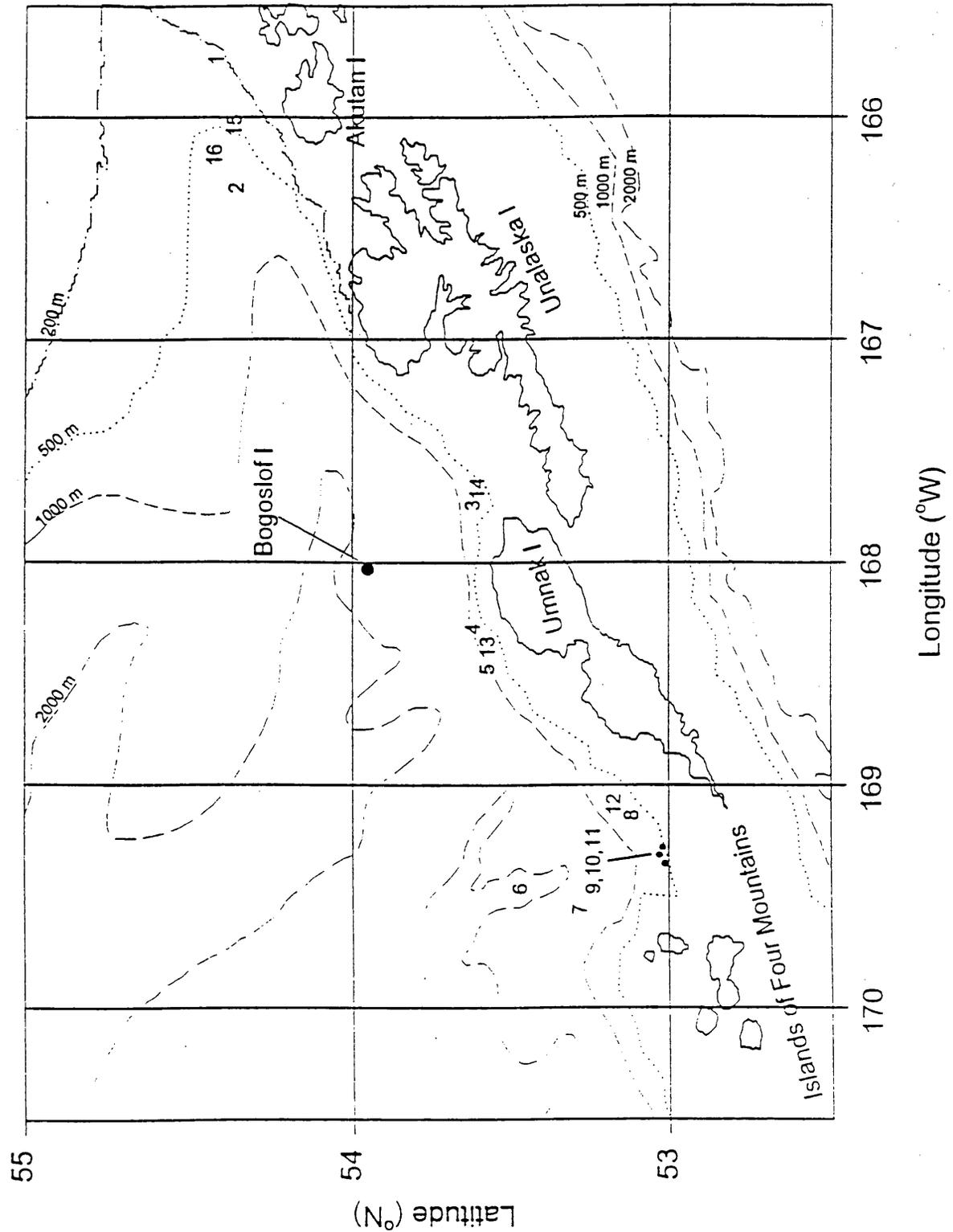


Fig. 1 Haul locations (1-16) from the echo integration-trawl survey of walleye pollock in the Bogoslof spawning ground during the period Feb. 28-March 11, 1997 (From Honkalehto and Williamson, 1997).

A: East of the convention area

B: CBS convention area

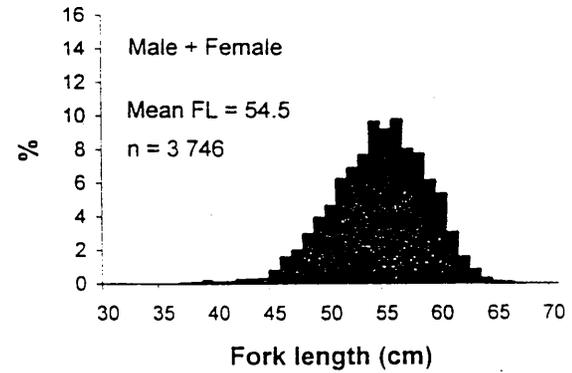
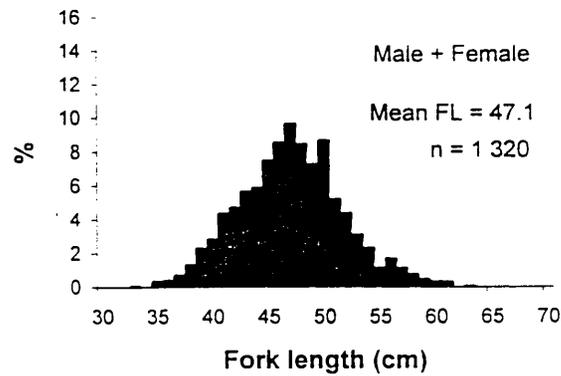
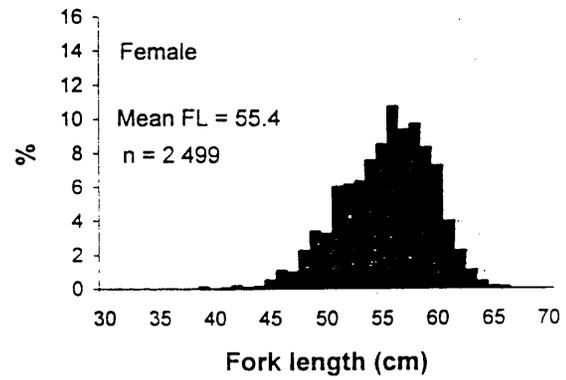
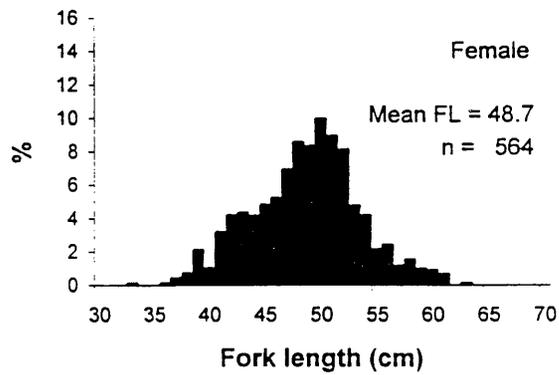
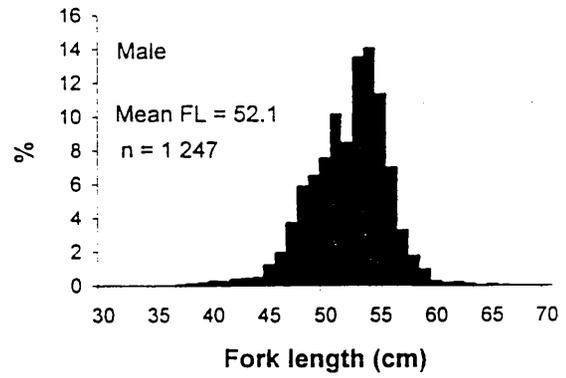
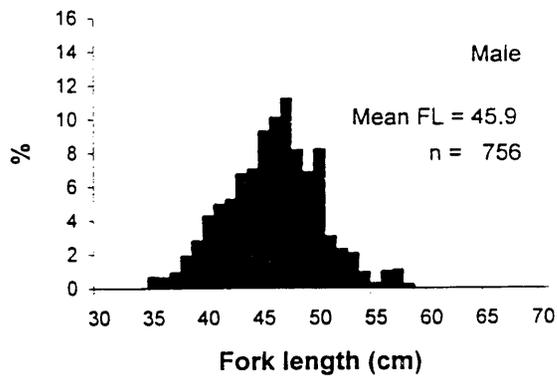


Fig. 2 The length composition of walleye pollock in the Bogoslof spawning ground (March 1-11, 1997).

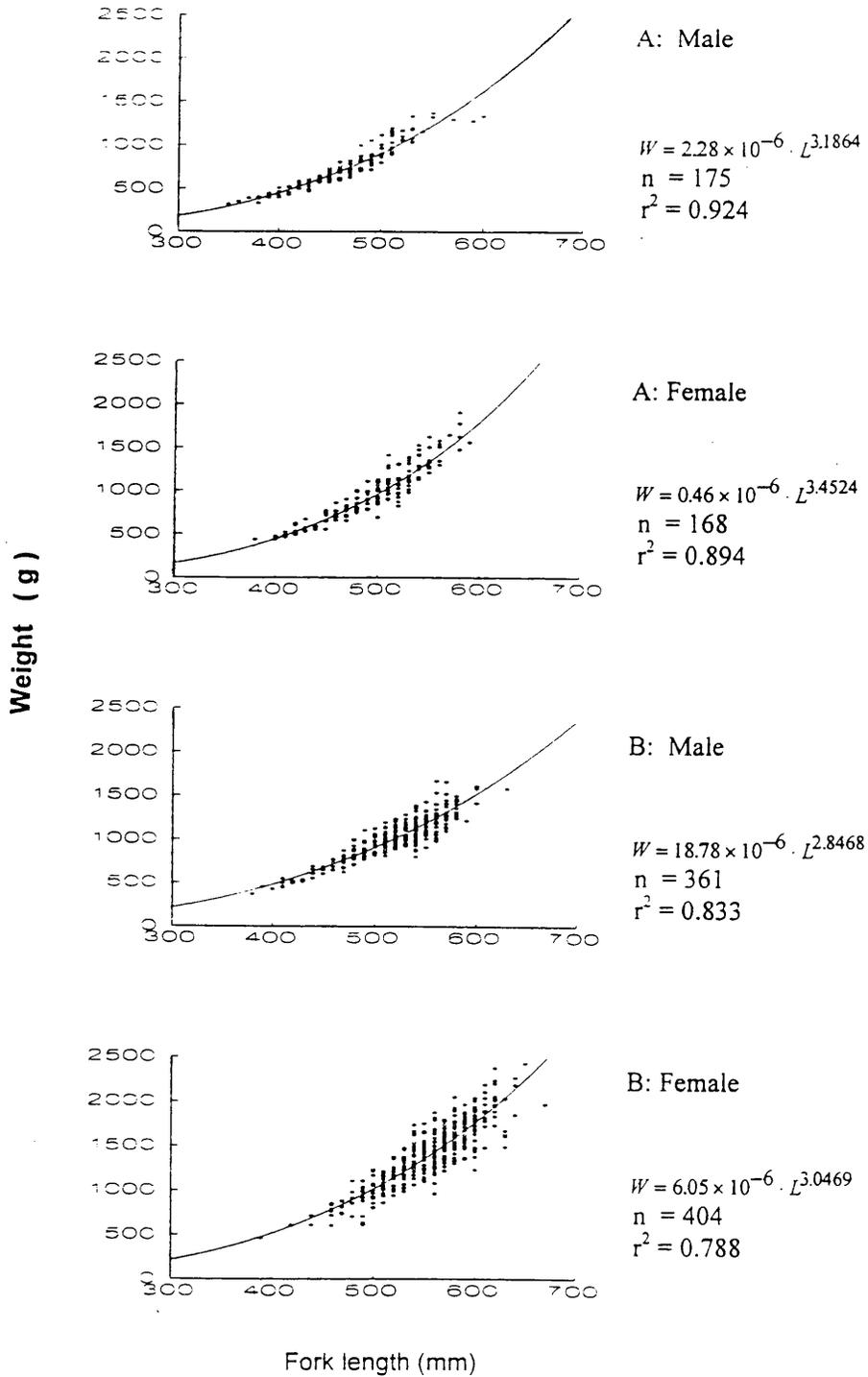


Fig. 3 The length-weight relationships of walleye pollock in the Bogoslof spawning ground (March 1-11, 1997). **A:** The east of the convention area; **B:** The CBS convention area.

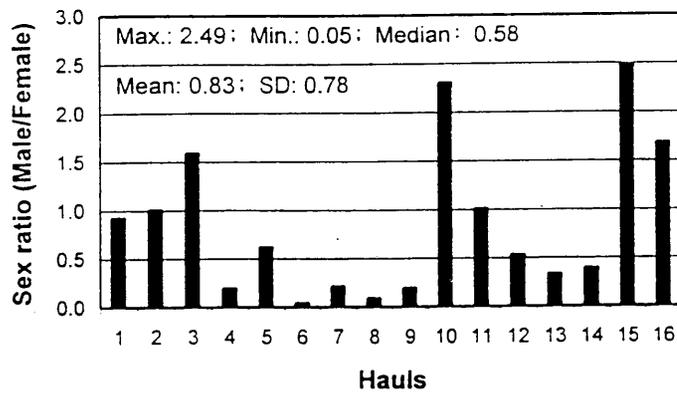


Fig.4 The sex ratio of walleye pollock in the Bogoslof spawning ground (March 1-11, 1997).

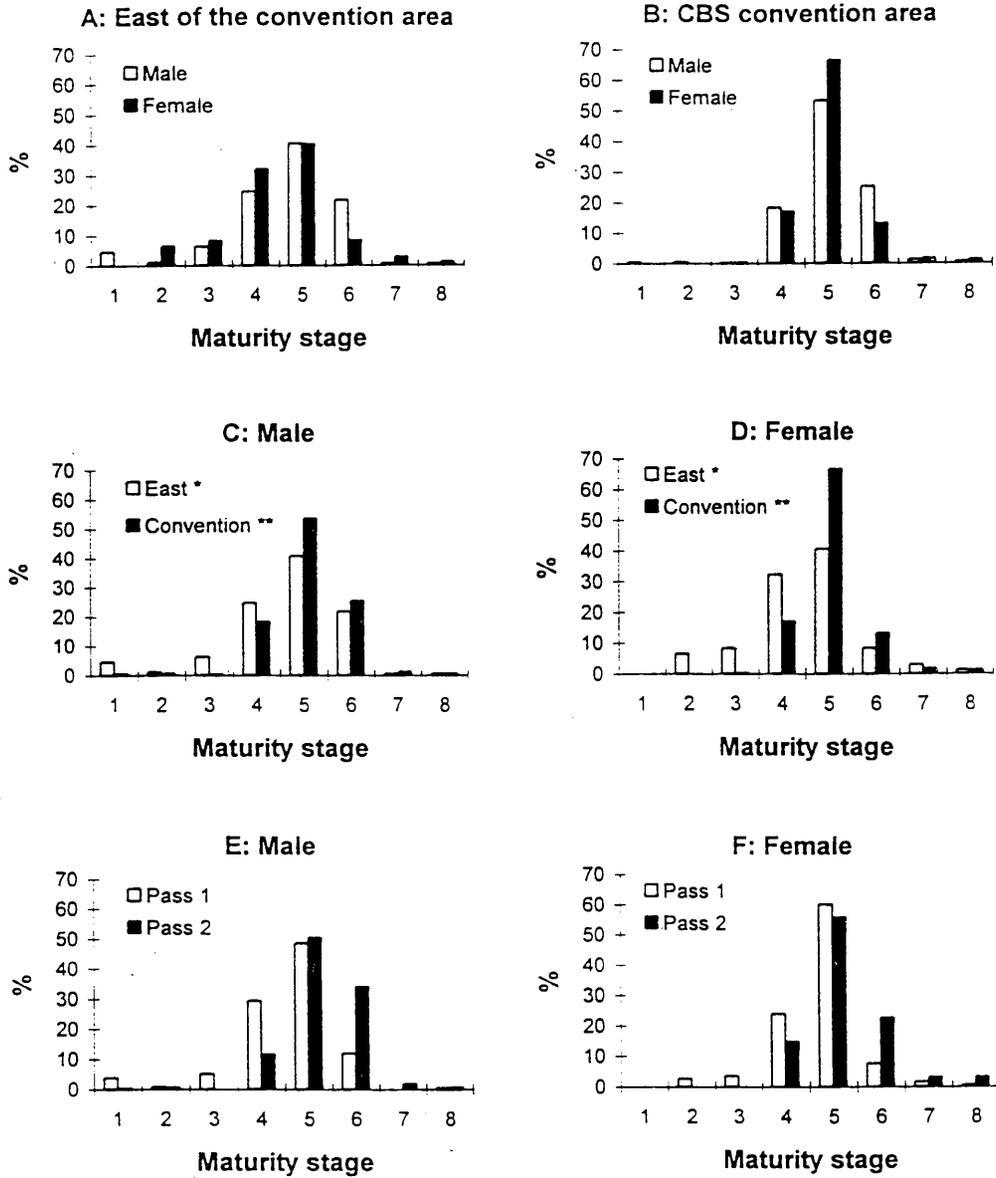


Fig. 5 The maturity compositions of walleye pollock in the Bogoslof spawning ground (March 1-11, 1997). **A & B:** Comparison between males and females; **C & D:** Comparison between strata, * denotes the east of the convention area, ** denotes the CBS convention area; **E & F:** Comparison between passes.

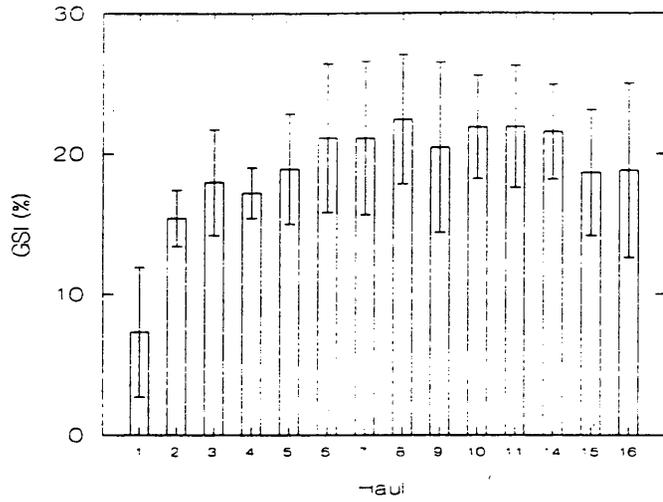


Fig. 6 The Mean GSI of mature female pollock caught in each haul during the survey from March 1 to March 11, 1997. Also shown are \pm one standard deviation of the sample. No gonad weight data was available from haul 12 and 13.

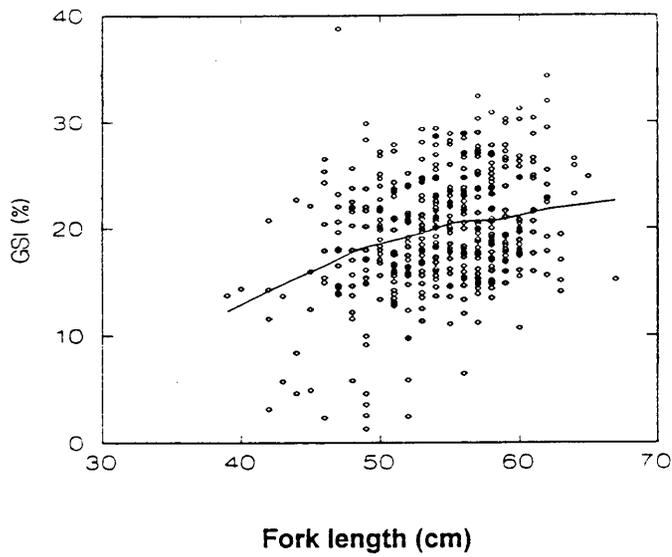


Fig. 7 The scatterplot of GSI VS. fork length for walleye pollock in the Bogoslof spawning ground (March 1-11, 1997). Also shown in the figure is the robust locally weighted smoothing curve of Cleveland (1979), as implemented in SYSTAT(1992); The stiff parameter used was 0.5.

Document for Science Group Meeting, Gdynia
August, 1997

Cruise Results of Mid-water Trawl Survey on Pelagic Pollock in the International Waters of the Bering Sea, 1996

Fisheries Agency of Japan
(NRIFSF)

Objectives

The objectives of the 1996 autumn cruise were to collect information about pollock distribution and their biological characteristics in the international waters of the Bering Sea, in autumn.

Survey outline

The #128 *Meishou Maru* (Stern trawler; 279 t) was chartered for scientific research vessel of Fisheries Agency of Japan. Ecogram of vessel equipped acoustic system was collected continuously along the transects (Fig. 1). When significant echo sign appears, trawl haul was conducted to identify the echo sign and to provide biological data for these organisms. Ship speed was maintained at average 8-10 knots in favorable weather.

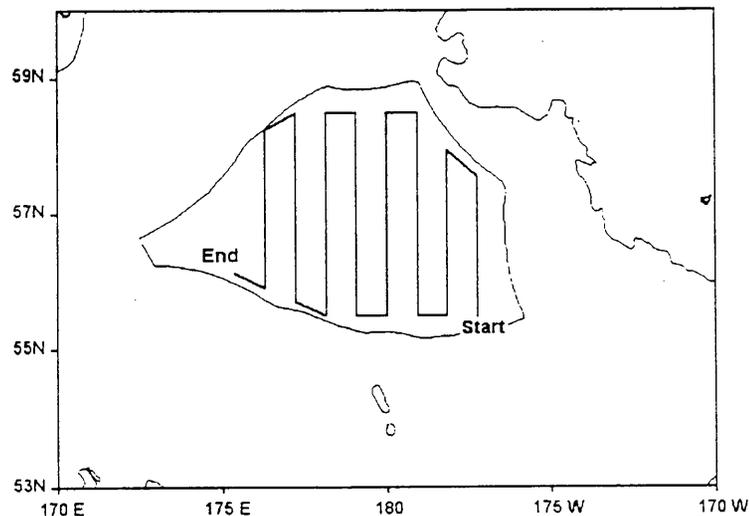


Fig. 1. Transect line during 1996 DH survey by #128 *Meishou Maru*.

Table. Itinerary

Date	Item
Nov. 1	Leave Shiogama
Nov. 2-7	Transit to Donut Hole
Nov. 8-17	Survey in Donut Hole
Nov. 18-23	Homeward voyage to Shiogama
Nov. 24	Arrive Shiogama

Survey Results

Acoustic survey was conducted from Nov. 8 to Nov. 17. During this survey period, no significant echo sign of adult walleye pollock was observed in the international waters. Only faint echo signs were observed at 90-140 m depth layer, and one mid-water trawl haul was made on Nov. 8, however, there was no catch in the codend and only a few lanternfishes and squids were observed on the net body.

Thus, in this survey, there was no pollock catch and we could not get any biological data.

Document for Science Group Meeting, Gdynia
September, 1997

Outline of the Kaiyo Maru survey cruise in 1997
(May 19, 1997 - July 4, 1997)

**The 3rd Survey on Larval Walleye Pollock
in the eastern Bering Sea**

Akira Nishimura
National Research Institute of Far Seas Fisheries
Fisheries Agency of Japan

INTRODUCTION

Natural fluctuations in population size are commonly observed in walleye pollock stocks, and interannual variation of biomass is thought to be largely dependent upon year class strength. However, the factors and the processes affecting year class strength are still largely uncertain in the Bering Sea.

The existence of separate spawning stocks of pollock in the eastern Bering Sea is known. One stock is located in the Aleutian Basin near Bogoslof Island and the others are located over the eastern continental shelf. These stocks have different biological characteristics including the spawning period. National Research Institute of Far Seas Fisheries conducted larval and juvenile pollock survey in the Bering Sea in 1993 and 1995. In these surveys, our attention was focused on the survival and recruitment processes in the early life stage of walleye pollock in the Bogoslof area and southeastern Bering Sea shelf area. Much of information about survival and growth of larval pollock, and abiotic and biotic environmental conditions were collected in the area. These results highlighted the differences in recruitment between spawning stocks in the basin and the shelf. Interannual variation were also observed, and thus the necessity of continuous survey was recognized. The *Kaiyo Maru* survey in 1997 was the third larval and juvenile pollock survey in the area.

METHODS

The survey cruise was conducted by the R/V *Kaiyo Maru* (Fisheries Agency of Japan, Tokyo) from May 19 to July 4, 1997. The field survey was divided into 2 cruises of Leg 1 and Leg 2. Leg 1 survey was conducted during May 27 to Jun 5, and Leg 2 survey was conducted during June 16 to 24. In each Leg, biological and

oceanographic research activities were carried out on the shelf grid stations between Unimak I. and St. George I., and basin grid stations near Bogoslof I. (Fig. 1).

Biological sampling

IONESS, a new Multiple Opening/Closing Net system was used for collecting larval walleye pollock and zooplankton. The mesh size of each net was 0.333 mm. IONESS was lowered to 150 m depth (bottom depth minus 10 m when the bottom is shallower than 150 m) with first net open, and the sampling was carried out at each depth layers from 150 to 50 m, 50 to 30 m and, 30 m to surface with changing the nets. Larval pollock were sorted from the IONESS samples, measured, and then preserved in ethanol. The other fish specimens and the zooplankton were fixed with 5-10 % formalin.

Double NORPAC nets (0.154 & 0.333 mm mesh size) were used for collecting plankton samples. They were hauled vertically from within 5 m of the bottom or 150 meters depth when the bottom depth is deeper than 150 m. Samples were fixed with 5% formalin.

Continuous counting of zooplankton and monitoring of temperature, salinity, dissolved oxygen, and chlorophyll at sub-surface layer were conducted using the EPCS, Electronic Plankton Counting System. A quantitative echo sounder system was used to collect back-scattering data in the survey area.

At selected stations, sampling for predatory fish was conducted by hook and line. Collected fish were identified and measured. Stomachs of these pelagic fish were dissected out and fixed with formalin.

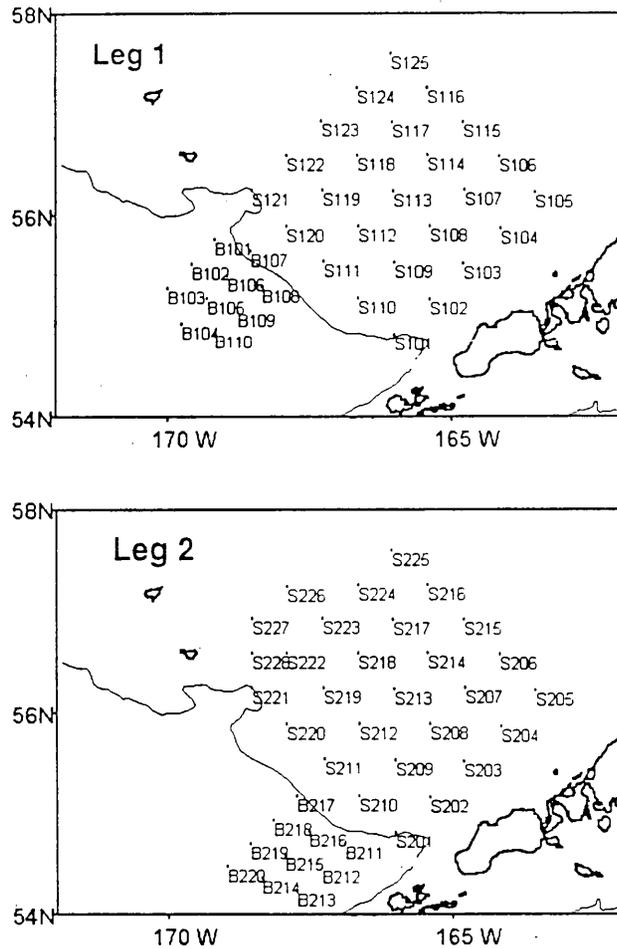


Fig. 1. Location of grid stations during the 1997 survey of the *Kaiyo Maru*.

Oceanographic observation

CTD cast was conducted at each sampling station. Water samples were collected with 10-l Niskin bottles at a depth of 10, 20, 40 and 80 m. Chlorophyll and microzooplankton samples were obtained from these water samples. Chlorophyll and nutrients analyses were carried out on the vessel.

Multiple layer Acoustic Doppler Current Profiler (ADCP) measurements were conducted in the survey area. Other measurements and observations for weather conditions were recorded.

PRELIMINARY RESULTS

Biological information

In Leg 1, 3135 individuals of larval pollock were collected. Most of the larvae (88%) were collected from 0-30 m depth layer in the shelf grid, and only a few larvae were distributed in the basin area around Bogoslof Island (Fig. 2). Only 10% of larvae were collected from deeper 30 m depth. High density distributions were observed around the 100 m isobath (St. 3, 8, 13, 18 and 22) in Leg 1. At station S118, 1081 individuals of larval pollock were collected and high aggregation was observed around this station. Total length of the larvae randomly selected from the shelf region ranged from 3 to 15 mm, and a prominent mode was observed at 5 mm, and a faint mode was observed at around 9 mm (Fig. 3). The major part of the larvae around 5 mm are thought to have originated from shelf spawning stock, that the hatching took place after early May, and the larvae around 9 mm are thought to have hatched earlier. The large larvae were observed to be distributed in the southwest area of the shelf grid where was facing to the oceanic waters. These large larvae

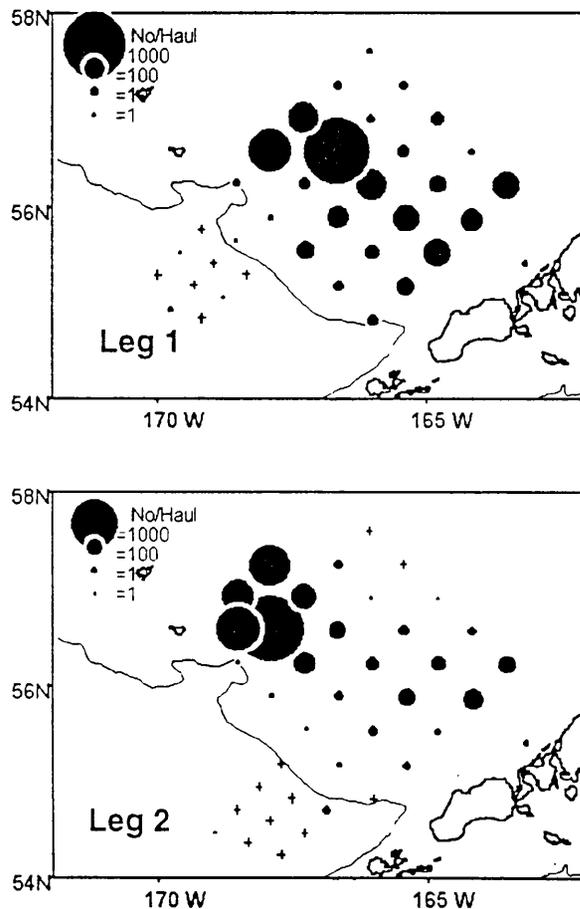


Fig. 2. Horizontal distribution of larval walleye pollock on May and June, 1997.

might have originated from basin spawning pollock. In Leg 1, only 7 individuals of pollock larvae (around 10 mm length) were collected in the basin area.

In Leg 2, 3220 individuals of larval pollock were collected from station S201 to S225. High concentration of larval pollock was observed at station S222, that is on the northern most transect line (St. 20-25) of our shelf grid. In order to confirm the center of the high abundance, three extra stations (S226-228) were added around S222, and 1959 larvae were collected from these 3 stations. Most of the larvae (87%) were collected from S218 to S228, and the highest catch was observed at S222 (37%). Larvae were distributed in the shallower layer at stations S201-S217, whereas they were distributed in shallower to deeper layers at station S218-S228, where high concentration was observed.

Total length ranged from 4 mm to 24 mm and the modes were observed at around 9, 11, 14 & 17 mm. The major mode was observed at around 9-11 mm. The major group of larvae with 5 mm length in Leg 1 are thought to have grown up to 9-11 mm between Leg 1 and Leg 2. The larvae and juveniles larger than 14 mm are thought to be large larvae observed in Leg 1.

At station S222, where the highest concentration was observed, the length mode was observed around 9 mm and the large juvenile fish was not observed. The large fish appeared at the stations located in the southwest area of our shelf grids. Considering these size distribution and our results of age determination of 1993 and 1995 samples, these large fish were originated from basin spawning stock, that spawned in middle to end of March.

In the basin area 18 individuals of pollock larvae were collected, with showing size around 15 mm. Only 25 individuals of larval pollock were collected in the basin area during Leg 1 and Leg 2.

Details of the distribution, growth, and survival with referring oceanographic and biotic environment will be analyzed in future. At this moment we do not have detailed estimates of survival rate or larval density at each station, however we feel the concentration of larval pollock

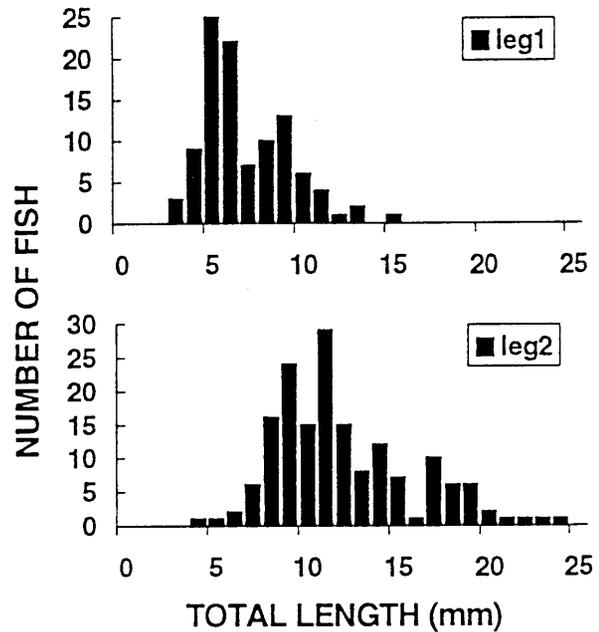


Fig. 3. Length frequency distribution of larval walleye pollock collected at the shelf grid during Leg 1 & Leg 2 (not standardized).

in the northern area of our shelf grids was extremely high comparing with our survey results from 1993 and 1995. Planktonic (phyto & zoo) studies and acoustic analysis are now in progress.

During Leg 1 and Leg 2, 197 young and adult pollock were collected by hook and line. These fish were measured and the otoliths and the stomach were dissected out.

Oceanographic conditions

Surface water temperature of shelf grids ranged from 3 to 7 °C in Leg 1, and from 6 to 9 °C in Leg 2 (Fig. 4). Surface water temperature of basin grid area increased from 4 °C in Leg 1 to 6 °C in Leg 2. Horizontal profile of the water temperature at surface, 20, 40, and 75 m showed isothermal along to the isobath line (Fig. 4). Existence of cold water mass was shown at the bottom of the coastal side of the shelf grid. Water temperature in 1997 were observed to be higher than the results of 1993 and 1995. A prominent thermocline was observed at 20 to 40 m depth in Leg 2 (Fig. 5).

Salinity ranged from 31.3 to 33.0. The isohalines paralleled to the isobaths and the salinity decreased gradually from the ocean side toward the coastal side.

EPCS and ADCP data analyses are now in progress. During our Leg 1, the weather was fine and the sea was very calm. We do not have any storm during our Leg 1 and also Leg 2. These weather condition is thought to affect to the high water temperature in the shallower layers and to the formation of the prominent thermocline.

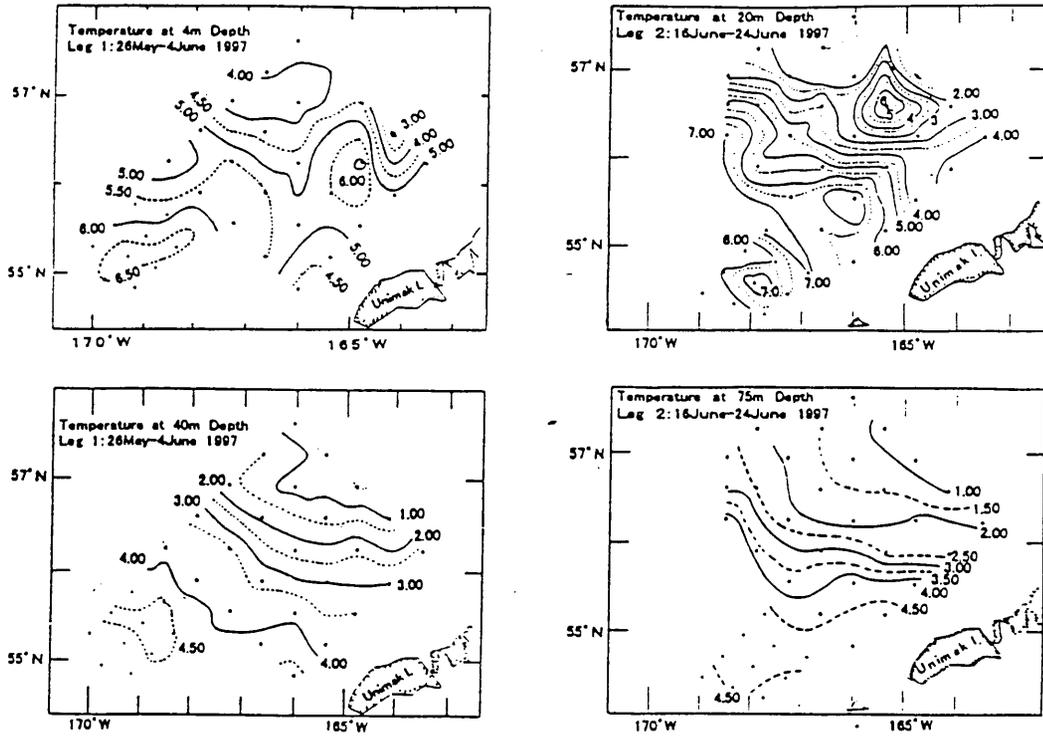


Fig. 4A. Horizontal profile of water temperature at each standard layer during Leg 1.

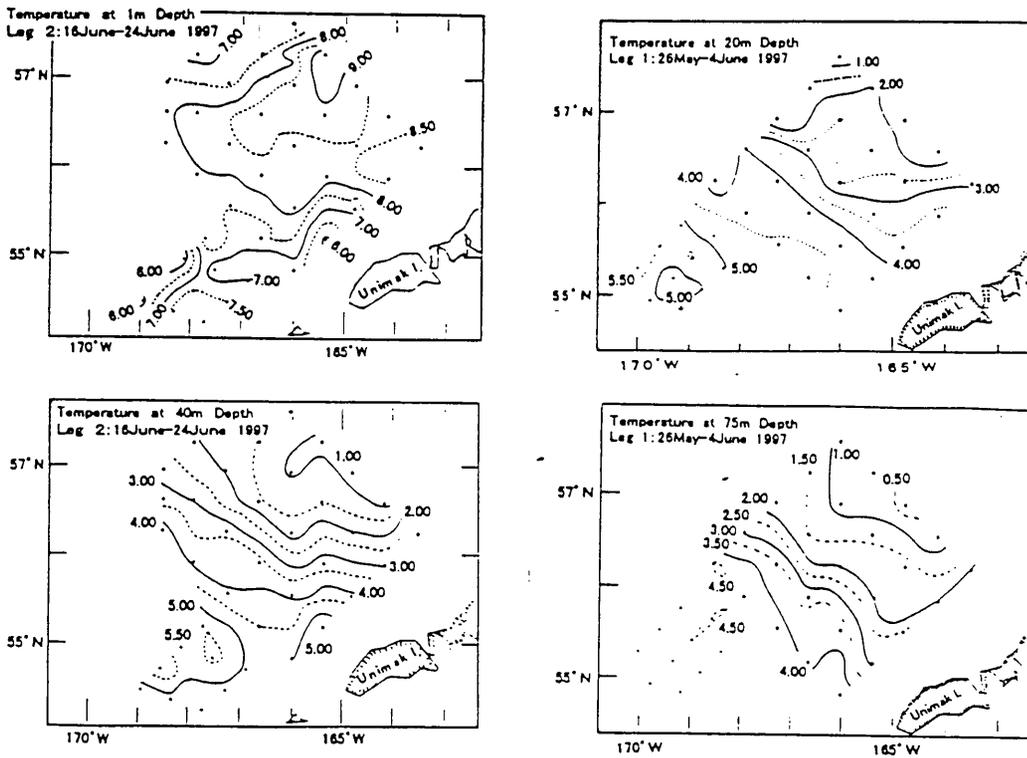


Fig. 4B. Horizontal profile of water temperature at each standard layer during Leg 2.

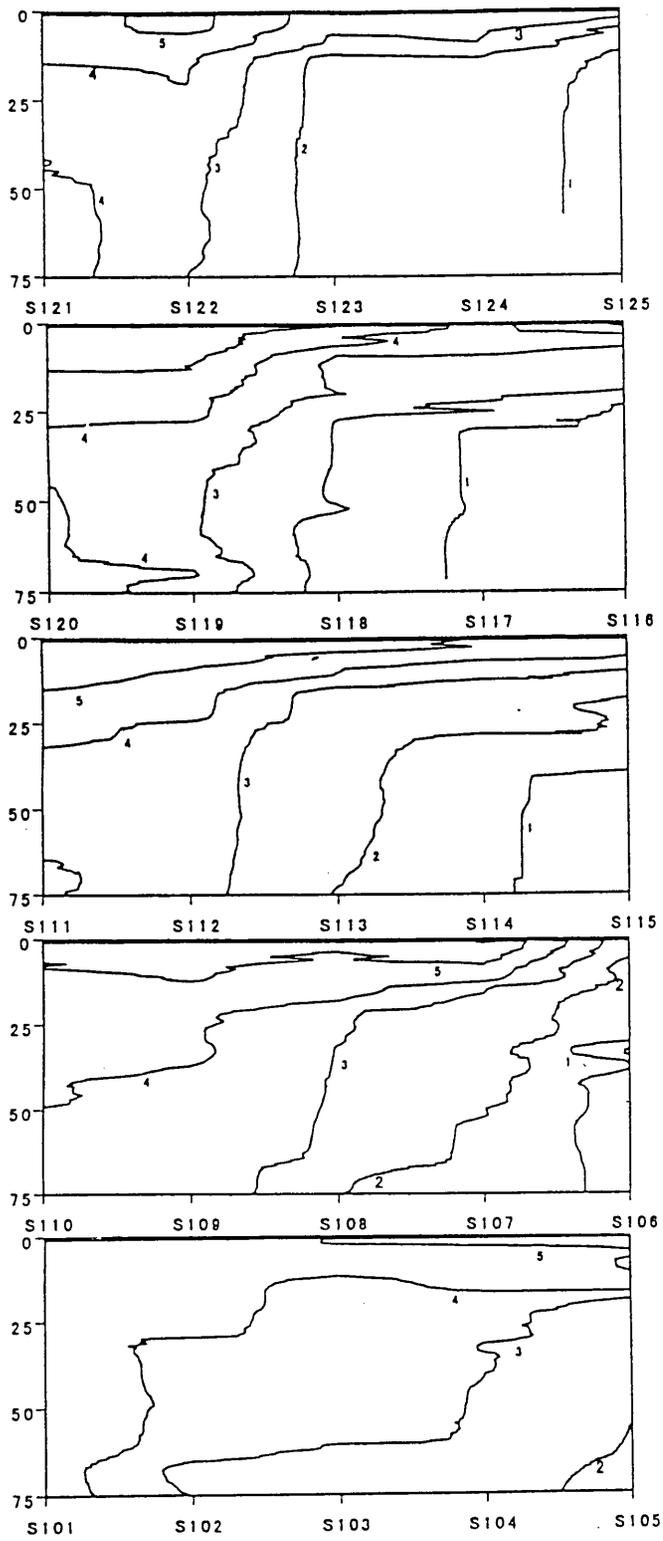


Fig. 5A. Vertical profile of water temperature for each transect line during Leg 1.

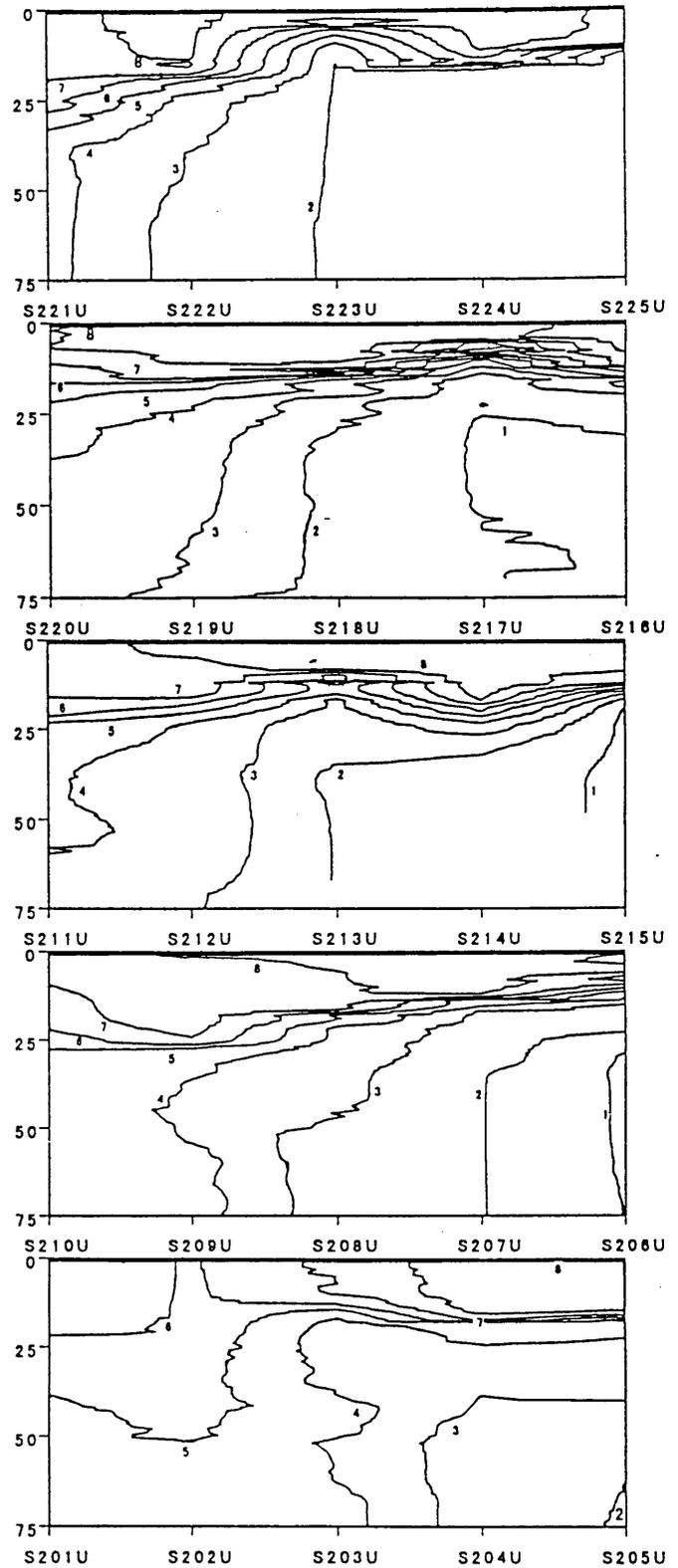


Fig. 5B. Vertical profile of water temperature for each transect line during Leg 2.

Results from the 1997 Echo Integration and Midwater
Trawl Survey for the Bering Sea Walleye Pollock
by the *R/V Pusan 851*

National Fisheries Research and Development Institute
Republic of Korea
September 1997

Results from the 1997 Echo Integration and Midwater Trawl
Survey for the Bering Sea Walleye Pollock
by the *R/V Pusan 851*

*Won Seok YANG, Chul In BACK, Soon Song KIM, Seok Gwan CHOI,
Taeg Youn OH and Doo Nam KIM*

*National Fisheries Research and Development Institute
Republic of Korea*

Introduction

The National Fisheries Research and Development Institute (NFRDI) conducted an echo-integration midwater trawl survey of walleye pollock in the Bering Sea from the Bogoslof Island area to the Donut Hole by the Korean *R/V Pusan 851* during May~June 1997. The purposes of the survey were to grasp the estimation of biomass, horizontal/vertical distribution and biological composition of walleye pollock and to understand oceanographic structure including the distribution of planktons in the Bering Sea.

The itinerary of the *R/V Pusan 851* was as follows;

April 29~May 9, 1997 : Departure from Pusan port and navigation of
Pusan 851

May 9~12 : Inport Dutch Harbor and supplies

May 13~17 : Transfer to the Captain Bay and sphere calibration

May 17~June 12 : Acoustic-midwater trawl surveys from the
Bogoslof Island area to the Donut Hole

June 13~25 : Navigation of Pusan 851 and arrival in Pusan port

Materials and Methods

Research vessel and fishing gear

The R/V Pusan 851 is a stern trawler of 64.8 m long and 1,126 gross tonnage with research equipments built on the exploratory fishing for midwater and bottom fishes. The major characteristics of the vessel are as follows;

Hull : Steel	Length of vessel : 64.8 m
Type : Stern trawler	Engine : 2,600 horsepower
Gross tonnage : 1,126 t	Top speed : 12.8 knots
Radar : Furuno FRP-100	Radio : VHF, SSB

Midwater trawl was employed to identify the detected echosigns and to collect biological samples. The fishing gear of midwater trawl was constructed with ropes in the forward section, a 540 m circumference in the stretched net mouth and stretched mesh sizes ranging from 900 cm immediately behind rope section to 10 cm in the codend. Both headrope and footrope lengths were 56.7 m, respectively.

Survey area

The survey areas of the Bering Sea were divided into four areas in order to deal with the target strength-length relationship in the function of the length and weight and to estimate the biomass of walleye pollock by area; the Bogoslof Island area (A), Middle area between Bogoslof Island area and Donut Hole (B), Continental Shelf (C) and Donut Hole (D) (Fig. 1).

Echo intergration

For acoustic data collection, a scientific echo sounder system (SIMRAD EK 500) was mounted on the research room and a SIMRAD VD 500 towed body with special electric cable of 150 m long was used for towing a SIMRAD 38 KHz split beam transducer. Data from the SIMRAD EK 500 sounder were stored and processed using a SIMRAD BI 500 Integrator which was based on the use of

graphic workstation, Trigem workstation compatible with the SUN workstation, installed an echo integration and target strength data analysis software.

The survey was designed to cover a vast area of the Aleutian Basin, while it was designed to observe in detail the Bogoslof island area (Fig. 1). Since the high dense aggregation of spawning stock of walleye pollock was known to be taken place in the Bogoslof Island area during the winter, transects were spaced 20 and 10 nautical miles apart in parallel north-southward and 60 nautical miles apart in the middle and the Donut Hole areas.

The survey cruise was started from near Dutch Harbor and proceeded to the westwards. Echo integration outputs were logged each 5 nautical miles at both day and night. While transecting, towed body was hauled at the depth between 15 m and 20 m below the surface with ranging 8~10 knots of vessel speeds according to the weather conditions.

Oceanographic observations

40 oceanographic research stations were selected to understand oceanographic structure and distribution of planktons (Fig.1). Water temperature and salinity profile data were collected from surface to 500m in the oceanographic research stations with a CTD system. Bongo net was used for collection of plankton samples at 100 m layer in each stations. Seawater samples for chlorophyll *a* determination were collected at the surface.

Midwater trawl and biological sampling

Midwater trawl hauls were made to identify fish species and biological sampling at the selected location where a good echosign was encountered in day time (Fig. 1). The towing hours and speeds were about 30 minutes and 4 knots. In each trawl haul, all species caught were counted and weighed. Samples of walleye pollock were treated to analyze sex ratio, maturity stage, fork length and body weight. Lengths were measured on the measuring board with a caliper scaling in 1 mm and body weight was scaled into the nearest gram.

Results

Standard sphere calibration

Calibration procedures were conducted at the sphere depth of 30.8 m from the transducer where bottom depth was 53.3 m, water temperature 4.1 °C and salinity 32.3 PSU in Captain Bay. The values of the split beam target strength were corrected repeatedly to find the known value of -33.6 dB and the TS transducer gain parameter. The values of the echo integration for the sphere were corrected repeatedly to find the value identical to the theoretical value and the Sv transducer gain parameter. Transducer beam pattern characteristics (longitudinal offset, transversal offset and 3 dB beam width of the beam) were used the default values.

This was no significant differences from default setting of the maker in the acoustic system gain parameters and transducer beam pattern characteristics. Calibration results and overall system parameters were presented in Table 1.

Oceanographic conditions

The summarized vertical water temperature was shown in Table 2. The surface water temperature had similar trend in the whole survey area. At the 50~199m layer, however, it was warmer in the Bogoslof Island area than the other areas. There was a cold water mass of 1.0 °C~3.0 °C at the 70~180 m layer in the Donut Hole which is known as one of the major distributed layer of walleye pollock targeted by commercial fishing in the past years (Fig. 2). It can be suggested that the cold water mass is moved from northwestern part to southeastern area in the Donut Hole. It may also influence the distribution of walleye pollock in the Central Bering Sea.

Salinity was fluctuated from 33.0 PSU to 33.8 PSU in the survey area (Fig. 2). Vertical distribution of salinity showed the range of 33.0~33.4 PSU at the layer of 100~200m which is the major distributed layer of walleye pollock in the survey area. There is a pattern in the survey area that the deeper the depth the higher salinity was shown.

The highest abundance of chlorophyll *a* was shown in the Bogoslof Island area (A) (Fig. 3). In the vicinity of 168° W and 55° N, the abundance of chlorophyll *a* was more than 2.0 µg/l and along the 170° W it was about 1.0 µg/l. From the results of fish larvae identification it is considered that most of larvae were classified to pollock larvae. Higher distributions of fish larvae were appeared in the area A of 3,301.05 ind./1000 m³ and area C of 2555.72 ind./1000 m³ (Fig. 4).

Midwater trawls

The results of the midwater trawls were summarized in Table 3. A total of 12 hauls were made in the cruise; 4 hauls in the Bogoslof island area (A), 3 hauls in the Middle area (B) and 5 hauls in the Continental Shelf (C). Catch per unit effort (CPUE ; kg/hour) of walleye pollock was ranged from 17.8 kg to 2,495.1 kg with an average of 414.6 kg in the whole survey areas. The highest catch and CPUE was shown in the area A, followed by area C and B (Table 4). Species composition showed that walleye pollock was accounted for about 99.2 % of the total catch in the whole trawling positions (Table 5).

Size compositions

Fork length composition of walleye pollock were shown in Figure 5. Two different fork length compositions of pollock were shown between eastern (haul no. 1) and western (haul no. 2~4) areas of the Bogoslof Island area. The small sized group of 40 cm was caught in the eastern Bogoslof Island area. On the other hand, about 50 cm sized group was caught in the western Bogoslof Island area. In the Middle area (haul no. 5, 8, and 9), even though 55 fishes were caught, large sized group of 47~59 cm was appeared. The trends of weight compositions of pollock were almost same with the fork length composition (Fig. 6). The mean body weight of female was from 523 g in the eastern Bogoslof Island area to 966 g in the Middle area. Relationship between fork length and body weight from the biological samples by area were expressed as follows (Fig. 7);

$$\text{Eastern Bogoslof : } W = 0.2687 \times L^{2.0033} \quad (r^2=0.70)$$

$$\text{Western Bogoslof : } W = 0.0209 \times L^{2.7188} \quad (r^2=0.76)$$

$$\text{Middle area : } W = 0.0492 \times L^{2.5133} \quad (r^2=0.85)$$

Continental Shelf : $W = 0.0733 \times L^{2.3882}$ ($r^2=0.76$)

where, L is fork length in cm and W is body weight in g.

Relative density (S_a) and biomass estimation

Echo integrator output, S_a , was reintegrated with a S_v threshold of -69 dB currently used in the AFSC. To convert S_a into absolute density, the length-target strength relationship used was $TS=20\log(L)-66$ and the length-weight relationships used were $W=0.2687 \times L^{2.0033}$ in the eastern Bogoslof Island area and $W=0.0209 \times L^{2.7188}$ in the western Bogoslof Island area for the area A, $W=0.0492 \times L^{2.5133}$ for B and D, and $W=0.0733 \times L^{2.3882}$ for C, respectively. Relative density (S_a) distribution of pollock was presented in Figure 8. Higher density was observed along the slope and margin of the Continental Shelf (C). Dispersed and poor echosigns were generally appeared in the Middle area (B) and Donut Hole (D). The survey areas swept by echo integration were 8,885 n.mile² for the area A, 31,842 n.mile² for B, 16,944 n.mile² for C and 57,392 n.mile² for D. The results of estimated biomass was shown in Table 6. Estimated biomass of walleye pollock in the whole survey areas was 200,263 mt. For the area A it was 13,274 mt, 17,795 mt for B, 157,098 mt for C and 12,096 mt for D. In area C it was accounted for 78.4 % of the total estimated biomass.

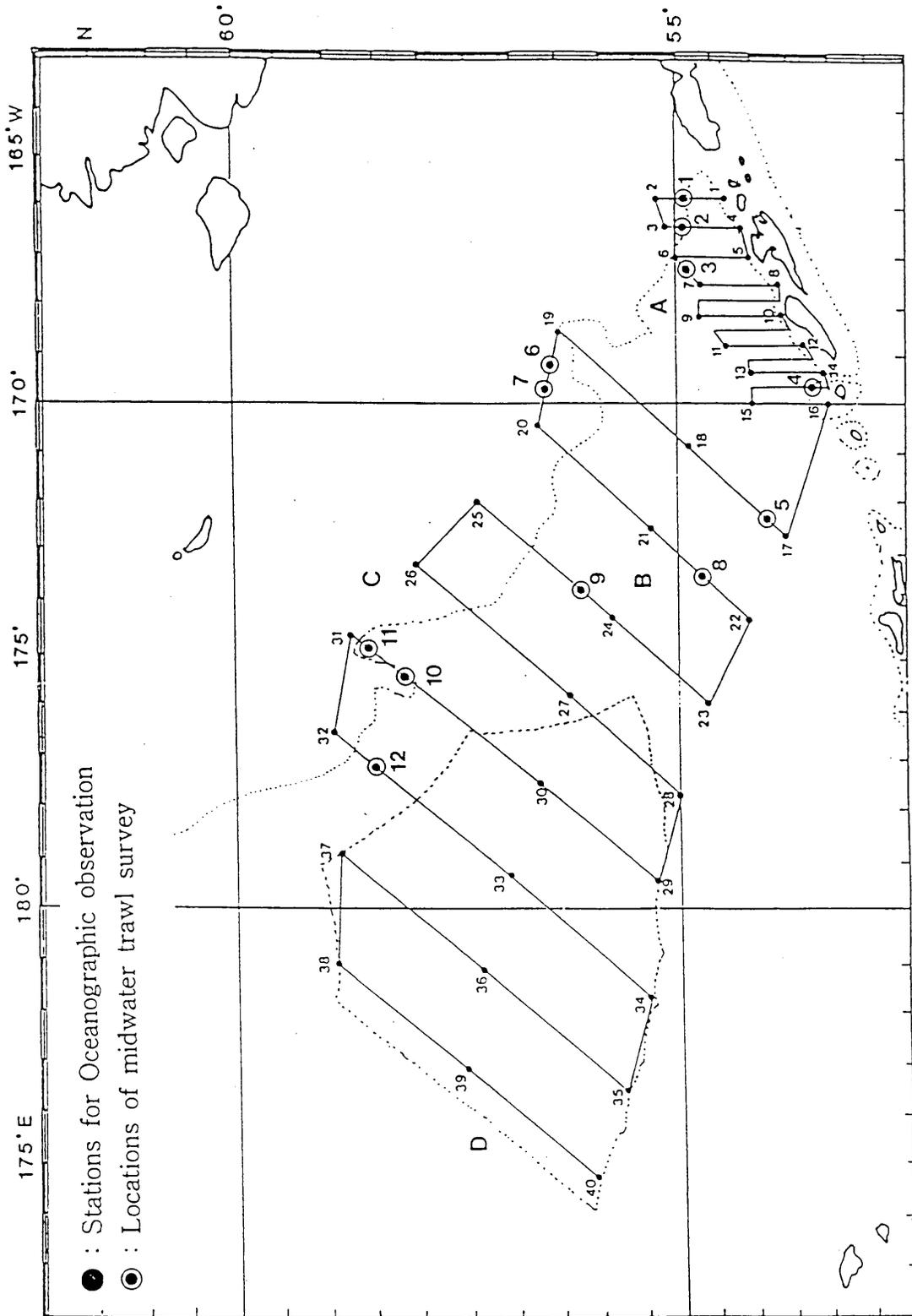


Fig. 1. Track lines of R/V Pusan 851 survey cruise in the Bering Sea from May 17 to June 12, 1997

Table 1. The report of standard sphere calibration conducted at the Captain Bay in May 15~16, 1997 for echo integration and midwater trawl survey by the *R/V Pusan 851* in the Bering Sea

<u>CALIBRATION REPORT EK500</u>			
VESSEL : R/V PUSAN 851		DATE : May 15~16, 1997	
PLACE : CAPTAIN BAY		BOTTOM DEPTH : 53.3 M	
SST : 4.1 °C.	SALINITY : 32.36 PSU.	SOUND VELOCITY: 1,464 M/SEC	
FREQUENCY	38		
ABSORPTION COEFFICIENT	10 dB		
TRANSDUCER	ES 38		
ANGLE SENSITIVITY	21.9		
PING INTERVAL	1.0 sec		
TRANSMIT POWER	Normal		
MAX. POWER	4 kw	for towed body	
PULSE DURATION	1 ms		
BANDWIDTH	3.8 kHz		
TS OF SPHERE	-33.6 dB		
DEFAULT TS TRANSDUCER GAIN	26.5		
MEASURED TS	-36.1 dB		
ADJUSTED TS TRANSDUCER GAIN	25.8		
CALIBRATED TS	-33.6 dB		
DEFAULT EQUIVALENT 2-WAY BEAM ANGLE	-20.6		
TRANSDUCER DATA 2-WAY BEAM ANGLE	-20.6		
DEPTH TO SPHERE	30.8 m		
DEFAULT SV TRANSDUCER GAIN	26.5		
THEORETICAL SA	2,282		
MEASURED SA	1,579		
ADJUSTED SV TRANSDUCER GAIN	26.0		
CALIBRATION SA	≅2,282	Sphere moved a little	
DEFAULT 3 DB BEAM WIDTH*	7.1		
CALIBRATION -3 DB BEAM WIDTH*	7.1		
LONGITUDINAL OFFSET*			
TRANSVERSAL OFFSET*			

Table 2. Water temperature(°C) by depth and area during the survey of *R/V Pusan 851* in the Bering Sea from 17 May to 12 June 1997

Depth (m)	Area			
	A	B	C	D
0~49	6.2~3.7	6.3~3.7	7.2~3.2	6.2~3.7
50~99	5.0~3.1	4.2~3.3	4.4~2.6	4.2~2.3
100~199	4.7~3.4	3.8~2.8	4.3~2.7	3.9~1.5
200~299	4.6~3.7	4.2~3.6	4.1~4.0	4.0~3.4
300~500	4.4~3.5	4.8~3.5		3.8~3.5

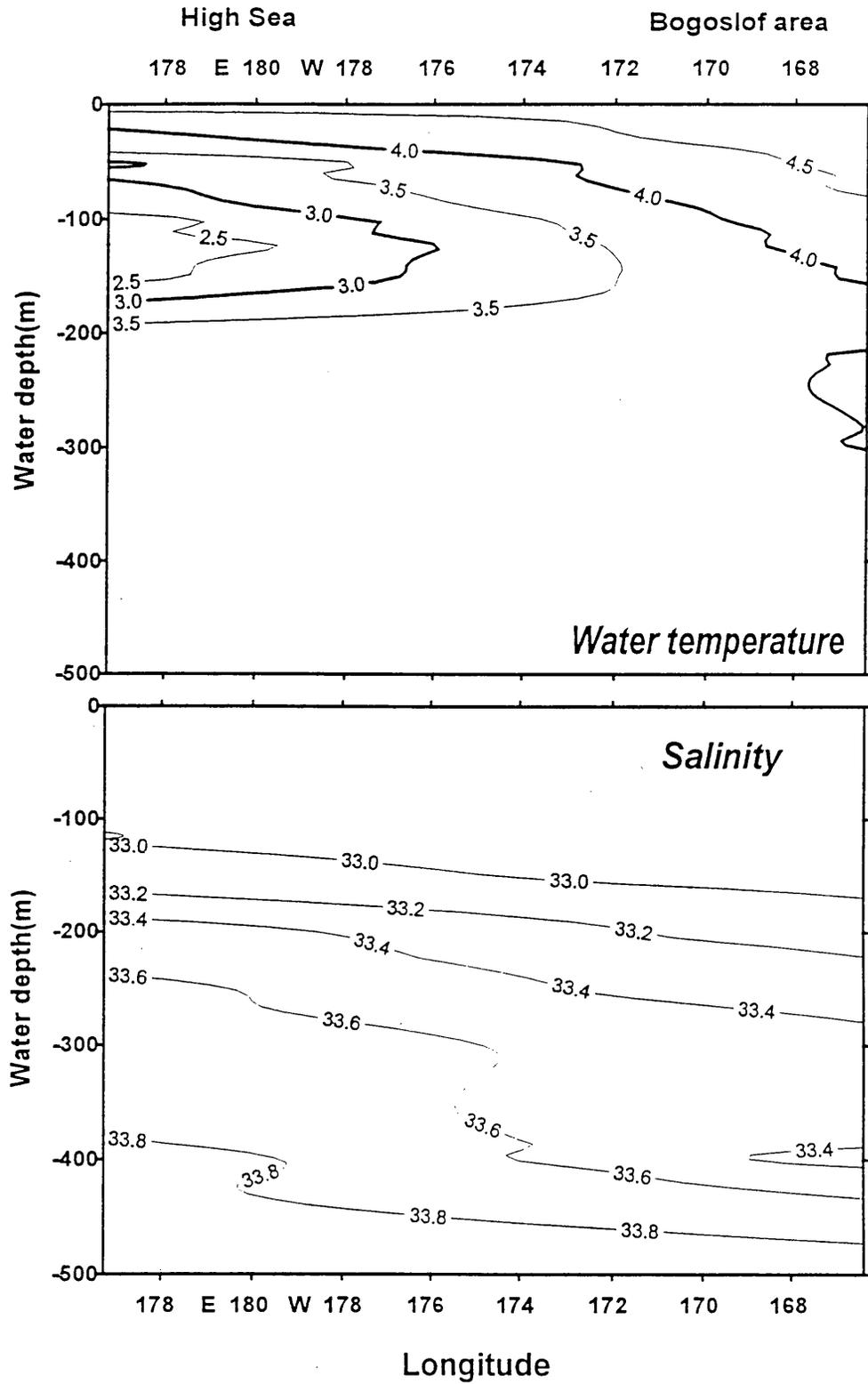


Fig. 2. Vertical distribution of water temperature (C, upper) and salinity (PSU, lower) by depth during the survey of R/V Pusan 851 in the Bering Sea from 17 May to 12 June 1997.

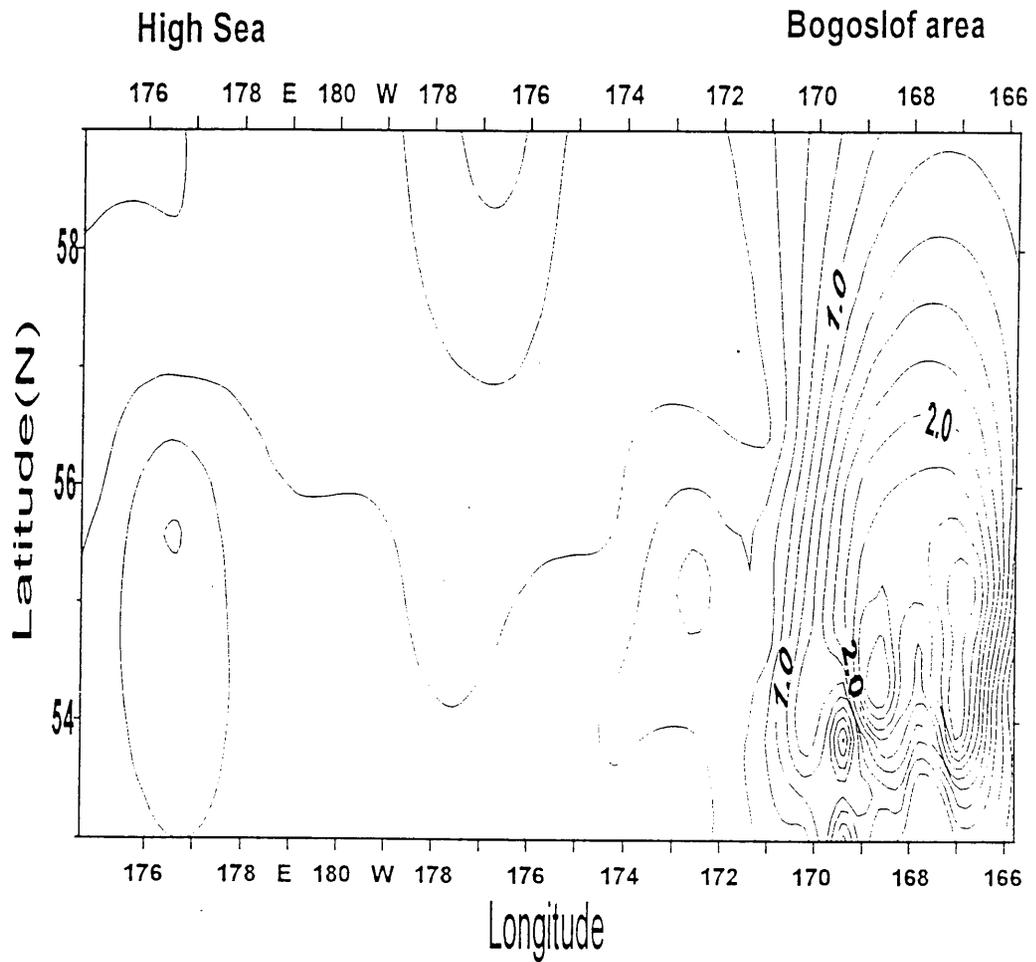


Fig. 3. Distribution of chlorophyll a during the survey of RV Pusan 851 in the Bering Sea from 17 May to 12 June 1997.

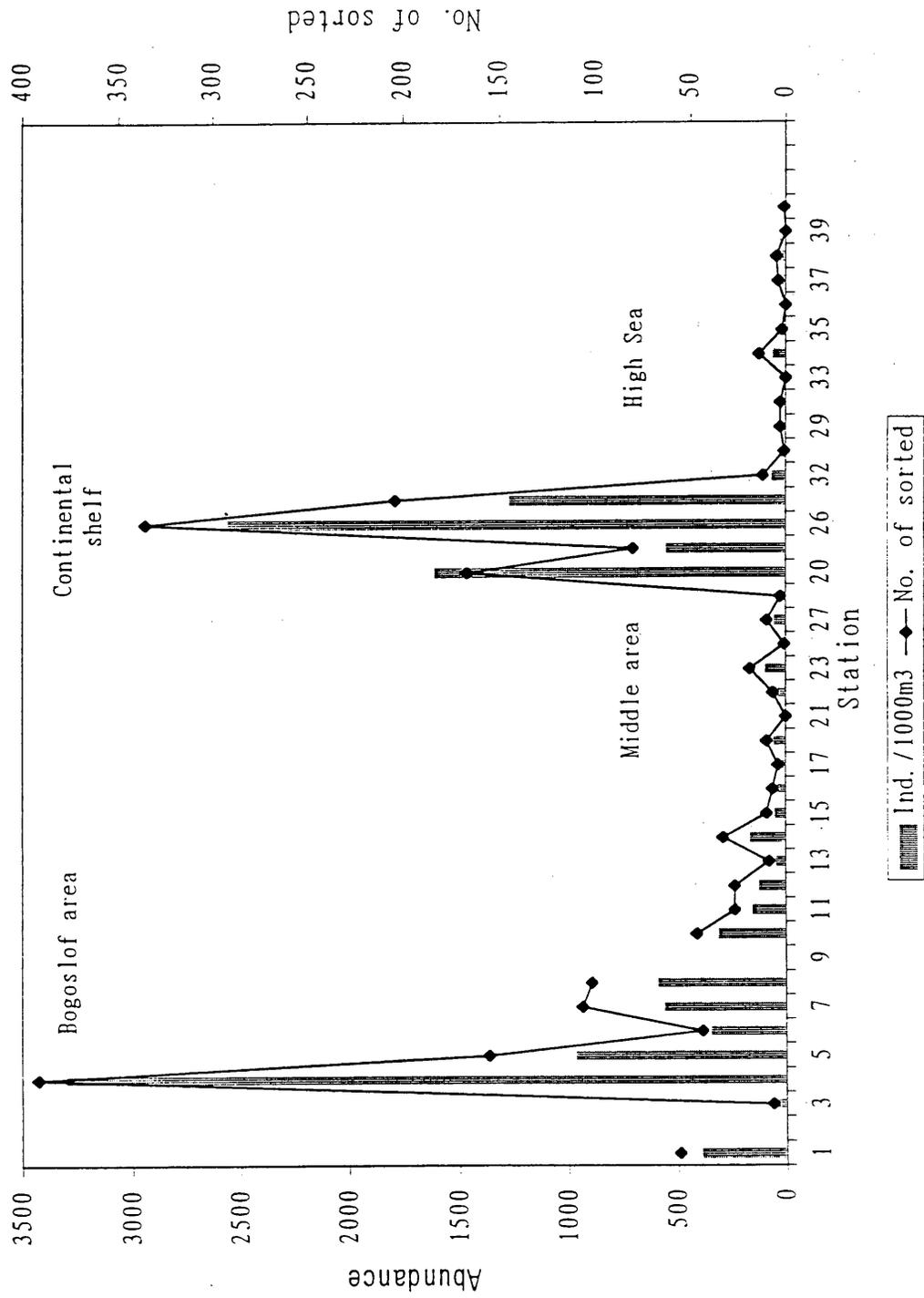


Fig. 4. Abundance of fish larvae during the survey of *R/V Pusan 851* in the Bering Sea from 17 May to 12 June 1997.

Table 3. The summary of midwater trawl results for walleye pollock during the acoustic survey by *R/V Pusan 851* in the Bering Sea from May 17 to June 12 1997

Location No.	FS-01	FS-02	FS-03	FS-04	FS-05	FS-06
Date	May 17	May 20	May 28	May 31	June 1	June 2
Depth	135	160	400	>1,000	>1,000	400
Start time of tow	15 : 00	13 : 52	18 : 20	18 : 35	16 : 40	14 : 45
End time of tow	15 : 30	14 : 26	18 : 50	19 : 10	17 : 15	15 : 16
Start position Lat.	54° 57' N	54° 49' N	54° 35' N	53° 49' N	53° 38' N	56° 08' N
Long.	165° 54' W	166° 28' W	166° 59' W	169° 42' W	172° 26' W	169° 38' W
End position Lat.	54° 56' N	54° 48' N	54° 37' N	53° 41' N	53° 36' N	56° 07' N
Long.	165° 56' W	166° 28' W	166° 59' W	169° 43' W	172° 29' W	169° 35' W
Towing hours (min)	0.5 (30)	0.56 (34)	0.5 (30)	0.58 (35)	0.58 (35)	0.51 (31)
Towing speed (knots)	4.0	3.7	4.0	4.0	4.0	3.8
Towing distance (n.m)	2.0	2.1	2.0	2.3	2.3	1.9
Towing depth range (m)	80-120	60-100	350-390	50-85	130-170	270-310
Water temperature (°C)	3.5-3.9	3.4-3.6	3.7-3.8	3.9-4.3	4.0-4.3	4.0-4.3
Value of SA	110	12	7	23	>1	15
Total Catch (kg)	546.5	1413.9	0.5	386.6	17.0	66.05
Pollock Catch (no.)	1101	1934	-	375	14	84
Pollock Catch (kg)	546.5	1413.9	-	383.7	14.6	64.2
Pollock CPUE(no./hour)	2202	3413	-	643	24	162
Pollock CPUE(kg/hour)	1093.0	2495.1	-	657.	25.0	124.3

Table 3. Continued

Location No.	FS-07	FS-08	FS-09	FS-10	FS-11	FS-12
Date	June 2	June 3	June 4	June 7	June 7	June 8
Depth	≈400	>1,000	>1,000	>1,000	≈600	≈400
Start time of tow	16 : 48	14 : 43	16 : 36	12 : 37	15 : 50	08 : 10
End time of tow	17 : 46	15 : 13	17 : 10	13 : 10	16 : 34	08 : 45
Start position Lat.	56° 06' N	54° 32' N	56° 17' N	58° 03' N	58° 12' N	58° 35' N
of tow Long.	169° 31' W	173° 37' W	173° 26' W	175° 33' W	175° 22' W	177° 19' W
End position Lat.	56° 09' N	54° 33' N	56° 15' N	58° 01' N	58° 18' N	58° 37' N
of tow Long.	169° 38' W	173° 35' W	173° 28' W	175° 36' W	175° 26' W	177° 16' W
Towing hours (min)	0.96 (58)	0.5 (30)	0.56 (34)	0.55 (33)	0.73 (44)	0.58 (35)
Towing speed (knots)	3.8	3.8	4.0	4.0	4.0	4.0
Towing distance (n.m)	3.7	1.9	2.3	2.2	2.9	2.3
Towing depth range (m)	40-80	140-180	140-180	180-220	120-160	150-190
Water temperature (°C)	4.4-4.5	3.3-4.0	4.0-4.1	3.1-3.9	3.2-3.3	3.4-3.5
Value of SA	40	10	17	39	30	94
Total Catch (kg)	227.2	13.9	23.4	42.9	28	222.2
Pollock Catch (no.)	279	8	23	58	32	332
Pollock Catch (kg)	227.2	8.9	21.2	41.8	24.5	217.8
Pollock CPUE(no./hour)	289	16	41	76	44	569
Pollock CPUE(kg/hour)	234.9	17.8	37.9	105.0	33.4	373.4

Table 4. Catch and CPUE of walleye pollock taken from the *R/V Pusan 851* in the Bering Sea during 17 May to 12 June 1997

	A	B	C	Total
No. of hauls	4	3	5	12
Catch(kg)	2,344.1	45.1	575.5	2,964.7
CPUE(kg/h)	1,090.3	27.3	171.8	414.6
Water Tem.(°C)	3.4~4.3	3.3~4.3	3.1~4.5	3.1~4.5
Depth(m)	50~390	130~190	40~310	40~390

Table 5. Fish species composition by haul caught by midwater trawls during the survey of *R/V Pusan 851* in the Bering Sea from 17 May to 12 June 1997

Species	No. of haul	Unit : kg(%)												
		Total	1	2	3	4	5	6	7	8	9	10	11	12
Walleye pollock (<i>Theragra chalcogramma</i>)		2964.7 (99.2)	546.5 (100)	1413.9 (100)		383.7 (99.2)	14.6 (85.8)	64.2 (97.2)	227.2 (100)	8.9 (64)	21.6 (92.3)	41.8 (97.4)	24.5 (87.5)	217.8 (98)
Smooth lumpsucker (<i>Aptocycclus ventricosus</i>)		19.9 (0.7)				2.9 (0.8)	2.4 (14.2)			4.0 (36)	1.8 (7.7)	0.9 (2.3)	3.5 (12.5)	4.4 (2)
Lanternfish (Nyctophidea)		0.4 (0.0)			0.4 (80)									
Rougheye rockfish (<i>Sebastes aleutianus</i>)		0.8 (0.0)												
Squid unidentified (Teuthoidea)		1.3 (0.1)			0.1 (20)									0.2 (0.3)
Total		2988.1 (100)	546.5	1413.9	0.5	386.6	17.0	66.0	227.2	13.9	23.4	42.9	28	222.2

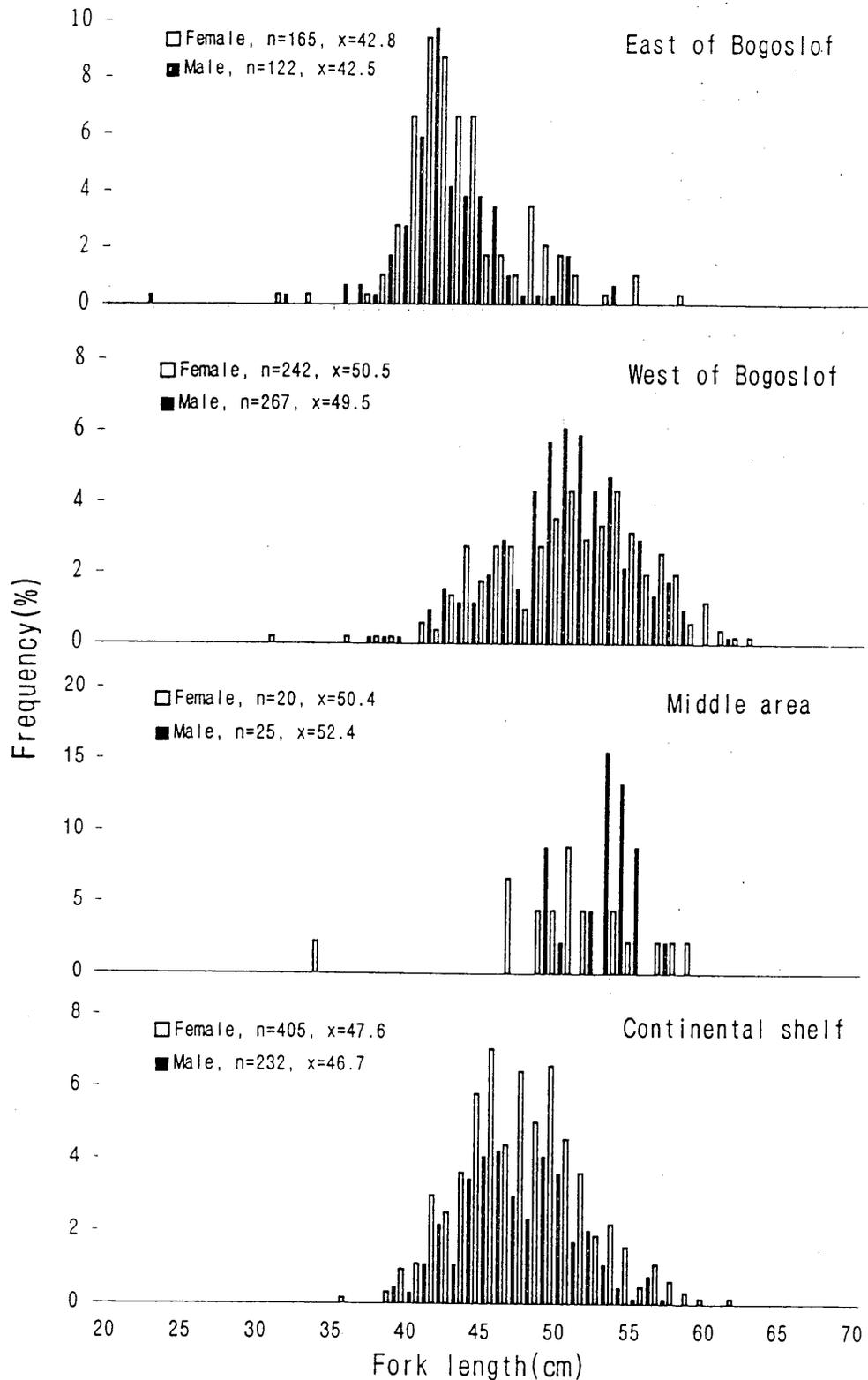


Fig. 5. Fork length composition by area and sex of walleye pollock taken from the midwater trawl during the survey of *R/V Pusan 851* in the Bering Sea from 17 May to 12 June 1997.

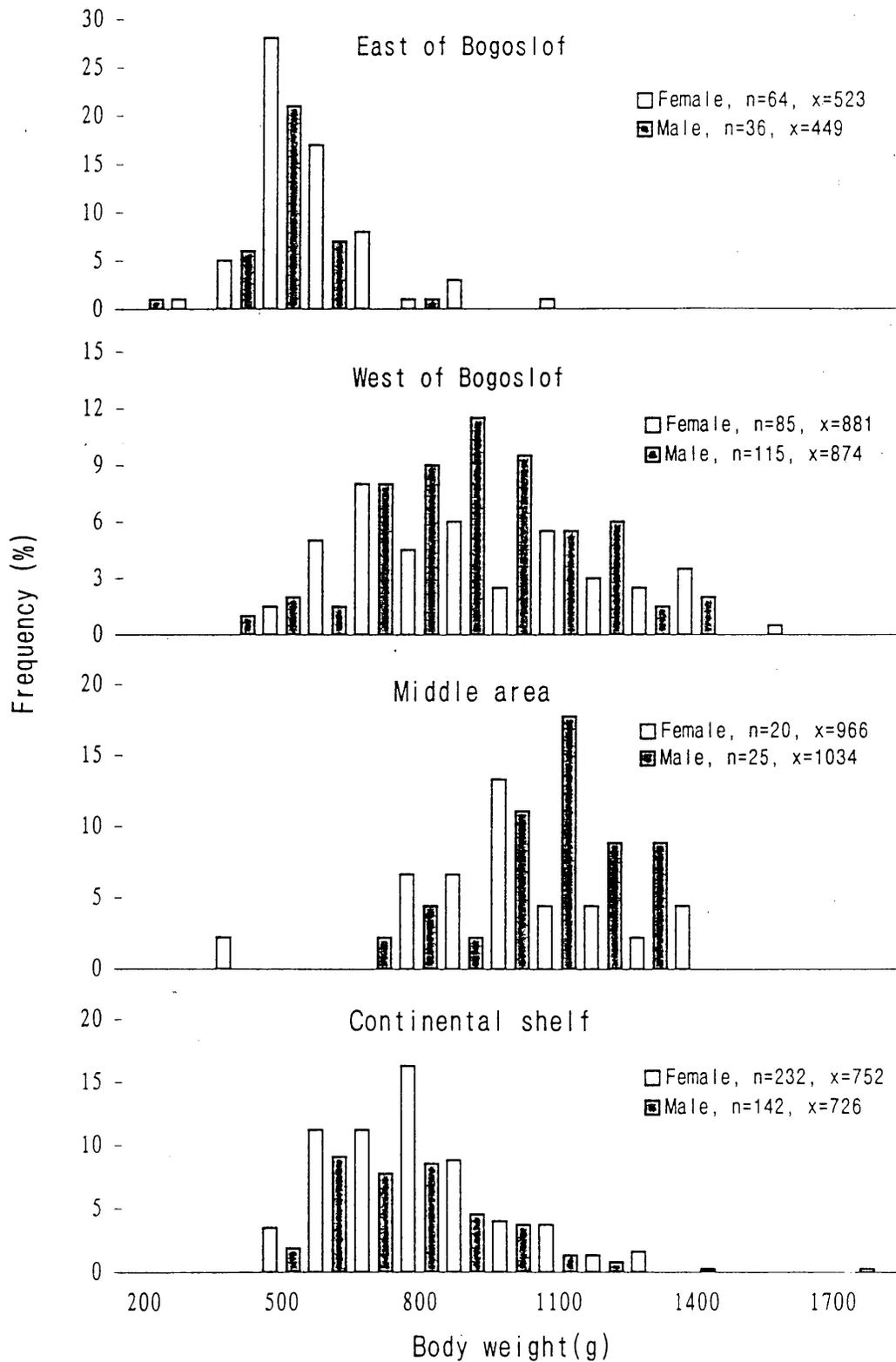


Fig. 6. Body weight composition by area and sex of walleye pollock taken from the midwater trawl during the survey of *R/V Pusan 851* in the Bering Sea from 17 May to 12 June 1997.

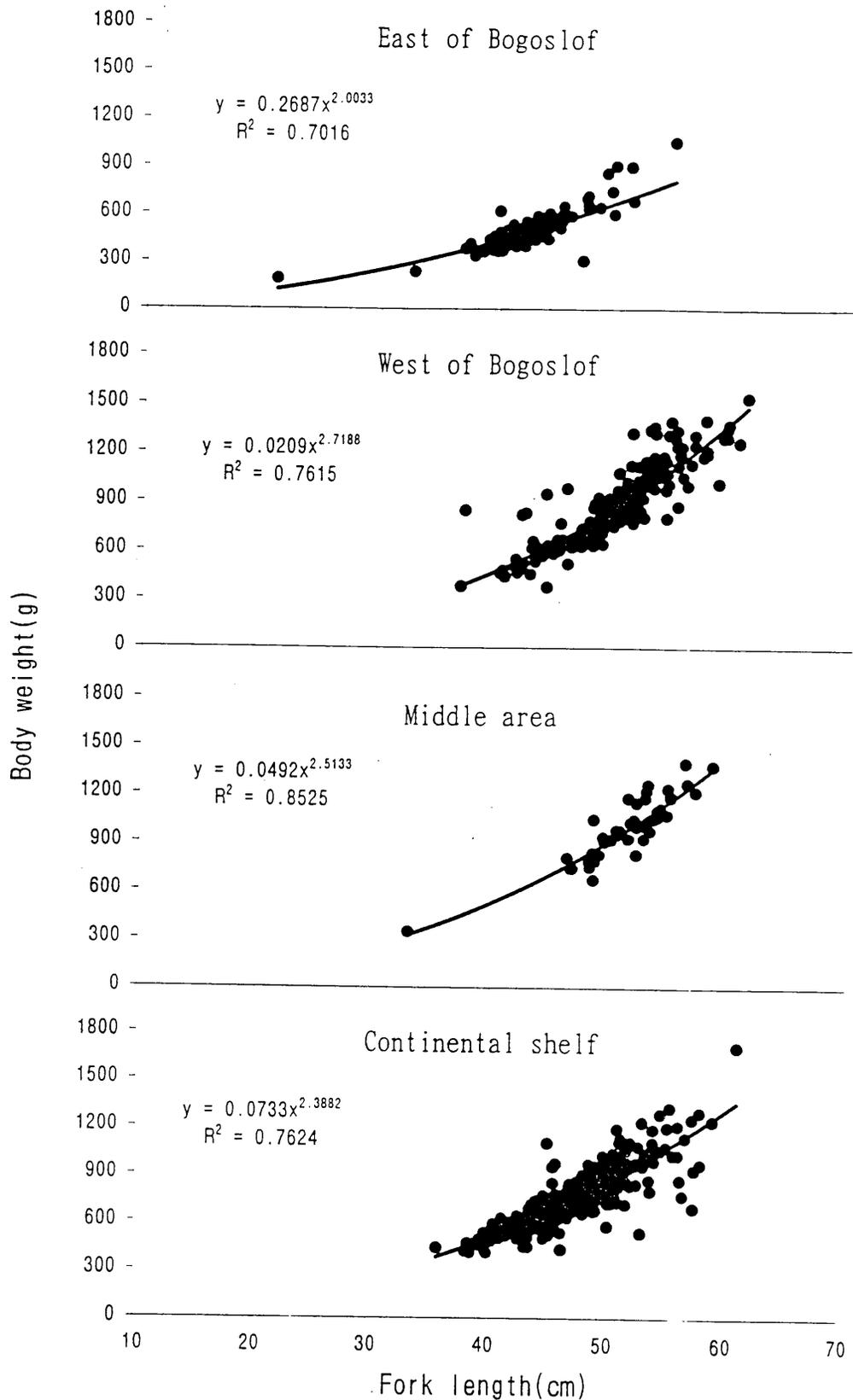


Fig. 7. Fork length-body weight relationship by area of walleye pollock taken from the midwater trawl during the survey of *R/V Pusan 851* in the Bering Sea from 17 May to 12 June 1997.

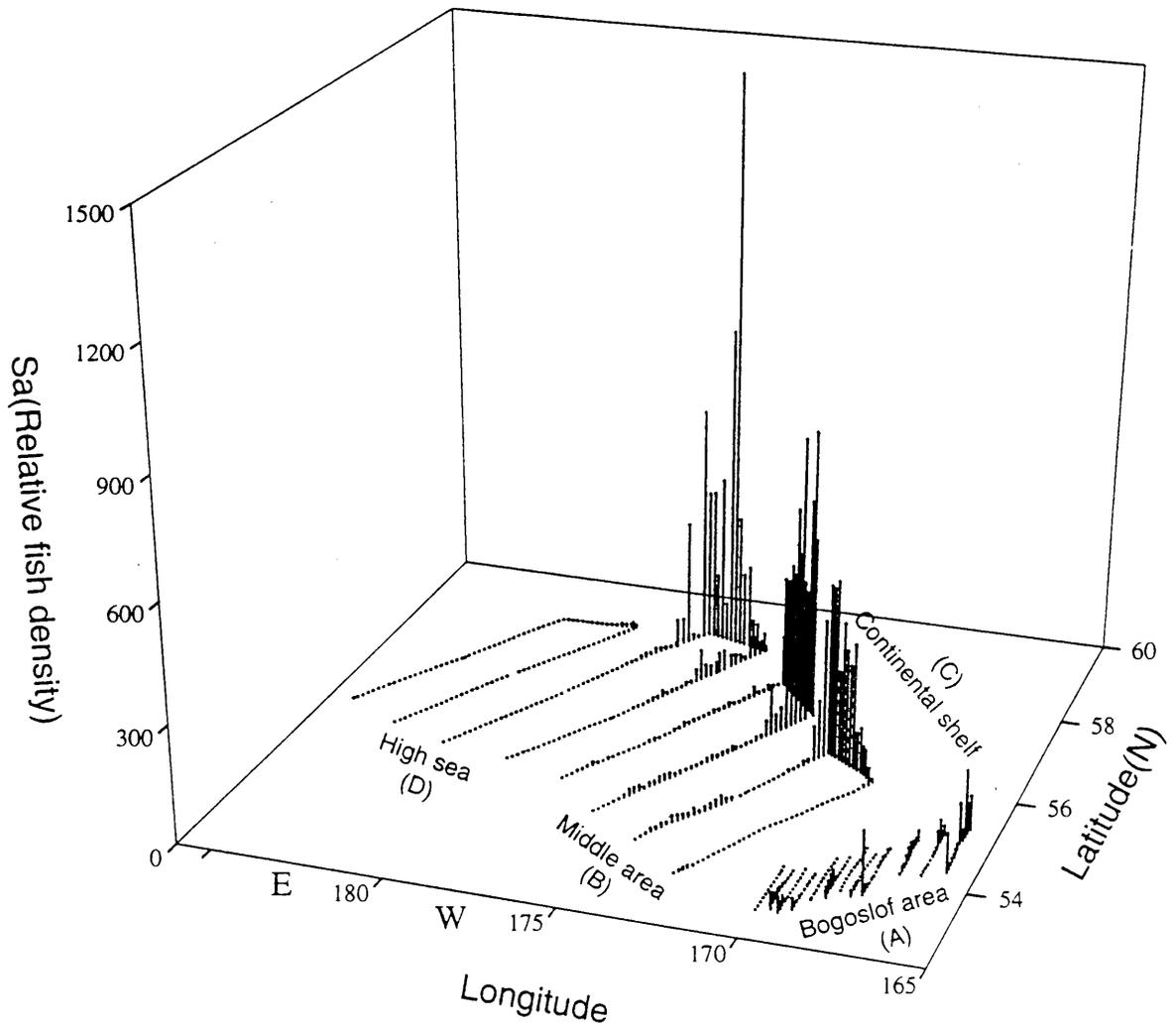


Fig. 8. Relative density of walleye pollock along the transects with the vertical histogram resulted from the echo integration during the survey of R/V Pusan 851 in the Bering Sea from 17 May to 12 June 1997.

Table 6. Estimated biomass of walleye pollock by area during the survey of R/V Pusan 851 in the Bering Sea from 17 May to 12 June 1997

	Total	A Bogoslof area	B Middle area	C Continental shelf	D Donut Hole
Area swept(n.mile ²)	115,063	8,885	31,842	16,944	57,392
Transect length(n.mile)	2,478	692	525	281	980
Mean S _a (m ² /n.mile ²)		11.5	4.7	86.7	2.0
<i>Estimation</i>					
Population(x 10 ⁶)	259.2	17.7	17.7	211.7	12.1
Biomass(tons)	200,263	13,274	17,795	157,098	12,096
Density(ton/n.mile ²)		1.5	0.6	9.3	0.2

DRAFT

False ring observed in the otolith of age 1 walleye pollock collected in the Bering Sea

Akira Nishimura
NRIFS, Japan

Introduction

Age determination of walleye pollock is mainly carried out using annual structure in the otolith. However, the difficulties in interpretation are often recognized as a result of the unclearness of annual structure in older ages and the existence of false ring. The identification of the first annual ring is one of the problem with relation to false ring formation. This study was undertaken to identify the first annual ring and false ring in the otoliths of young walleye pollock, with using otolith microstructural information.

Materials and Methods

Age 1 walleye pollock were collected on the eastern Bering Sea shelf in the summer of 1989. The sampling was conducted using a mid-water trawl net of the land based dragnet trawler #28 *Seijyu Maru* chartered as a research vessel. A net of 3 mm mesh size was attached inside the cod-end. The fish were frozen immediately and stored for a year. The frozen fish were thawed in the laboratory, measured the fork length, weighed, and the otoliths were dissected out. Otoliths from 130 individuals of age 1 walleye pollock were used for this study. Otoliths were embedded in the epoxy resin and thin sections were made along to the long axis perpendicular to the otolith surface (frontal section). Otolith sections were observed with microscope with translucent light, and the measurement of diameters were made from microphotographs.

Results & Discussion

Age 1 walleye pollock were collected at 7 stations in 1989. Most of the age 1 fish were collected in the northern area of the eastern Bering Sea shelf. The length of the

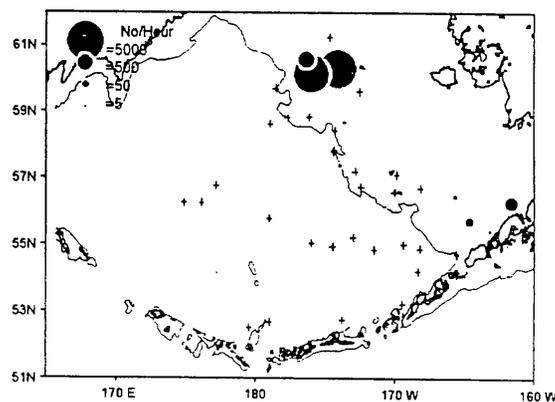


Fig. 1. Catches of age 1 walleye pollock collected in the summer of 1989.

age 1 fish ranged between 125 mm and 216 mm, and the mode was observed at 150 mm.

The otolith showed concentric structure, with alternation of opaque zone and translucent zone. In the most of the otoliths, the opaque zone was observed in the central area, and one translucent zone was observed near the outer edge of the otolith (Fig. 3: Type A).

Otolith daily growth increment was clearly observed on the otolith section. The increments were arranged densely around the otolith core. With an increase in number of the increment, the width gradually widened, and it attained a maximum width in the first opaque zone formed in summer. After then, the width become narrower again and it became obscure in the translucent zone. This translucent zone is the first annual ring that was formed in the first winter.

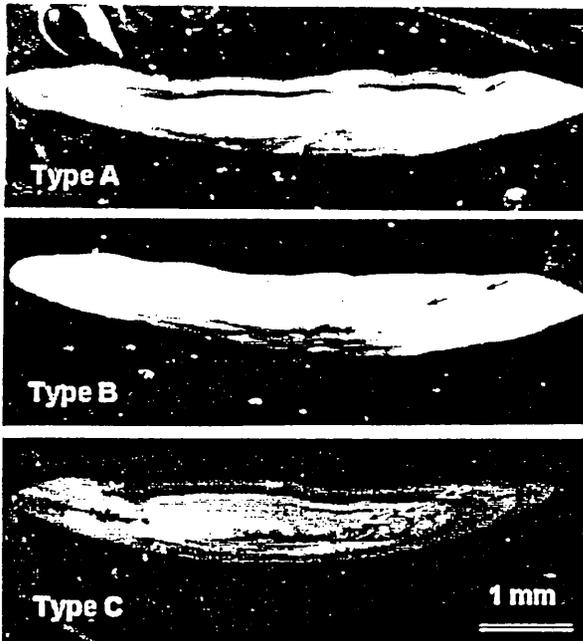


Fig. 3 Microphotographs of frontal section of age 1 walleye pollock collected in the eastern Bering Sea. Arrows indicate translucent zone. Type A, B and C show 1, 2, and 3 translucent zone respectively.

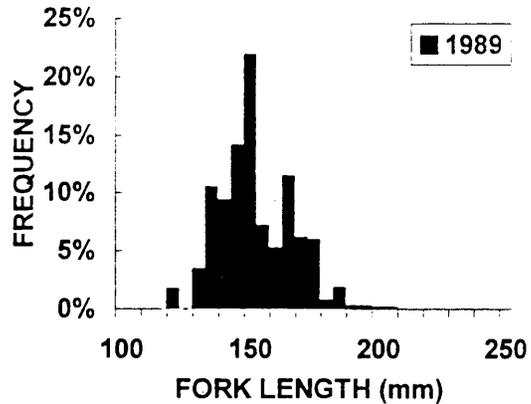


Fig. 2. Length frequency distribution of age 1 walleye pollock, collected in 1989.

In some otoliths, plural translucent zones were observed. Some otoliths showed two translucent zone (Type B), and some showed three or more (Type C). The microstructure around the outermost translucent zone of these otoliths were same as that of Type A, and the outermost translucent zone was identified as first annual ring. In the Type B otolith, 10 to 20 increments were observed with considerable width in the inner translucent zone, and the increment counts from otolith core to the beginning of the inner translucent zone were about 130. It was suggested that the inner translucent zone was formed about 130 days after hatching, that is in summer. So inner translucent zone was identified as false ring.

The occurrence frequency of each type was 67% for type A, 21% for Type B, and

12% for Type C in the age 1 walleye pollock collected in 1989.

Average diameter of the first annual ring (outer translucent zone) of all type otoliths ranged between 4.5-5.1 mm (inner -outer diameter). Using the relationship between otolith length and body length, this first annual ring was estimated to be formed at fish size 90-98 mm on an average. Whereas, the false ring in Type B otolith was observed with diameter of 2.8-3.0 mm on an average. These false ring was estimated to be formed at body length of 66-71 mm. This length shows good accordance with the length of age 0 fish in the summer.

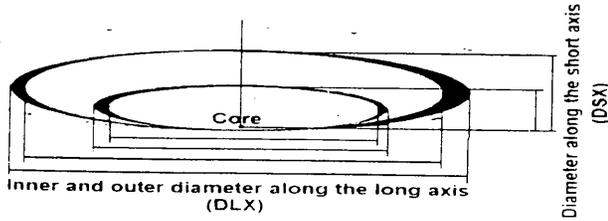


Fig. 4. Direction of otolith measurement.

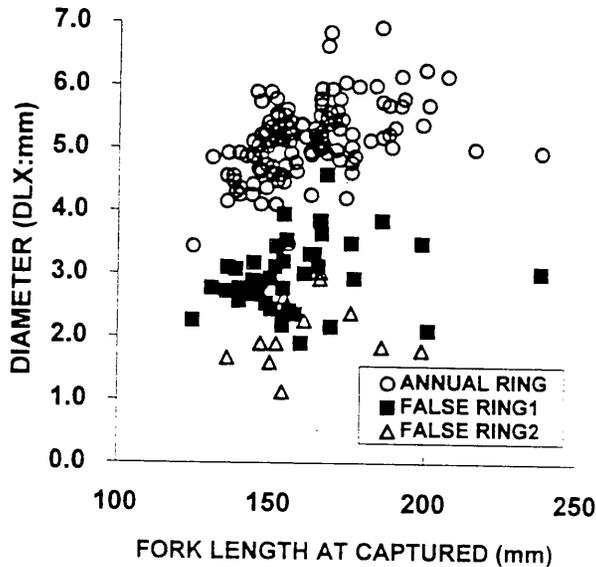


Fig. 5. Relation between fork length at captured and outer diameter along the long axis of each translucent zone.

Fig. 6. Microphotographs of transverse section of age 1 walleye pollock, with showing translucent zone (arrows). Bar indicates 1 mm

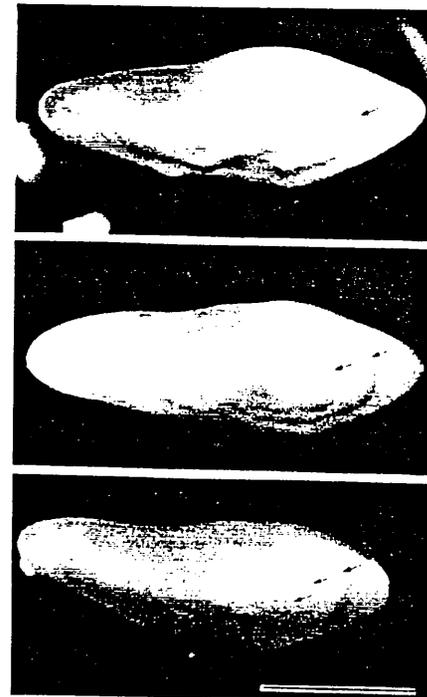


Figure 5 shows the relationship between the fork length at captured and diameter along the long axis of the first annual ring and false ring (Fig. 4: DLX). The positive regression between DLX of the first annual ring and fish size at captured was observed, whereas no significant relationship was observed between false ring DLX and fish size at captured.

Age determination is carried out using break-

burn method with transverse section along the otolith short axis. Even in this method, false ring was observed in the otolith of age 1 walleye pollock (Fig. 6). Overestimation in aging older fish might result from existence of the false ring formed in the first summer.

Figure 7 shows the relationship between the fork length at captured and outer diameter of the annual and false ring along the short axis (Fig. 4: DSX). The figure showed that DSX of the first annual ring is longer than 0.4 mm, whereas that of the false ring is shorter than 0.4 mm. This criteria might be useful for identify first annual ring even in the age reading process with break-burn method.

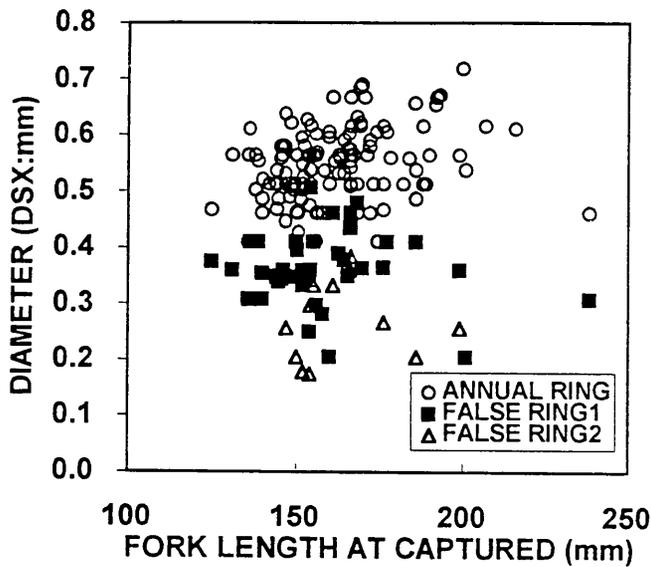


Fig. 7.
Relationship between fork length at captured and outer diameter along the short axis (DSX) of each translucent zone observed in the otoliths of age 1 walleye pollock.

Document for Science Group Meeting, Gdynia
September, 1997

Cruise Plan for Mid-water Trawl Survey on Pelagic Pollock in the International Waters of the Bering Sea, 1997

Fisheries Agency of Japan

I. Objectives

The objectives of the 1997 autumn cruise are to:

- ① Collect information about pollock distribution in the international waters in the Bering Sea, in Autumn.
- ② Collect biological information of pelagic pollock in the International Waters in the Bering Sea, in Autumn.

II. Institution

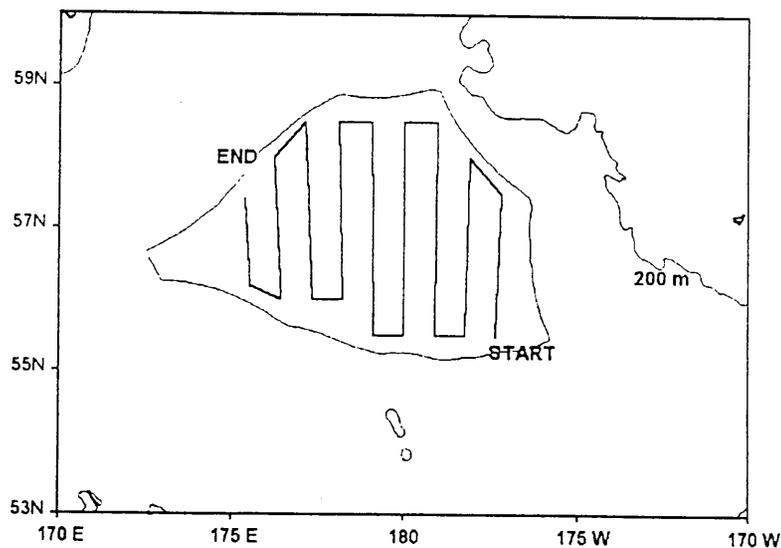
National Research Institute of Far Seas Fisheries (NRIFSF)
5-7-1, Orido, Shimizu, Shizuoka, 424, Japan

III. Research Vessel

A stern trawler will be chartered for the survey. The vessel is not decided yet.

IV. Survey areas

International waters of the Bering Sea (Donuts Hole; Fig. 1).



V. Itinerary (Tantative)

Date	Item
Nov. 1	Leave Shiogama
Nov. 2-7	Transit to Donut Hole
Nov. 8-17	Survey in Donut Hole
Nov. 18-23	Homeward voyage to Shiogama
Nov. 24	Arrive Shiogama

VI. Scientific Personnel

Researcher: Undecided (FAJ)

VII. Research Items

1) Collection of the information about pollock distribution in the Donut hole by using vessel equipped acoustic system.

Ecogram of vessel equipped acoustic system will be collected continuously along the transects (Fig. 1). When significant echo sign appears, trawl haul will be conducted to identify the echo sign and to provide biological data for these organisms. Ship speed is expected to average 8-10 knots in favorable weather.

2) Collection of the biological samples by using mid-water trawl net. The duration each trawl haul should be kept to minimum time necessary to ensure an adequate sample size (600-1000 kg). The following biological data will be collected from the samples.

Species composition and weight and numbers of each species.

Pollock length frequencies of each trawl haul.

Age composition from otolith reading.

Growth analyses and bio-chemical analyses.

VIII. Data

All of the data will be transferred to NRIFSF and will be analyzed. The results will be presented to STC meeting under the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea.