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Groundfish Stock Assessments for the West Coast of Canada in 1988 and Recommended Yield Options for 1989

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GROUNDFISH STOCK ASSESSMENTS FOR THE WEST COAST OF CANADA IN 1988 AND RECOMMENDED YIELD OPTIONS FOR 1989

by

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ABSTRACT

Fargo, J. and A. V. Tyler. 1989. Groundfish stock assessments for the west coast of Canada in 1988 and recommended yield options for 1989. Can. Tech. Rep. Fish. Aquat. Sci. No. 1646: 294 p.

Stock assessments and yield options are developed for the Pacific coast of Canada for the following species: lingcod, Pacific cod, petrale sole, Dover sole, rock sole, English sole, arrowtooth flounder, sablefish, Pacific hake, spiny dogfish, walleye pollock, Pacific ocean perch, yellowmouth rockfish, rougheye rockfish, redstripe rockfish, silvergray rockfish, yellowtail rockfish, canary rockfish, quillback rockfish, copper rockfish, and yelloweye rockfish. The yield options are recommendations to the fishery managers of the Offshore Division of the Fisheries Branch on catch limitations and other fishery management procedures. Biological considerations only, rather than economic factors, are addressed in this document. The yield options are quantitative and are based on a series of appropriate mathematical methods, e.g. virtual population analysis, dynamic pool analysis, and Fournier stock-reconstruction procedures. Alternative options address the possibility of the fishery managers' considering high risk and low risk yields in relation to a stock's potential to produce. Other options, particularly for rockfish species, provide a selection of alternatives for managers to consider in regard to whether a stock should be re-built, maintained at status quo, or decreased through non-sustainable catches for present economic emergencies.

Key words: groundfish, stock assessment, fishery yields

ABSTRACT

Fargo, J. and A. V. Tyler. 1989. Groundfish stock assessments for the west coast of Canada in 1988 and recommended yield options for 1989. Can. Tech. Rep. Fish. Aquat. Sci. No. 1646: 294 p.

Évaluation des stocks et options de récolte sur la côte canadienne du Pacifique pour les espèces suivantes: morue-lingue, morue du Pacifique, plie de Californie, sole à petite bouche, sole du Pacifique, sole anglaise, plie à grande bouche, morue charbonnière, merlu du Pacifique, aiguillat commun, goberge de l'Alaska, sébaste à longue mâchoire, sébaste à bouche rouge, sébaste à oeil épineux, sébaste à raie rouge, sébaste argenté, sébaste à queue jaune, sébaste canari, sébaste à dos épineux, sébaste cuivré, sébaste à bouche rouge. Les options de récolte sont des propositions faites aux gestionnaires des pêches de la Division de la haute-mer, Direction des pêches, sur les limites de prises et sur d'autres méthodes de gestion des pêches. Dans ce document, on considère plutôt les facteurs biologiques qu'économiques. Les options de récolte sont de nature quantitative; elles sont fondées sur une série de méthodes mathématiques appropriées, comme l'analyse démographique virtuelle, l'analyse par groupe dynamique et la technique de Fournier de reconstitution du stock. D'autre options concernent la possibilité pour les gestionnaires des pêches d'envisager des récoltes à haut risque et à faible risque selon la capacité de production d'un stock. D'autres options encore, particulièrement dans le cas des sébastes, proposent un choix de solutions de remplacement à l'intention des gestionnaires, quant à savoir si un stock doit être reconstitué, maintenu tel quel, ou réduit par des récoltes temporaires pour faire face aux urgences actuelles d'ordre économique.

Mots clés: poissons de fond, évaluation du stock, récoltes de pêche

1.0 EXECUTIVE COMPENDIUM

This document contains brief summaries of stock conditions of the important groundfish stocks, and recommendations for their management to the Offshore Division of the Fisheries Branch. The report is based on the more extensive report prepared by the staff of the Groundfish Section of the Biological Sciences Branch, located at the Pacific Biological Station, Nanaimo, British Columbia, Canada, V9R 5K6.

Department biologists begin their assessments in the spring of the year using a multi-year data base for fishery statistics and biological research. A variety of assessment models are used including several sequential analysis models, age-independent surplus production models, yield-per-recruit, and linear models. Assessments are completed in August after review by the Groundfish Sub-Committee of the Pacific Stock Assessment Review Committee (PSARC). Review may incorporate outside investigators (government or non-government), where desired by DFO. Recommended yield options are collated and sent to the Offshore Division of Fisheries Branch for consideration.

LIST OF ASSESSMENTS

Assessment texts are presented as species/species group chapters.

Lingcod -- L. J. Richards and C. M. Hand
Pacific cod -- R. P. Foucher and A. V. Tyler
Flatfish -- J. Fargo
Sablefish -- M. W. Saunders, W. Shaw, and G. A. McFarlane
Pacific hake -- M. W. Saunders, W. Shaw and A. Babcock Hollowed
Dogfish -- M. W. Saunders
Walleye pollock -- W. Shaw and M. W. Saunders
Slope rockfish -- B. M. Leaman
Shelf rockfish -- R. D. Stanley
Inshore rockfish -- L. J. Richards

MANAGEMENT POLICY

While management policy is not set by the stock assessment process, a statement on policy as it exists should help to provide the setting to understand the assessments. Policy is set by the managers in consultation with representatives from industry. The analyses conducted by assessment biologists address items of policy, and specific problems brought forward by management and industry.

The overriding objective of the present management approach is to achieve a 10-month trawl fishery. An annual quota is usually set if a stock is considered to be under sufficient fishery pressure to warrant concern. The managers and industry representatives then set quarterly sub-quotas and trip limits so that fishing opportunities are available through most of the calendar year.

In setting the annual catch quota, biologists are first concerned with maintaining a sufficient spawning stock to permit at least reproductive replacement of the capacity to produce. The ultimate goal for this high-volume, commercial fishery is to maximize potential catch in the long term, while taking into account natural long-term trends and year-to-year variation in natural production. When the data to derive these estimates are lacking, quotas are calculated that are least likely to cause a diminshed potential for production in the near future. Managers are usually given a range of yield options, as defined below.

DEFINITIONS OF YIELD OPTIONS

A number of levels of yield options are presented. All may not be appropriate to apply to a particular species or stock. The seven yield options are: (i) zero yield; (ii) rebuilding yield; (iii) sustainable; (iv) low risk-sustainable; (v) high risk-sustainable; (vi) non-sustainable and (vii) unrestricted yield.

(i) Zero yield

This option could be entertained under situations of known and severe stock depletion, or where particular areas may represent necessary refuges for the fish. Additional ecological considerations might include situations where the subject species stock acts as a predator on a less desirable species, and the objective is to maximize predation.

(ii) Rebuilding yield

Under this option the probability of overfishing is minimized while that of rehabilitating depleted stocks is increased. With the exception of option (i), this approach will incur the lowest risk of deleterious effects on stock biomass and dynamics. It is also true that it represents a lower yield than could be taken out of the stock on a sustainable basis. The most common application of this option is for stock rebuilding although for rockfish stocks this should be the approach to developing fisheries, because of the detection, response and corrective time frames (10 - 20 y) for rockfish species.

(iii) Sustainable yield

This option provides some opportunity to maintain stocks at existing levels. In many ways this is the least certain of the options available since it entrains many assumptions about the behaviour of stocks in response to fishing and biological processes. This option should be taken to mean that the probabilities of either decline or increase in yield (biomass) are approximately equal. The term "sustainable" should be understood in its broad sense, i.e., that the stock will oscillate around the expected level as a result of oscillation in recruitment, rather than be maintained at a fixed level. The amplitude and frequency of these oscillations may vary considerably among and within stocks at different levels of biomass. In the simplest terms, this is our best estimate of the highest yield at existing levels of natural production. For a species with low longevity (say under 15 years) due to high natural mortality rate, sustainable yield is usually given in relation to a short period. When the stock is increasing and net natural production rate is high, the annual sustainable yield is calculated as being high. The sustainable yield is that which can be removed from the stock so long as the current natural production rates hold. The average long-term sustainable yield is not very meaningful. For species with a slow turnover and high longevity yield potentials do not change rapidly, and so the annual yield is likely to be the same for many years in a well managed stock.

(iv) Low-risk sustainable yield

Like the Sustainable Option this is an estimate of the tonnage that can be caught during the year and leave enough of the biomass for the stock to replenish itself through reproduction and body growth. However, data are often not as complete as they should be for calculation of a single, firm estimate of the true value of the sustainable yield. When there is a high degree of uncertainity about the estimate, a cautious approach to setting the catch limits should be taken. The cautious or conservative estimate is often set simply as 50% or 75% of the calculated sustainable yield, depending on the biologist's understanding of the reliability of the estimate.

(v) High-risk sustainable yield

This catch limit has some small chance of being a sustainable yield. The estimate is at the other end of the range from the low-risk sustainable yield, and is above the Sustainable yield estimate. The level is often set simply as 25% or 50% higher than the sustainable yield value. Sometimes a central value for the sustainable yield is not given, only the low and high risk levels. Risk levels should only be selected to provide relief from a specific case of economic hardship, with conscious recognition being made that decreases to sustainable levels in the near future might be the result of selecting this option.

(vi) Non-sustainable yield

While the sustainable option is derived from the biological properties of the species and stock composition, the non-sustainable level is largely an economic and management concept. The benefits of increased yield over the short-term must be weighed against the lowered future yields resulting from overfishing. Employment of this option implies either experimental or non-biological management, since stock declines are highly probable with such a policy in effect over a significant part of the average life of a population cohort. This option might be considered when: socio/economic conditions require short-term yields in excess of sustainable harvest; experiments concerning well-defined and disparate exploitation rates are necessary; or, management policy requires sequential, pulsed fishing on several stocks.

The option requires that management will have to shift to a conservative policy to offset deleterious effects prior to major and irreversible stock changes. Thus, this option either guarantees a pulsed exploitation pattern if the stock is to be maintained at the most productive level, or accepts short-term gains over long-term productivity.

The hazard associated with this option will vary with the biological characters of the target stocks. In particular, the residence time of a cohort in the vulnerable stock will be a key determinant in the time for detection and response. Where residency is long, higher than sustainable yields may be maintained over several years in spite of strongly deleterious, yet undetected effects on subsequent cohorts. Conversely, a short residency may permit more rapid detection of adverse effects, although incremental increases in quotas should be small if uncertainty about effects is high.

(vii) Unrestricted yield

Few conditions would call for consideration of this option. Depletion of stocks and elimination of fisheries when harvests are uncontrolled are well documented throughout the world. However, this option might be considered: for experimental purposes; for stock eradication in the case of competing species.

(viii) Other measures

The trawl fishery for groundfish is characterized by a multi-species catch. Managers, biologists, and vessel captains have noted that there are two principal difficulties created because of the multi-species characteristics. (1) Biological interactions among species may interfere with the simultaneous maximization of fisheries potential yield in all co-existing species. (2) Where there are several annual quotas on a group of co-existing species, the species quota that is taken first could close down fishing on the entire group. At present biological interactions are not explicitly built into the stock assessments. This is cause for avoiding the risk-sustainable options if at all possible. On the other hand, regarding problem 2, multi-species yield options are arranged so that premature closure for a whole group of species is unlikely. Trip limits have been used to spread the take of lower production species through the year. In a few cases species-mixture or group quotas are given, and an area not closed until the group quota is reached. Species ratios are checked for imbalance. If a gross imbalance is found, the group quota is adjusted the following year.

DEFINITIONS FOR CATCH STATISTICS

In the past we have used the terminology "Landings" to mean round-weight of fish landed by vessels in port. This has logically led to the term "Landings per unit effort" as an index of catch rate. Because some confusion has resulted from use of these terms, and because other standard terms are used by FAO, ICES, NAFO, as well as most marine fisheries biologists of the Canadian Atlantic community, we have decided to shift to the FAO standard terms starting with this year. In this stock assessment document we have used the terms NOMINAL CATCH and NOMINAL CPUE (or just CPUE) following the FAO definitions.

We take the following definition from the FAO Yearbook of Fishery Statistics: "The concept of NOMINAL CATCH refers to the landings converted to a live weight basis. The closely related concept LANDINGS refers to the quantities on a landed weight basis. ... There are many instances where the catches on board fishing vessels or factory ships are gutted, eviscerated, filleted, salted, dried, etc." Thus, landings come in a variety of forms.

We recognized that whole, or round fish-weight measured in port as nominal catch is not precisely the live weight of the fish as specified in the FAO statistics yearbook. When fish are iced, or refrigerated in chilled brine as is the custon with many vessels of the west coast of Canada, an individual fish takes on a small amount of extra weight due to an increase in water content.

MAJOR FISHERY CONCERNS

Major fishery concerns in the past year relate to the rockfishes. There is a disagreement between fishermen and biologists regarding the size of the standing stocks. The trawler captains believe that the stocks will support more catch than the annual quotas allow. Biologists have pointed out that the stocks are so slow-growing, that a large biomass is necessary in order to maintain the existing catch. There is both demonstrated and high potential risk of over-fishing. The species are very slow-growing and the populations have a slow turnover rate. For example, individuals are 8-15 years old before they spawn for the first time. If a quota is set too high on a trial basis for 5-6 years, and overfishing occurs, it will take 25 to 30 years to repair the stock. Pacific ocean perch and yellowtail rockfish are among the species of concern.

Groundfish research staff have met with the industry's Deep Sea Trawlers Association (DSTA) to try to develop a joint DFO-DSTA rockfish survey. The minimum objective is to form a relative abundance trend series that both industry and fisheries staff will believe. The procedures are in an advanced state of planning, and a plan that is jointly agreeable should be in place within the next few months.

An additional problem which hampers effective management is a lack of formal objectives for each stock, and the fishery as a whole. This results in confusion as to the appropriate management protocols which need to be adopted when dealing with the mixed-species nature of the groundfish fishery, and the often opposing results of alternative actions. More effort is required in the development of stock-by-stock objectives and integration of these objectives into the overall groundfish management plan. The long-term economic tradeoffs of fisheries on short-lived, highly dynamic vs. long-lived, stable species require analysis. The biological assessments produced by this Branch will form only one part of such an analysis. We are increasingly concerned that the biological and economic penalties arising from the lack of a more integrated management plan may be large and result in overall decreases in stock yields. By highlighting these concerns we hope to stimulate the process of developing an improved system.

The recommendations for west coast groundfish for 1987 are summarized below:

Area	Species	Management options
4B	Lingcod	1. Sub-area closures. 2. Add time to winter fishing closure Nov. 15-Apr. 30. 3. Introduce minimum size limit of 58 cm for sport-caught lingcod to protect young.
3C	Lingcod	1. Winter closure Nov. 15-Apr. 30. 2. Low risk-sustainable: 900 t. 3. Sustainable: 1400 t 4. High risk-sustainable: no quota, fishing effort correlated with abundance.
3D, 5A, 5B, 5C, 5D, 5E	Lingcod	No options proposed.
4B	Pacific cod	No options proposed.
3C/3D	Pacific cod	Open fishing due to high abundance.
5A/5B	Pacific cod	No options proposed.
5C/5D	Pacific cod	Open fishing due to high abundance.
5E	Pacific cod	No options proposed.
Coastwide	Petrale sole	1. Sustainable: trip limit 44,000 lb.
4B	Flatfish	No options proposed.
3C/D	Flatfish	No options proposed.

Area	Species	Management options
5A	Rock sole	1. Sustainable: 100 t (30,000 lb trip limit). 2. Non-sustainable: 200 t.
5B	Rock sole	1. Low risk-sustainable: 200 t, 30,000 lb trip limit. 2. High risk-sustainable: 400 t. 3. Non-sustainable: 500 t.
5C	Rock sole	1. Low risk-sustainable: 500 t, 30,000 lb trip limit. 2. High risk-sustainable: 700 t. 3. Non-sustainable: 900 t.
5D	Rock sole	1. Low risk-sustainable: 500 t, 30,000 lb. trip limit. 2. High risk-sustainable: 850 t. 3. Non-sustainable: 1,000 t.
5C/D	English sole	1. Low risk-sustainable: 400 t. 2. High risk-sustainable: 600 t. 3. Non-sustainable: 800 t.
5C/5D/5E	Dover sole	1. Low risk-sustainable: 800 t quota, 20,000 lb/trip permitted after 75% of the quota is reached. 2. High risk-sustainable: 1,000 t quota, 20,000 lb/trip permitted after 75% of the quota is reached.
Coastwide	Sablefish	1. Low risk-sustainable: 2,800 t quota. 2. Sustainable: 3,600 t. 3. High risk-sustainable: 4,500 t quota.
4B, not including MSA 19, 20	Pacific hake	1. Low risk-sustainable: 8,000 t. 2. Sustainable: 11,000 t. 3. High risk-sustainable: 14,000 t.

Area	Species	Management options
3C	Pacific hake	Canadian Zone Quotas 1. Low risk-sustainable: 87,000 t 2. Sustainable: 93,000 t 3. High risk-sustainable: 98,000 t Total Stock Quotas, Canadian and U.S. 1. Low risk-sustainable: 291,000 t 2. Sustainable: 310,000 t 3. High risk-sustainable: 326,000 t
Coastwide (not including 4B)	Dogfish	1. Pulse fishing: variable annual quota until non-nuisance abundance reached. 30,000 t for four years. 2. Low risk-sustainable: 15,000 t in 3rd and 4th quarter of year. 3. Low risk-sustainable alternative: 9,000 t in 1st and 2nd quarter of years only. 4. High risk-sustainable: 25,000 t in 3rd and 4th quarter only. 5. High risk-sustainable alternative: 15,000 t in 1st and 2nd quarter of yearly only.
4B, not including MSA 12, 19, 20.	Dogfish	1. Pulse fishing: variable annual quota, see text. 2. Low risk-sustainable: 2,000 t annual quota. 3. High risk-sustainable: 3,000 t annual quota.
4B	Walleye pollock	1. Low risk-sustainable: 2,500 t quota. 2. High risk-sustainable: 5,400 t quota.
3C/3D	Walleye pollock	Options not proposed.
5A/5B	Walleye pollock	Options not proposed.

Area	Species	Management options	
5C/5D	Walleye pollock	Open fishing option proposed.	
5E	Walleye pollock	Options not proposed.	
Coastwide	Yellowtail rockfish	Low risk-sustainable: High risk-sustainable:	2,000 t. 4,000 t.
3C/3D	Silvergray rockfish	Low risk-sustainable: High risk-sustainable:	400 t 600 t
5A/5B	Silvergray rockfish	Conservative-sustainable: Risk-sustainable:	700 t 1,000 t
5C/5D	Silvergray rockfish	Conservative-sustainable: Risk-sustainable:	500 t 800 t
5E-S	Silvergray rockfish	No recommendation. Currently an incidental fishery.	
5E-N	Silvergray rockfish	No recommendation. Currently an incidental fishery.	
3C/3D	Canary rockfish	Low risk-sustainable: High risk-sustainable:	500 t 700 t
5A/5B	Canary rockfish	Low risk-sustainable: High risk-sustainable:	300 t 500 t
5C/5D	Canary rockfish	Low risk-sustainable: High risk-sustainable:	Unknown 500 t
5E-N/S	Canary rockfish	Low risk-sustainable: High risk-sustainable:	Unknown 500 t

Area	Species	Management options	
3C (Including management Area 125)	Pacific ocean perch	1. Rebuilding: 2. Low risk-sustainable: 3. High risk-sustainable:	<100 t 100 t 200 t
3C	Redstripe rockfish	Low risk-sustainable: High risk-sustainable:	200 t 1,000 t
3D	Pacific ocean perch	Low risk-sustainable: High risk-sustainable:	200 t 600 t
3D/5A	Yellowmouth	Low risk-sustainable: High risk-sustainable:	250 t 750 t
3D/5A	Redstripe	Low risk-sustainable: High risk-sustainable:	350 t 900 t
5A/5B	Pacific ocean perch	Rebuilding: Low risk-sustainable: High risk-sustainable:	<700 t 700 t 1,000 t
5C/5D	Pacific ocean perch	Low risk-sustainable: High risk-sustainable:	1,900 t 3,000 t
5C/5D	Yellowmouth	Low risk-sustainable: High risk-sustainable:	160 t 500 t
5C/5D	Redstripe	Low risk-sustainable: High risk-sustainable:	350 t 570 t
5E-S	Pacific ocean perch	Low risk-sustainable: High risk-sustainable:	300 t 500 t
5E-S	Yellowmouth	Low risk-sustainable: High risk-sustainable:	400 t 700 t
5E-S	Rougheye	Low risk-sustainable: High risk-sustainable:	200 t 300 t

Area	Species	Management options	
5E-S	Grouped slope rockfish (Pacific ocean perch, yellow-mouth and rougheye)	<u>January-June</u>	
		Low risk-sustainable:	300 t
		High risk sustainable:	500 t
		<u>September-December</u>	
		Low risk-sustainable:	600 t
		High risk-sustainable:	1,000 t
5E-S	Redstripe	Low risk-sustainable:	50 t
		High risk-sustainable:	100 t
5E-N	Pacific ocean perch	Low risk-sustainable:	150 t
		High risk-sustainable:	170 t
5E-N	Yellowmouth	Low risk-sustainable:	350 t
		High risk-sustainable:	500 t
5E-N	Rougheye	Low risk-sustainable:	50 t
		High risk-sustainable:	100 t
5E-N	Redstripe	Low risk-sustainable:	500 t
		High risk-sustainable:	700 t
4B-MSA-12	Copper/ Quillback	Low risk-sustainable:	75 t
		High risk sustainable:	150 t
4B-MSA-13	Copper/ Quillback	Low risk-sustainable:	50 t
		High risk-sustainable:	100 t
4B-MSA-14-20, 28,29	Copper/ Quillback	Low risk-sustainable:	150 t
		High risk-sustainable:	250 t
4B	Yelloweye	Low risk-sustainable:	50 t
		High risk-sustainable:	100 t
3C/D	Grouped line rockfish	Low risk-sustainable:	60 t
		High risk-sustainable:	750 t

Area	Species	Management options	
5A/B/C/D/E	Grouped line rockfish	Low risk-sustainable: High risk-sustainable:	120 t 870 t

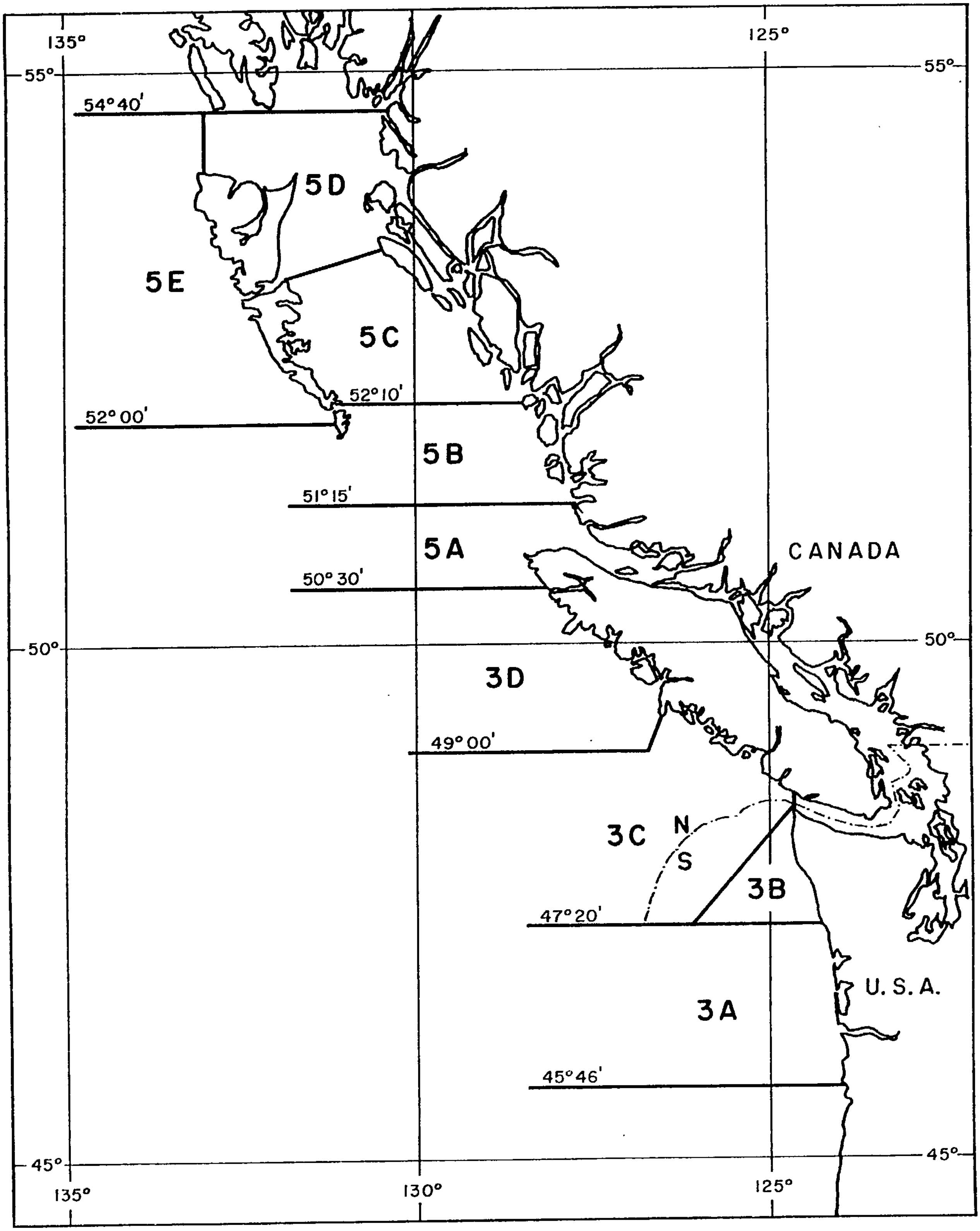

Fig. 1.1 International (Pacific Marine Fisheries Commission) Major Statistical Areas along the British Columbia coast.

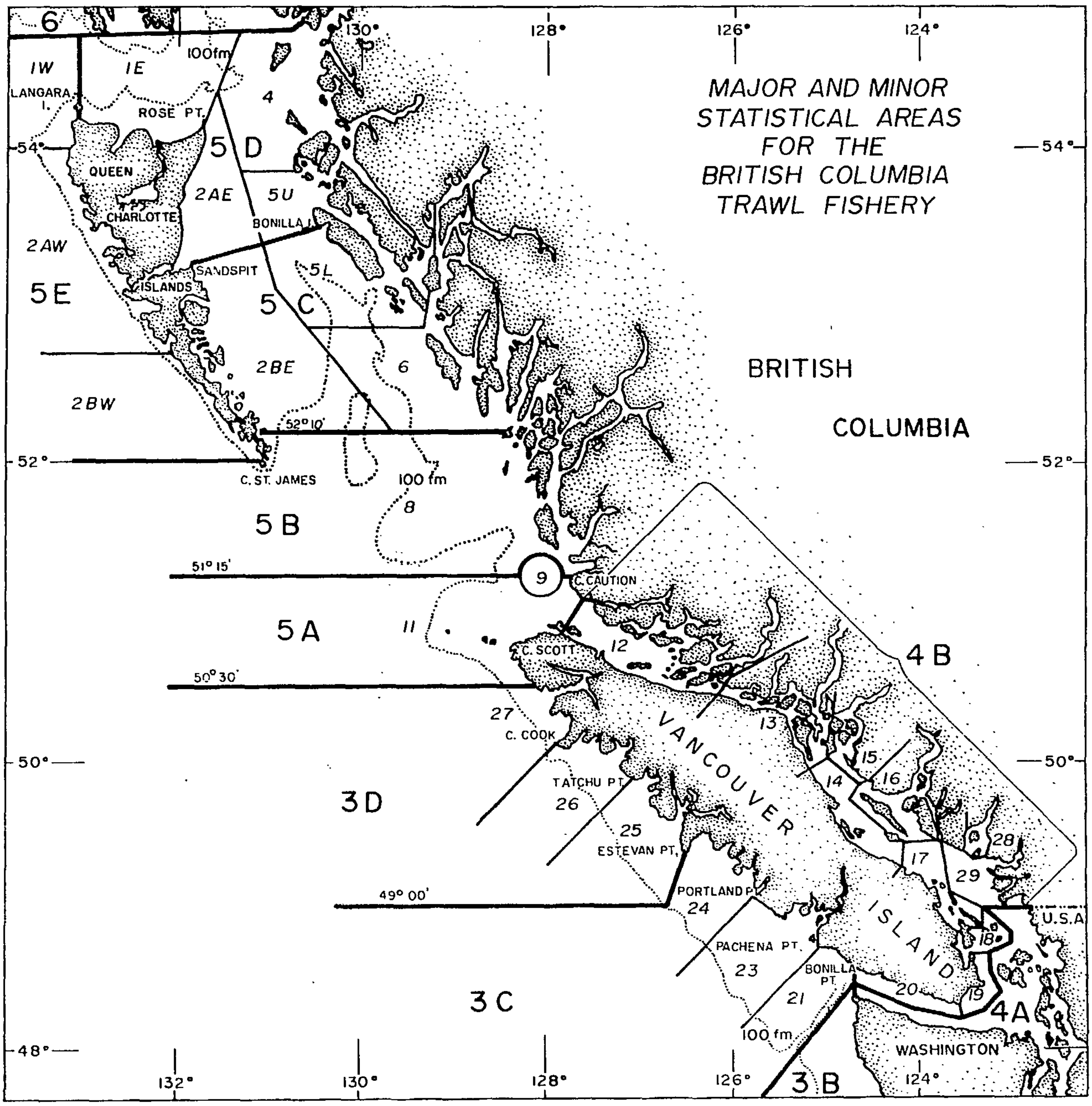

Fig. 1.2. International (Pacific Marine Fisheries Commission) Major and Minor Statistical Areas along the British Columbia coast.

SUMMARY OF STOCK CONDITIONS AND YIELD OPTIONS

Views on current condition of groundfish species/species groups on the west coast of Canada.

Species or species group	Current stock condition
Strait of Georgia lingcod	Low
Offshore lingcod	Average
Pacific cod	High
Petrale sole	Low
Rock sole, English sole, Dover sole, arrowtooth flounder	Average to high
Sablefish	Average
Pacific hake	High
Spiny dogfish	Average to high
Walleye pollock	Low to average
Slope rockfish	Low to average
Shelf rockfish	Average
Inshore rockfish	Low to average

TEXT SUMMARY OF YIELD OPTIONS

LINGCOD - AREA 4B STRAIT OF GEORGIA

Yield Options

Whatever the cause of the decline, it is apparent that lingcod stocks in the Strait of Georgia cannot sustain current levels of exploitation. As the sport fishery now takes a greater share of the catch, the management strategy must involve both sport and commercial fisheries. Three management options are proposed. A combination of these options may provide the best management strategy.

(A) Closures of areas or subareas to reduce catch and fishing effort. As lingcod are relatively sedentary and probably recruit from localized areas, closure of areas should help to rebuild stocks in that area. A closure has been implemented in 1988 near Campbell River, but applies to the commercial fishery only. As the sport fishery now takes a greater share of the catch, closures must apply to both sport and commercial fisheries to be effective. Ideally, there should be several closed areas in different parts of the coast. These could be developed as experimental management areas, and the sport fishing community could be involved in assessing the impact of the closures. As lingcod are fast-growing, the benefits of closed areas might be more readily measured for lingcod than for other fishes such as rockfish.

(B) A further extension of the winter spawning closure. This is a modification of Option A, in that all areas are closed for a period of time instead of a complete closure for selected areas. This option may not be as effective as (A). A winter closure has been in place for many years and has not been sufficient to halt the decline in stock abundance.

(C) A size limit of 58 cm for the sport fishery. This is the size limit in effect for the commercial fishery. At present, the sport fishery takes a high proportion of immature fish, and a size limit would increase the probability that fish spawn at least once before they are caught. A size limit is a reasonable option for lingcod. Although there have been no studies to examine release mortality, lingcod survival has been high in tagging studies. Further, the survival of lingcod is high for fish above the suggested size limit.

Between 1983-87, 67% of the number of fish caught were less than 58 cm in length, but this corresponds to only 42% of the biomass caught (Fig. 2.4). Although a size limit will initially reduce the number of fish caught in the sport fishery, it should increase the yield, or the weight of the catch over the longer term. This would make it possible to promote lingcod as a trophy fish. A size limit of 56 cm has been imposed in Puget Sound and anglers in Puget Sound favor a size limit to increase the chance of catching a trophy fish (Bargmann 1983). The Puget Sound study showed that a minimum size limit is more effective in increasing the number of large spawning fish than a maximum size limit.

LINGCOD - AREA 3C - SW VANCOUVER ISLAND

Yield Options

Because of the risk of stock collapse, it is recommended that a quota on the Area 3C stock be maintained while abundance is low. The low risk option is 900 t, the sustainable option is 1400 t, and the high risk option is unlimited yield. These options will be re-evaluated after studies are conducted on stock distribution. Due to the possible decrease in recruitment, it is also recommended that the winter fishing closure (Nov. 15-Apr. 30) be maintained to protect nesting lingcod. Yield options are not proposed for Area 3D.

PACIFIC COD - AREA 3C - SW VANCOUVER ISLAND

Yield Options

With the stock appearing to be strong it does not appear necessary to impose a spawning-season closure for the first quarter of 1989 as has been done in recent years.

PACIFIC COD - AREA 5C/5D

Yield Options

The recommendation last year was that there be no quota or other restrictions to the fishery. The CPUE in 1986 was the highest for the previous ten years and in 1987 increased again, by 177% over 1986 levels due to the strong 1985 and 1986 year classes entering the fishery. These year-classes are contributing strongly to the 1988 fishery and their effects should still be felt in 1989. Mortality rates are such, however, that by the 1990 fishery there will be little significant contribution from the 1985 year-class. We again recommend no quota for the 1989 fishing year.

PETRALE SOLE - COASTWIDE

Yield Options

The yield options presented here are based on a "short term" equilibrium situation. Refer to Section 4.0.1. for an explanation of this.

(1) sustainable option: A 44,000 lb trip limit regulation for petrale sole from January 1-March 31 is in effect, coastwide. The

January-March period corresponds to the spawning time for petrale sole, a period when these stocks are particularly vulnerable to exploitation. This regulation is the result of a request by industry aimed at reducing a target fishery on petrale sole while stocks are depressed. Recently, some members of industry have presented arguments against a "coastwide" trip limit for this species, particularly in light of catches of petrale sole in the free-fishing area north of 54 degrees latitude. At present we have no evidence that the petrale sole in the northern portion of Area 5E are part of the "northern" or "southern" stocks. In fact, available evidence indicates that a number of discrete stocks of petrale sole exist along the Pacific coast (Ketchen and Forrester 1966, Pederson 1975b). Thus the trip limit for petrale sole could be considered applicable only to the west coast of Vancouver Island. However, area trip limits for individual species have created enforcement problems in the past.

(2) High risk sustainable option: Previous analyses have all indicated that petrale sole stock size has no effect on year-class production for the species and the trip limit should be removed and free-fishing allowed. As a caveat to this option, all previous analyses concerning stock and recruitment for the species were conducted when petrale sole stocks were at significantly higher levels of abundance than they are at present.

ROCKSOLE - AREA 5A - SOUTH QUEEN CHARLOTTE SOUND

Yield Options

The yield options presented here are based on a "short-term" equilibrium situation.

Sustainable Yield option: A yield of 100 t is considered to be sustainable for the current stock level and low recruitment mode. The 30,000 lb trip limit regulation is consistent with this option.

Non-sustainable Yield option: Yields of 200 t are considered to be non-sustainable at this time. This is assuming that recruitment to the stock will not increase significantly in the next year.

ROCKSOLE - AREA 5B - NORTH QUEEN CHARLOTTE SOUND

Yield Options

The yield options presented here are based on a "short-term" equilibrium situation.

Low risk sustainable yield option: A yield of 200 t is considered to be sustainable for the Area 5B stock. The 30,000 lb trip limit currently in effect for Queen Charlotte Sound is consistent with this option.

High risk sustainable option: Yields of 400 t could be sustained with a significant increase in recruitment. However, the size of the recruiting year-classes cannot be accurately determined at this time.

Non-sustainable yield option: Based on trends in CPUE, yields of 500 t can be considered to be non-sustainable for the stock.

ROCKSOLE - AREA 5C - SOUTH HECATE SOUND

Yield Options

The yield options presented here are based on a "short-term" equilibrium situation.

Low risk sustainable yield option -- The sustainable yield with recruitment at above average levels in the past has ranged between 500 and 1000 t for the Area 5C stock. A yield of 500 t is equivalent to the average yield sustained during the late 1970s recruitment surge for the stock. A trip limit of 30,000 lbs is consistent with this option.

High risk sustainable yield option -- A yield of 700 t could be sustained if the current recruitment level is mid-way between 1970s and 1960s levels. The exact level of recruitment cannot be determined at this time and 700 t can be considered to constitute a high risk for the stock until additional years' data are analyzed.

Non-sustainable option -- Yields of 900 t have not been observed for the Area 5C stock since the mid-late 1960s. Both the stock size and recruitment at that time were higher than they are currently, based on analysis of standardized CPUE and length frequency data. Also, the current recruiting year-classes have not had time to make a significant reproductive contribution to the stock. This contribution may be important to stability in the long term for the stock. For these reasons, yields of 900t are considered to be non-sustainable at this time.

ROCKSOLE - AREA 5D - NORTH HECATE STRAIT

Yield Options

The yield options presented here are based on a "short-term" equilibrium situation.

Low risk sustainable yield option -- CPUE increased significantly in 1987. This increase is due, presumably, to an increase in recruitment. Yields of 500-1200 t were sustained in the past, depending on the size of recruiting year-classes. The current recruitment is intermediate in strength. Therefore, 500 t would be a low risk take from the stock. The 30,000 lb trip regulation currently in effect for rock sole in Hecate Strait is consistent with this option.

High risk sustainable yield option -- If the current level of recruitment is intermediate in strength to that of the 60s and 70s, yields of 850 t annually would be sustainable. However, the size of the recruiting year-class(es) cannot be accurately determined at this time. Therefore 850 t is considered to be a high risk for the stock.

Non sustainable yield option -- Yields of over 1000 t have only occurred during one period in the past when several consecutive strong year-classes were produced. VPA results suggest excessive exploitation rates during this period (mid 1960s). The current stock size is lower than in the mid 1960s as indicated by CPUE. Therefore, yields of 1000 t are considered to be non-sustainable for the Area 5D stock at this time.

ENGLISH SOLE - AREA 5D - NORTH HECATE STRAIT

Yield Options

The yield options presented here are based on a "short-term" equilibrium situation.

Low risk sustainable yield option -- Yields of 400 t are sustainable with recruitment at low levels. This is based on CPUE trends for the Area 5D English sole stock.

High risk sustainable yield option -- Yields of 600t have been sustainable with recruitment at average levels in the past and CPUE trends have remained fairly stable with yields at this level. However length composition for the stock indicates some signs of juvenation with removals near this level for 3 of the last 4 years. Therefore, the risk of recruitment overfishing for the stock is assumed to be a possibility with yields at this level.

Non-sustainable yield option -- Analysis of CPUE and yield simulations indicate that yields of 800 t are possible for short periods if recruitment is at high levels and age composition for the stock is not truncated. Recruitment is currently not high and indications are that the proportion of older fish in the stock has decreased, at least since the early 1980s. Therefore, yields of 800 t are deemed to be non-sustainable for the Area 5D English sole stock at this time.

DOVER SOLE - AREA 5C/5D/5E - HECATE STRAIT/DIXON ENTRANCE

Yield Options

The yield options presented here are based on a "long-term" equilibrium situation.

Low risk sustainable option -- The analysis estimates MSY at 800 t for the Area 5CDE Dover sole stock. However, the rising trend in CPUE with removals of 800 t over the last several years indicates that the true MSY may well be higher than 800 t. Therefore, 800 t is recommended as the low risk option.

High risk sustainable option -- With effort at an optimum level and CPUE at 1987 levels, a catch of 1165 t would be observed. An estimate of 1000 t is therefore provided as a high risk option for sustainable yield.

SABLEFISH - COASTWIDE

Yield Options

Risk in the yield options below is a function of the uncertainty regarding recruitment. There exists a strong possibility that the high-risk level may interfere with the future yield.

Given a commitment to optimizing return from the existing stock, the following levels are appropriate from variable catch simulations. Again, risk is associated with the uncertainty regarding appropriate recruitment levels from 1985 to the present.

Sustainable - low risk	-	2,800 t
Sustainable	-	3,600 t
Sustainable - high risk	-	4,500 t

PACIFIC HAKE - AREA 4B - STRAIT OF GEORGIA
(Not including Minor Areas 19, 20)

Yield Option

The risk associated with the harvest levels results from the inability to predict the strength of incoming year-classes. The three levels of harvest presented are capable of sustaining a spawning stock biomass assuming low, average and high recruitment respectively. Higher risk implies a greater likelihood of depleting the stock below a critical spawner biomass in the event of poor recruitment.

Constant yield	- Low risk sustainable	- 8000 t
	- Sustainable	- 11000 t
	- High risk sustainable	- 14000 t

PACIFIC HAKE - AREA 3C - OFFSHORE, SW VANCOUVER ISLAND

Yield Option

The yield options for the Canadian fishery are presented below with associated coastwide quotas in brackets. The Canada-U.S. split is based on the proportion of exploitable biomass in the Vancouver INPFC area. The proportion has ranged from 22.2 to 41.1 over the period 1977 to 1986, hence are mean value of 30% was applied to the coastwide quotas to arrive at the Canadian allocation. It is recognized that the Vancouver INPFC area includes a small portion of the U.S. zone, however, movement and exchange of fish in the transboundary area is believed to be considerable and variable from year to year.

Risk reflects uncertainty in the assessment in particular with respect to weight-at-age. At higher yield levels the probability of seriously affecting the spawning biomass and hence stock collapse is greater. The options presented below have been derived using the variable effort scenario, stochastic recruitment, and the variable recruitment estimate. The range results from the two possible weight-at-age scenarios and the sustainable level chosen as the mean of the high and low risk levels.

Low risk sustainable	- 87 (291) thousand t
Sustainable	- 93 (310) thousand t
High risk sustainable	- 98 (326) thousand t

DOGFISH - COASTWIDE

Yield Option

Possible options include sustained yield, pulse fishing and a variable catch no-nuisance strategy.

A sustained yield fishery will produce oscillations in abundance but they will decrease in amplitude with time. Hence this strategy provides a steady supply while maintaining a stock size lower than present levels. For removals from the offshore stock, including Alaska, British Columbia, Washington, Oregon, and California waters, up to 15,000 t may be considered low risk sustainable and from 15,000 to 25,000 t high risk sustainable assuming an equal sex ratio. If a first and second quarter fishery is to be sustained then yields up to 9,000 t are low risk while 9 to 14,000 t yields are high risk.

The ranges in levels presented are a reflection of the uncertainty surrounding estimates of starting stock size and the degree of compensatory mortality used in forward simulations. At risk is the collapse of the spawning stock.

Industry has expressed concern over the high abundance of dogfish, which is viewed as a nuisance, and has asked if it is possible to maintain the population at below nuisance levels while continuing to support a directed domestic fishery.

One of the control options proposed is periodic or pulse fishing which is the removal of large quantities of fish at a specific time interval. The biomass of marketable stock is capable of rebuilding to present levels within 3-4 years of removing 30,000 t and within 10 years of removing an unattainable figure of 210,000 t. The large removal accentuates and perpetuates the pulse in abundance introduced by the 1940s liver fishery. The extreme variation in abundance resulting from a pulse fishery is further illustrated by Figure 7.2 (Saunders 1986, p. 49), a forward simulation of marketable biomass with catches of 60,000 t taken every fifth year. While 60,000 t removals keep the population below the present level for 10 years, over the ensuing 25 years the stock fluctuates to well above present levels and to well below a level where commercial fishing is likely to be viable. The point when fishing is assumed to be non-viable is at, or below, the level of the predicted biomass in 1950, at the end of the liver fishery when, as a result of heavy fishing pressure the abundance decreased to a level where fishing success was poor.

An alternative approach, entitled variable catch/no nuisance option, is to fish intensively for several years until the stock is below nuisance levels and then regulate catch to remove more fish in years when recruitment is high from the liver fishery pulse and vice versa when recruitment is decreasing. Initial catches of 30,000 t for the first four years will lower the stock rapidly and catches thereafter ranging from 8,000 to 25,000 t per year will maintain a relatively stable stock size.

At current catch rates, the trawl effort required to catch the maximum tonnages involved is equivalent to the effort expended in a year by the entire groundfish trawl fleet on all species. One possible way to obtain sufficient effort is to establish a joint venture fishery to remove the difference of the yearly catch that domestic markets cannot utilize.

All options refer to coastwide (including U.S.) removals and no provision has been made for adjusting Canadian catches in the event of increased U.S. catch.

Yield option 1: Sustained yield, no 1st and 2nd quarter fishery
- low risk < 15,000 t
- high risk 15-25,000 t

Yield option 2: Sustained yield - first and second quarter fishery, only.
- low risk < 9000 t
- high risk 9-15,000 t

Yield option 3: Pulse fishing.

Yield option 4: Variable catch/no nuisance

DOGFISH - AREA 4B - STRAIT OF GEORGIA
(Not including Minor Areas 19, 20)

Yield Option

Dogfish may be harvested on a sustained or periodic fishery basis. The reader is referred to section 7.1.4 for a discussion of the implications of pulse fishing and variable catch/no nuisance strategies.

Over the long term, removals from the Strait of Georgia-Puget Sound stock that are in the range of 4000 to 6000 t may be considered low-risk sustainable, while removals in excess of 6000 t are considered high-risk sustainable. Assuming an even split in biomass between the Strait of Georgia and Puget Sound, 2000-3000 t is considered low-risk and > 3000 t is considered high-risk for the Strait of Georgia.

Again this range is a reflection of the uncertainty surrounding estimates of starting stock size and the degree of compensatory mortality used in forward simulations.

Yield option 1: Sustained yield - low-risk - 2000 - 3000 t
Yield option 2: Sustained yield - high-risk - > 3000 t
Yield option 3: Pulse fishing
Yield option 4: Variable catch/no nuisance

WALLEYE POLLOCK - AREA 4B - STRAIT OF GEORGIA

Yield Options

The conservative level is based on the lower level of unexploited biomass (15,800 t), a natural mortality of M=0.5, and a constant (a) value of 0.3. The high risk level is based on a midpoint of the biomass estimate (22,600 t), a midpoint in the natural mortality estimate M=0.6 and a constant value of a=0.4, which Gulland (1983) indicated as a realistic value for gadid-like species.

Yield options may be chosen from:

Yield option 1: Conservative sustainable - 2500 t
Yield option 2: Risk sustainable - 5400 t

PACIFIC OCEAN PERCH - AREA 3C - SW VANCOUVER ISLAND

Yield Option

The *S. alutus* stock off southwest Vancouver Island remains in poor condition. Equilibrium yield estimates (≈70-200 t) remain as calculated in the 1987 assessment (Table 9.1). The upper end of this range is probably not sustainable in view of the generally poor recruitment expected over the next 5-8 y. Rehabilitation of this stock to its most productive level should not be expected within the next decade, even with very low fishing mortality, although this process would be enhanced if the 1976 cohort were allowed to contribute maximally to stock biomass and reproduction.

PACIFIC OCEAN PERCH - AREA 3D - NW VANCOUVER ISLAND

Yield Option

The catch history of *S. alutus* in Area 3D suggests that the historical fishery, although it has been brief, has been able to sustain removals of ≈250 t/y. The intense *S. alutus* fisheries of the mid-1960s found no significant quantities of fish in Area 3D, hence the virgin biomass must have been considerably less than those of either Queen Charlotte Sound (≈80,000 t) or southwest Vancouver Island (≈68,000 t). If the biomass was in the 10,000-30,000 t range, then long-term sustainable yield might be ≈200-600 t.

PACIFIC OCEAN PERCH - AREA 5A - GOOSE ISLAND GULLY

Yield Option

As with all rockfish stocks, the dynamics of the Goose Island Gully stock of *S. alutus* are relatively slow and rehabilitative management actions of even large measure have little impact over the short term. Previous work has shown that, with the exception of complete closure, there are relatively small differences in the periods of rehabilitation between F=0.0-0.05. However, increased yields in the future could be realized if fishing mortality on the stocks was decreased (i.e. F<0.06). The timetable of reconstruction at various levels of fishing mortality has been outlined previously (Archibald et al. 1983).

While there may be some uncertainty about the exact level of stock biomass in 1988, the values of F associated with long term maximum yield are relatively well determined (F≈0.06). Present stock biomass is estimated to be in the range of 8000-13000 t, suggested by the simulations using the 1985 and 1977 age compositions, respectively. Yields from these biomasses are dependent on the choice of management policy and have been outlined in previous assessments (Table 9.1, Archibald et al. 1983, Leaman 1985). For example only, yields at F=0.06 would range, including the contribution of the Mitchell's Gully component of the stock, from ≈700-1000 t. Yields at this level of F are not predicted to produce rehabilitation of the stocks. If management considers maximum available yield and a balanced sex ratio to be desirable management goals then a winter fishery, with its female bias, would reduce available yield relative to an unbiased summer fishery.

PACIFIC OCEAN PERCH - AREA 5C - MORESBY GULLY

Yield Options

In 1987, an internal Groundfish Section review of the Moresby Gully *S. alutus* assessment stated that considerably greater yield (3500 t) than was previously identified (2000 t) could be taken from the stock. The present assessment indicates that concerns previously expressed about the condition of the stock, on the basis of catch statistics and general life history, should be heeded. While there has been no change in the primary assessment for 1988, the high-risk yield (3000 t) is based on the alternative 1987 review. The low-risk sustainable yield is estimated as 1900 t (Table 9.1). Management is cautioned that the long delay to full recruitment of a cohort renders most measures of stock status insensitive during the early stages (5-10 y) of rockfish fisheries. When declines such as those noted for this stock are observed, their import should be even greater.

PACIFIC OCEAN PERCH - AREA 5E-S - WEST QUEEN CHARLOTTE ISLAND

Yield Option

The continued decline of catch in 1987-1988 and the mortality rate estimated from size frequency analysis endorse the concerns previously expressed. A reduction of the estimated yield from this stock is therefore presented for 1989; sustainable yield is estimated to range from 300-500 t.

PACIFIC OCEAN PERCH - AREA 5E-N - WEST QUEEN CHARLOTTE ISLAND

Yield Option

Yields of *S. alutus* in the order of 2000 t/y appear to have generated total mortality rates in the 0.6-0.7 range. If these figures are correct, then sustainable yields should be in the range of 140-170 t. The upper limits of sustainability are unlikely to be more than twice this figure, and may be less if stock biomass has been reduced below levels giving rise to observed mortality rates. Similar calculations were applied to the average yield of 300 t/y for S. aleutianus. Yield options for S. reedi and S. proriger are simply guideline figures based on Francis' (1986) observations concerning the relationship between initial and long-term yields (see Section 9.5.1.3). Hence, sustainable yields are estimated to be ≈350-500 t and 500-700 t, respectively. A cautionary note concerning the potential yield from these two species should be added. Both species were recorded by observers in catches by Japanese trawlers during 1977 (Leaman et al. 1978). The exact exploitation history for these species is therefore uncertain and yields identified here as those of initial fisheries may overestimate long-term yield, when used in this fashion. Characteristics of these two species in this area will bear careful scrutiny in the future.

The open-fishery component of this experiment was originally proposed to terminate at the end of 1987 and be followed by a second phase, where the process of stock rebuilding at low or no fishing mortality could be initiated. The results of the second phase will be used to provide guidance on management policies for this and other rockfish stocks. Management chose to continue the open-fishery portion of the experiment in 1988, to provide further evidence of the negative effects of unrestricted fishing. The decline in stock biomass and the deterioration of all stock status indices as a result of the open fishery have been well demonstrated (Leaman 1988). Incremental scientific benefits from continued open fishing are expected to be very small.

REDSTRIPE ROCKFISH - AREA 3C

Yield Options

The sustainable yield (Table 9.1) for S. proriger in Area 3C is estimated to range from 200-1000 t (Leaman 1988). In the absence of detailed analysis, but recognizing the biological affiliation of the species and rockfish exploitation histories, it would be prudent to maintain yield at ≤500 t for a period sufficiently long to evaluate its suitability (5 y).

REDSTRIPE ROCKFISH - AREAS 3D/5A

Yield Options

The yield options for S. proriger in Area 3D/5A are based on published work (Francis 1986) relating initial yields from fisheries to their ultimate long-term yields. Francis estimated that these latter yields seldom exceed 200-300% of initial yields. The average yield from the first six years of the fishery was approx. 350 t and this may be used as a lower estimate of sustainable yield (Table 9.1). The upper limit would then be estimated at approx. 900 t (i.e., 250% of 350 t). Stability of quotas over the next 3-5 y may assist in the evaluation of their validity.

REDSTRIPE ROCKFISH - AREAS 5C/5D

Yield Options

Yield from the Moresby Gully stock of S. proriger cannot be determined analytically. In the absence of any adverse indications from the limited available data, we assume that the minimum historical landings can be sustained. Indeed, the large stock of S. alutus in this area may infer a relatively large stock of S. proriger, based on analysis of historical patterns of association between these species (Leaman and Nagtegaal 1987). The catch proportion ratio from that analysis (0.217) implies a yield range of ≈350-570 t for S. proriger in Moresby Gully (Table 9.1).

REDSTRIPE ROCKFISH - AREA 5E-S - WEST QUEEN CHARLOTTE ISLAND

Yield Option

In the previous assessment we suggested that the present level of landings (600 t/y) was unlikely to be sustainable. Cluster analysis of landings from this area (Leaman and Nagtegaal 1987) suggested that the normal catch ratio of S. proriger to S. alutus was ≈0.217. Based on the yield options identified for S. alutus (Table 9.1), the estimated level of sustainable yield for S. proriger is in the 60-100 t range. These figures may be conservative if the landing patterns, upon which the catch ratio is based, do not accurately reflect the catch of S. proriger. There has been no evidence of such market limitations in recent years, although they may have been operative in the late 1970s.

YELLOWMOUTH ROCKFISH - AREAS 3D/5A - NW VANCOUVER ISLAND

Yield Options

The stock of S. reedi in the 3D/5A area has apparently sustained removals of ≈200-250 t/y by the domestic fishery. The previous catch history by foreign vessels is less certain due to species designation problems (Leaman et al. 1978). While the upper limit of sustainable yield is unknown, at this time, it would be prudent to approach the expansion of this fishery in a staged manner. Experience in other rockfish fisheries (Gunderson 1984, Francis 1986) suggests that yields in excess of 200-300% of the initial yields from such fisheries are seldom sustainable. Accordingly, the estimated upper limit for the sustainable yield option from this stock is ≈400-750 t (Table 9.1).

YELLOWMOUTH ROCKFISH - AREA 5C - MORESBY GULLY

Yield Options

The long-term average harvest from this stock (≈160 t) is assumed to be a lower limit of sustainable yield (Table 9.1). There is little to guide the determination of an upper estimate; we will use the percentage of initial catch criterion, i.e. 200-300% of initial harvests represents a non-sustainable level (Francis 1986, Gunderson 1984). The upper limit is therefore estimated to be ≈500 t.

YELLOWMOUTH ROCKFISH - AREA 5E-S - WEST QUEEN CHARLOTTE ISLAND

Yield Option

Yield options for the *S. reedi* stock in Area 5E(S) remain approximately the same as in 1987, although the range of values in Table 9.1 reflects the uncertainty associated with this assessment. Sustainable yield is estimated to range from 400-700 t.

ROUGHEYE ROCKFISH - AREAS 5E-S - WEST QUEEN CHARLOTTE ISLAND

Yield Option

The estimated yield options for the *S. aleutianus* stock in Area 5E(S) reflect the uncertainty of our assessment (Table 9.1), although the generally low level of available yield from the area is recognized. Sustainable yield is estimated to range from 200-300 t.

YELLOWTAIL ROCKFISH - COASTWIDE

Yield Option

Without consistent trends of declining size or catch rates, there is no sign of growth overfishing. The mean landings for the preceding 20 years, 2360 t, represent a minimum estimate of the sustainable yield. We suggest that the U.S. recommendation of a combined yield of 4000 t for the Oregon, Washington, and southern B.C. coasts serve temporarily as a high-risk estimate for the traditional south and central grounds of B.C. waters. We remind managers that the offshore hake fishery produces a significant incidental catch of yellowtail rockfish.

SILVERGRAY ROCKFISH - AREA 3C/3D - WEST VANCOUVER ISLAND

Yield Option

The fishery seems to be focussing on a new pulse of recruitment with no indication yet of whether there are strong year-classes to follow. The 20-year mean harvest of 523 t remains our minimum estimate yield. However, if catch rates should fall or if the age distribution that is observed in our 1988 survey is more truncated and indicates a higher Z, then we will recommend lower harvests for coming years. Owing to the lower estimates of Z in this assessment, we are less concerned about the stock but still see no evidence to suggest that the stock can support a sustained harvest significantly in excess of historical removals. We recommend a yield range of 400-600 t for Area 3C + 3D.

CANARY ROCKFISH - AREA 3C/3D

Yield Option

The continued decline in catch rates is a growing concern and argues whether a yield in excess of the long-term average of 714 t can be sustained. While the changes continue to be viewed as "natural" variation in abundance or availability rather than as evidence for over-exploitation, should the declines continue managers might be advised to consider more conservative yields. A yield of less than two-thirds of the historical yield would be viewed as conservative. Owing to the continued decline in catch rates, the recommended yield range is 500-700 t, down from the sum of the Area-specific ranges recommended for 1988 of 700-1,000 t.

Combined Yield Option for Silvergray and Canary Rockfish for Areas 3C + 3D.

Managers may wish to combine quotas for the two species in Areas 3C + 3D. The annual catch ratio of silvergray to canary rockfish has been 0.87, 1.51 and 1.02 over the last three full years. The ratio of the midpoints of the yield ranges is approximately 0.58. Consequently, a combined quota will be a choice between an underage of canary rockfish or an overage of silvergrey rockfish landings.

SILVERGRAY ROCKFISH - AREAS 5A + 5B - QUEEN CHARLOTTE SOUND

Yield Option

The increasing catch rate indicates that the average of annual landings over the last 20 years can be considered a minimum estimate of sustainable yield. Managers may wish to maintain a harvest in excess of the average value of 679 t. We recommend a harvest range of 700-1000 t. Choice of the upper range would allow managers to experimentally increase harvest by almost 50% in comparison with the previous 20 years. However, managers are advised that there is no evidence to suggest that this stock can sustain this level of harvest.

CANARY ROCKFISH - AREAS 5A/5B - QUEEN CHARLOTTE SOUND

Yield Option

The increased catch rate in 1987 is a positive sign but viewed for the present as a short-term increase in availability. The chronically low nominal catch rates (0.25-0.44 t/hr) from grounds that have been extensively fished for a variety of species for over 30 years suggests that there is a relatively small biomass, probably not capable of supporting significantly more yield than the historical average of 357 t.

This level continues to be a minimum estimate of sustainable yield. Managers may wish to choose a yield option a modest amount higher. We recommend a yield range of 350-500 t.

Combined yield option for silvergray and canary rockfish

The catch ratios of silvergray to canary rockfish over the last three years, 2.23, 2.67 and 2.45, have been close to 2.00, the ratio of the midpoints of the recommended yield ranges. A combined quota will probably result in a slightly higher proportion of silvergray rockfish in the catches than might be desired.

SILVERGRAY ROCKFISH - AREA 5C/5D - HECATE STRAIT

Yield Options

The sustainable yield option was raised from 300 to 600 t in 1983, prior to any effective quota restrictions, under the suspicion that a significant biomass might be present. We suggested that the option be maintained at that level for 3-5 years while monitoring for signs of the fishery's impact.

The one sample of older fish tends to contradict the recent decline in catch rate therefore it cannot be demonstrated that the mean harvest of 518 t since 1977 has had a significant impact. We assume therefore that 518 t is a minimum estimate of the sustainable yield. Managers may continue to permit yields significantly in excess of this level, however the short-term decline in CPUE is a source of concern and, because of this, the recommended yield range of 400-1000 t, suggested in the last assessment, is changed to 500-800 t. We suggest that a harvest of 800 t annually be considered as a high risk yield.

SILVERGRAY ROCKFISH - AREA 5E - WEST QUEEN CHARLOTTE ISLAND

Yield Option

In spite of the declining catch rates, managers may choose not to impose any landing restrictions. The fishery is largely incidental to slope rockfish fishing, so trip limits will not reduce catches, only increase the amount of discarding. If the trend in catch rates is indicative of a decline in stock biomass, it provides managers with some insight as to the productivity of this species.

INSHORE ROCKFISH - AREA 4B - STRAIT OF GEORGIA

Yield Options

Yield options for the inshore rockfish assemblage, excluding yelloweye rockfish, are derived from the historical rockfish catch. It is assumed that increments of 25 t are the minimum that can be managed in a statistical area. A 75-t quota is listed as low risk for Area 12 and sustainable for area 13 because of the depletion that has already occurred in area 13. The option for the other areas is equivalent to the 1986 catch. The high risk-sustainable option for yelloweye rockfish is based on the 1987 red snapper catch. The 1987 catch is considered high risk-sustainable, as the stock currently shows sign of depletion.

Yield option	Other rockfish			Yelloweye
	Area 12	13	14-20, 28,29	Area 4B
low risk-sustainable	75 t	50 t	150 t	50 t
sustainable	100 t	75 t	200 t	75 t
high risk-sustainable	150 t	100 t	250 t	100 t

These yield options are intended to act as guidelines for managers, and not to imply that management by quota is the best strategy. The winter closure in 1987 was apparently effective in reducing the catch by approximately 25%. There were also serious conflicts with the dogfish longline fishery, such that a longline fishery for yelloweye rockfish was conducted during the closed period.

An alternative to a closure favored by some fishermen is a restricted size range of 1-2.5 lb (0.45-1.14 kg). This is the size range with the highest market value. This range limit would have a major effect in Area 13, where the average size of quillback rockfish in the commercial catch is less than 0.5 kg. The minimum size corresponds approximately to the size at 50% maturity for quillback rockfish.

Consideration should also be given to limiting the sport fishery, which accounts for at least 24% of the total rockfish line catch. This may be most important near Campbell River where local closures now apply to the commercial fishery.

INSHORE ROCKFISH - AREAS 3C/3D - WEST VANCOUVER ISLAND

Yield Options

The low risk-sustainable option is the average line catch over the 1956-85 period, prior to the build-up of the fishery. The sustainable option is based on the 1986-87 catch. It is not yet clear whether this level of catch has led to stock depletions. Because of the general uncertainty about appropriate yield levels, the high risk-sustainable option is arbitrarily chosen to be 50% above the sustainable level. The yelloweye rockfish share of the quota should be approximately 50%.

Yield Option	Quota (t)
low risk-sustainable	60
sustainable	500
high risk-sustainable	750

These yield options are intended to act as guidelines for managers, and not to imply that management by quota is the best strategy. Future assessments will examine yield levels based on available habitat relative to the Area 4B yield.

INSHORE ROCKFISH - AREAS 5A/B/C/D/E - NORTH COAST

Yield Options

The low risk-sustainable option is the average line catch between 1974-84, prior to the increase in the fishery. The sustainable option is the 1987 catch, as it is not yet clear whether this level of catch has led to serious stock depletions. Because of the general uncertainty about appropriate yield levels, the high risk-sustainable option is arbitrarily chosen to be 50% above the sustainable level. The yelloweye rockfish share of the quota is approximately 50%.

Yield Option	Quota (t)
low risk-sustainable	120
sustainable	580
high risk-sustainable	870

These yield options are intended to act as guidelines for managers, and not to imply that management by quota is the best strategy. Future assessments will examine yield levels based on available habitat relative to the Area 4B yield.

2.0 LINGCOD

2.1 Coastwide

Yield options are not proposed on a coastwide basis.

2.2 Strait of Georgia and vicinity (Area 4B)

2.2.1 The Fishery

The commercial lingcod fishery began in the Strait of Georgia in the early 1900s. The maximum reported catch of approximately 3000 t occurred in 1936 (Ketchen et al. 1983). Nominal catch remained high through the 1940s and 1950s, but has declined gradually since the 1960s to the 1987 low of 98 t (Fig. 2.1).

Historically, most of the commercial catch was taken by handline/troll gear, with minor catches by longline and trawl gears (Table 2.1). Fishing activity was concentrated near Campbell River (Statistical Area 13), Pender Harbour (Area 16), and the southern Gulf Islands (Area 17) (Table 2.2). Area 13 remains the most important area, although the second highest catch is now from Area 12. There is no longer a lingcod fishery in Area 16.

The sport angling fishery has been monitored since 1980 by creel and overflight surveys. These surveys provide estimates of the numbers of lingcod caught by anglers by Statistical Area (Table 2.3). The sport angling catch averaged 123 t annually between 1980-87, with the exception of 1984 when the estimated catch was 220 t. The sport catch has decreased continuously between 1984-87 and the 1987 catch of 105 t is the lowest recorded. However, because of the even greater decline of the commercial fishery, the sport fishery is taking an increasing share of the total lingcod catch. In fact, the sport angling catch has exceeded the comparable commercial handline/troll and longline catch since 1984 (Fig. 2.2). In 1987, the sport fishery accounted for 64% of the catch.

Lingcod are also the target of an underwater spear fishery. A survey of the diving community in the Strait of Georgia was conducted in the fall of 1983 to provide estimates of diving effort and collecting activities, including spearfishing (McElderry and Richards 1984). Approximately 50% of the divers surveyed made dives for the purpose of spearfishing. The lingcod spearfishing catch was very roughly estimated at 80 t for 1983, or 65% of the annual sport angling catch.

The sport catch is also recorded from the tidal diary program, combining a sport diary and a visitors survey. Tidal diary estimates of the lingcod sport catch are considerably higher than creel survey estimates. In part, this may be because the tidal diary program includes diving and pier fishing which are not included by the creel survey. In 1986-87, the tidal diary estimates were more than double the creel survey estimates (Table 2.3). Based on these estimates, the sport fishery accounted for 80% of the lingcod line catch in 1986 and 1987 (Fig. 2.2).

A winter (Dec.- Feb.) closure to commercial fishing was in effect as early as 1940 (Ketchen et al. 1983) to protect lingcod spawning stocks. In 1979, the existing closure (Dec. 31-Mar. 31) was extended (Nov. 15-Apr. 15) for both commercial and sport fishing. This was an attempt to further protect the prespawning aggregation and spawning males, and hence, to improve recruitment. Various measures continued to indicate a decline in lingcod abundance (Richards and Hand 1988). In 1988, the closure period was again extended to April 30. In addition, subareas near Campbell River (13-1 to 13-9, 13-11, and 13-27) were closed to commercial fishing. A size limit of 58 cm is in effect for the commercial fishery coastwide, and there is a bag limit of 3 fish/d for the sport fishery.

2.2.2 Catch Statistics

Because the commercial line fishery has traditionally been the most important, handline/troll and longline catch and effort data only are used to determine nominal catch per unit effort (CPUE), an abundance index. Catch and effort statistics from sales slip data files have been available from the Department of Fisheries and Oceans, Statistics Division, since 1967. Historically, most of the commercial handline/troll and longline fishery in Area 4B was targeted on lingcod. Since the late 1970s, however, increased effort has been directed at rockfish. To avoid including directed rockfish effort in the lingcod analysis, nominal CPUE is determined from sales slip records with a reported lingcod handline/troll or longline catch of at least 100 kg (Richards and Hand 1988). Effort is determined from the ratio of the combined handline/troll and longline lingcod catch to CPUE.

Nominal CPUE for Area 4B lingcod averaged 170 kg/d between 1967-79, and has since declined to the low of 50 kg/d in 1987 (Table 2.4). Decreases in catch, effort, and the number of commercial vessels targeting on lingcod have been coincident with the decrease in CPUE. These factors together are indicative of decreases in lingcod abundance. The proportion of the total line catch that meets the criterion for inclusion in the CPUE calculation has also decreased, although the 1987 value has increased again over 1986. In general, a greater proportion of the lingcod catch is now taken incidentally to other line fisheries such as the inshore rockfish fishery.

Declines in lingcod abundance are also evident from trends in CPUE by Statistical Area. For area 13, CPUE averaged 260 kg/d between 1967-76 and then declined to the 1987 low of 32 kg/d. The high values of CPUE between 1971-76 were associated with unusually low effort. The values of CPUE for recent years are low in spite of low effort, however. The pattern is similar for Area 17. CPUE remained fairly stable around 150 kg/d between 1967-78, even though effort declined during this period. CPUE, catch and effort have all since declined, although the decline has been less dramatic than in Area 13.

2.2.3 General Biological Information

Biological samples of the commercial handline fishery have been collected sporadically since 1957. Sampling has become increasingly difficult due to the small size of the catch. Samples from statistical areas 13 and 17 are available for 1981-84. Mean size of male and female lingcod decreased over this period in both areas (Table 2.5). In addition, one sample was collected from Area 13 by an observer in 1988. The mean length (63 cm) was considerably smaller than previous samples, and 46% of the total catch was smaller than the size limit. The decrease in mean size between 1983-88 cannot be attributed to strong recruitment of small fish, as catch and CPUE have declined concurrently. Large fish (>80 cm) were absent from the 1988 sample.

Size-frequency data may be used in the equilibrium model of Schnute et al. (1988b) to obtain a point estimate of total annual survival, τ, given estimates of growth. Growth parameters for the Area 3C lingcod stock (section 2.3.4) appear reasonable for the Area 4B stock, following the methodology of Schnute et al. (1988a). Estimates of survival obtained for different time periods are as follows:

Years	τ
1957-70	86%
1979-84	79%
1957-84	77%

Although there may have been a slight decrease in survival over recent years, these values are consistent with the values obtained for the Area 3C lingcod stock. Lingcod survival appears to be high for fish in the size range available to the commercial fishery. A similar conclusion is reached by applying the fishery model of Schnute et al. (1988b) without use of size-frequency data. Based on catch and CPUE between 1967-86, the 95% confidence interval for τ is approximately 66-89%, covering the range of values from the equilibrium model.

Size-frequency data on the lingcod sport catch have been collected by the creel survey since 1983. Mean fish size has remained fairly constant over the 1983-87 period. The sport fishery takes a different component of the lingcod stock than the commercial fishery. Most (67%) of the sport catch is comprised of fish smaller than the commercial size limit (Fig. 2.3, Fig. 2.4). As size at 50% maturity is between 65-70 cm for female lingcod (based on Area 17 surveys), most of the female lingcod caught in the sport fishery are immature.

Tagging studies have shown that adult lingcod are very sedentary and remain close to their home reef after maturity (Chatwin 1956, Cass et al. 1983). Lingcod tend to be caught by the fishery near the site that they were released. It is likely that lingcod living in a particular reef area are the main source of recruitment to that reef. This is because of their nest building and guarding behavior and because of the limited dispersion of larvae after hatching (Cass et al. in prep.).

2.2.4 Condition of the Stock

Lingcod stocks in the Strait of Georgia have continued to decline since the early 1960s and are presently at extremely low abundance, relative to historical levels. There are several types of evidence that demonstrate this decline. Commercial catch, CPUE, effort, and the number of vessels targeting on lingcod have all decreased progressively, especially over the last 10 y (Table 2.4). This is not a result of poor market conditions as lingcod catches have remained high in other areas of the coast. There have also been recent decreases in the size of lingcod in the commercial catch, and the sport catch contains a very high proportion of immature female fish.

Although there is strong evidence that lingcod stocks have declined, the cause of the decline is less clear. Overfishing is suspect, given the large catches during the early part of the commercial fishery. The decline may also have resulted from changes in lingcod predator abundance, food abundance, or other aspects of habitat quality, poor recruitment associated with small spawning stocks, or any combination of these factors. It is unlikely that research in the near future will be able to establish a cause-effect relationship. However, data are available to examine some of the possible hypotheses.

Herring are an important food source for lingcod. There is however, no relationship between lingcod CPUE and estimates of herring spawning biomass or stock abundance based on the escapement model (Haist et al. 1987) for any meaningful time lag. General climatic conditions do not appear to be a factor, as the continuous lingcod decline has occurred only in the Strait of Georgia and not in other areas of the coast. Major climatic changes should affect both Area 4B and Area 3C stocks concurrently. Although the number of sea lions and seals is increasing in the Strait of Georgia, lingcod are rarely eaten by these predators (Olesiuk, pers. comm.). One possible explanation for the recent decline is that the sport fishery is having a detrimental effect on recruitment due the very high proportion of immature fish in the catch.

2.2.5 Yield Options

Whatever the cause of the decline, it is apparent that lingcod stocks in the Strait of Georgia cannot sustain current levels of exploitation. As the sport fishery now takes a greater share of the catch, the management strategy must involve both sport and commercial fisheries. Three management options are proposed. A combination of these options may provide the best management strategy.

(A) Closures of areas or subareas to reduce catch and fishing effort. As lingcod are relatively sedentary and probably recruit from localized areas, closure of areas should help to rebuild stocks in that area. A closure has been implemented in 1988 near Campbell River, but applies to the commercial fishery only. As the sport fishery now takes a greater share of the catch, closures must apply to both sport and commercial fisheries to be effective. Ideally, there should be several closed areas in different parts of the coast. These could be developed as experimental management areas, and the sport fishing community could be involved in assessing the impact of the closures. As lingcod are fast-growing, the benefits of closed areas might be more readily measured for lingcod than for other fishes such as rockfish.

(B) A further extension of the winter spawning closure. This is a modification of Option A, in that all areas are closed for a period of time instead of a complete closure for selected areas. This option may not be as effective as (A). A winter closure has been in place for many years and has not been sufficient to halt the decline in stock abundance.

(C) A size limit of 58 cm for the sport fishery. This is the size limit in effect for the commercial fishery. At present, the sport fishery takes a high proportion of immature fish, and a size limit would increase the probability that fish spawn at least once before they are caught. A size limit is a reasonable option for lingcod. Although there have been no studies to examine release mortality, lingcod survival has been high in tagging studies. Further, the survival of lingcod is high for fish above the suggested size limit.

Between 1983-87, 67% of the number of fish caught were less than 58 cm in length, but this corresponds to only 42% of the biomass caught (Fig. 2.4). Although a size limit will initially reduce the number of fish caught in the sport fishery, it should increase the yield, or the weight of the catch over the longer term. This would make it possible to promote lingcod as a trophy fish. A size limit of 56 cm has been imposed in Puget Sound and anglers in Puget Sound favor a size limit to increase the chance of catching a trophy fish (Bargmann 1983). The Puget Sound study showed that a minimum size limit is more effective in increasing the number of large spawning fish than a maximum size limit.

2.3 West Coast Vancouver Island (Areas 3C and 3D)

2.3.1 Introduction

Lingcod off the west coast of Vancouver Island are assumed to exist as two discrete stocks or groups of stocks, one off southwest Vancouver Island (Area 3C), and one off northwest Vancouver Island (Area 3D). Analyses and catch statistics are presented by major statistical area. In 1988, a comprehensive analysis of the population dynamics of lingcod in Area 3C was completed. The analysis was based on the size-structured model of Schnute (1987), and is described in Schnute et al. (1988a,b). The results of this analysis form the basis for the Area 3C recommendations, and by extension, for the Area 3D recommendations.

2.3.2 The Fishery

Lingcod stocks off southwest Vancouver Island are exploited by trawl and by hook and line fisheries. There have also been undocumented, and presumably small, catches by Indian food fisheries, recreational fisheries and foreign national (other than United States) fisheries. The hook and line fishery includes a targeted longline fishery and incidental catches by salmon troll vessels. The commercial trawl fishery accounts for the majority of the lingcod catch. Prior to 1987, there were no legal restrictions on the lingcod catch, except for occasional winter closures and a size limit of 58 cm, implemented initially as a weight limit, in 1942. Lingcod catch was limited in the past by low market demand. In 1987, a 1400 t quota was placed on the Area 3C lingcod catch.

2.3.3 Catch Statistics

The compilation of lingcod catch statistics between 1956-86 for Area 3C is described in Cass et al. (1988). The identical procedure was used for the 1987 statistics. Briefly, nominal CPUE is calculated from interviewed trawl landings between May-September. A catch is included only if lingcod account for at least 25% of the total catch weight, and the vessel used double gear. Effort recorded for the catch is standardized for vessel horsepower class (Westrheim and Foucher 1985, Table 8). In addition, the proportion of the catch that could be accounted for by lingcod above a defined weight of 2.25 kg is determined annually from biological samples. The defined weight was chosen to approximate weight at recruitment to the fishery. Nominal CPUE is the ratio of the sum of the qualified catch to the sum of the qualified effort, corrected by the proportion of fish of recruitment weight or greater. Nominal effort is the ratio of total all-gear catch to the corresponding nominal CPUE.

The Area 3C lingcod catch has generally varied between 700-2000 t (Table 2.6, Fig. 2.5). The 1987 trawl catch is the second lowest on record at 492 t. Line catch (combined handline/troll and longline) has tended to be less variable than trawl catch and has averaged 187 t between 1956-87. A major increase in the 1987 line catch did not occur as projected by the trawl fleet. In fact, the 1987 line catch is below average at 173 t. The 1987 total catch is the second lowest on record at 665 t. Although nominal CPUE decreased for the second year in a row, the value in 1987 is within the range of values for the period 1976-81.

The compilation of landing statistics for Area 3D is similar to that discussed for Area 3C. In years for which there are no Area 3D biological samples, the proportion of fish of recruitment weight or greater in the catch is estimated from the Area 3C samples. Nominal CPUE calculated by this method from qualified trawl catch is a less useful abundance index for Area 3D than for Area 3C, because the line catch accounts for a higher proportion of the total Area 3D catch. For example, only 10% of the total catch met the qualification requirements in 1985 and in 1986.

The lingcod catch from Area 3D has ranged from 166 t in 1959 to 984 t in 1968 (Table 2.7, Fig. 2.6). The catch in 1987 was 320 t, just below the historical average of 401 t. However, the 1987 line catch was the largest recorded at 232 t. Nominal CPUE increased slightly in 1987 to 315 kg/h.

2.3.4 General biological information

In order to apply Schnute's (1987) size-structured model, it is important to first describe fish growth. The model uses two growth parameters as input. These are V', the expected weight of a fish one year after it entered the fishery, and ρ, the slope of the line relating fish weight in one year to its weight in the previous year. Estimation of these parameters for the Area 3C lingcod stock is detailed in Schnute et al. (1988a). Three sources of data are examined in the analysis, data from a tag-recapture experiment, weight-at-age data, and a time series of biological data from the commercial fishery. Parameter estimates based on these three sources do not differ significantly. The final tag-recapture estimates that are used in the subsequent analysis are as follows

$$(V',\rho) = (2.88 \text{ kg}, 1.024) \quad . \tag{1}$$

Data from both male and female lingcod are combined to obtain these estimates. Ideally, sexes should be separated for the analysis as the value of ρ (but not V') is significantly greater for female than male lingcod. This is not possible, however, as sex was not recorded for most commercial fishery samples between 1956-76. Instead, the combined estimates (1) are used to describe a typical exploited population.

Lingcod recruit to the fishery over ages 2-6 (Fig. 2.7). However, trends in the age-frequency distribution are somewhat difficult to interpret. There are no sharp peaks as might be expected if the fishery were maintained by a few strong year-classes. In most cases it is not possible to follow a mode in the distribution between years. Patterns in the age-frequency distributions may result from changes in availability among years, sampling bias, or ageing errors.

Schnute et al. (1988b) present a detailed analysis of lingcod survival. They compare estimates of the main parameters obtained from three different models. The fishery model uses the time series of catch and CPUE data and mean weight from biological samples for the commercial fishery over the period 1956-86. The equilibrium model uses the weight-frequency distribution of the biological samples averaged over 1956-86. The tag model uses recapture data between 1982-86 for lingcod tagged and released in 1982.

There are three main parameters of interest here, total annual survival, τ, survival from natural mortality, σ, and catchability, q. Let E represent fishing effort. Then

(2) $$\tau = \sigma(1-qE) \quad .$$

In other words, total survival is the product of survival from natural and fishing mortality.

Estimates of the parameters (σ,q,τ) are:

(3) $$(\hat{\sigma},\hat{q},\hat{\tau}) = (0.760, 0.000\times10^{-3}\ h^{-1}, 0.760)$$

from the fishery model, and

(4) $$(\hat{\sigma},\hat{q},\hat{\tau}) = (0.455, 0.071\times10^{-3}\ h^{-1}, 0.326)$$

from the tag model. The fishery model results in a high estimate of survival and a fishing mortality so low that the effect of the fishery cannot be measured. Conversely, the tag model results in a low survival with a relatively high fishing mortality. The difference between (3) and (4) is real statistically. However, since the equilibrium model gives

(5) $$\hat{\tau} = 0.78 \quad ,$$

a value of survival that is very similar to the point estimate from the fishery model, (3) is more credible than (4). If survival were as small as that indicated in (4), it would be impossible to account for the significant number of large (old) fish observed in size-frequency distributions of the catch (Fig. 2.7 in Richards and Hand (1988)).

One possible explanation for (4) might focus on common sources of error in a tag-recovery experiment. These include (i) mortality due to tagging, (ii) tag loss, (iii) non-reporting of tags, and (iv) non-random mixing of tagged fish within the total population. The first three sources represent tagged fish that are effectively lost to the experiment. If these fish had died from natural causes, the consequence to the analysis would have been equivalent. Thus, the disappearance of these fish is counted as natural mortality, resulting in underestimates of σ and τ. It is unlikely that these factors account completely for the large discrepancy between (3) and (4).

The fourth explanation, non-random mixing of tagged fish within the stock, is more likely in this case. Lingcod probably prefer hard-bottom areas, so that only a small component of the stock may be available to the trawl fishery. When fish are removed from the trawl grounds, other fish from nearby rocky areas may move into the newly vacated habitat. It may also happen that survivors from the fishery move slowly out to rocky areas when space becomes available there. Thus, fish may mix slowly between trawlable and non-trawlable habitats.

Under the above "slow-mixing" scenario, data from the fishery reflect the whole underlying stock in both habitats. For example, if a large catch is taken from the trawl grounds one year, the fish may be replaced in the next year by emigrants from rocky areas. The fishery model would thus detect the high survival and low catchability indicated in (3). By contrast, if mixing is slow, tagged fish that linger on the trawl grounds would be exposed to higher fishing mortality than the general population (which resides largely in rocky areas). Thus, the higher value of q in (4) may reflect catchability relative to the trawlable areas only. Finally, as tagged survivors slowly leave the trawl grounds for rocky regions, the tag model explains their absence as natural mortality, giving the low value of σ in (4). Inconsistencies in the age-frequency distribution among years also support a mixing scenario.

If the fishery model is representative of the lingcod stock, then it is possible to examine confidence intervals for the parameter estimates. The effort data provide enough contrast to define an upper 95% confidence limit for q at about $0.045 \times 10^{-3}\ h^{-1}$. Based on a typical effort $E=3.88 \times 10^{3} h$, this suggests that survival from fishing (1-qE) is typically at least as high as 83%. A corresponding 95% confidence interval for σ is 0.70-0.93. It is also possible to examine the effect of other abundance indices. The Option-2 CPUE index and a CPUE index based on total interviewed trawl effort give parameter estimates identical to (3), but wider confidence intervals. For example, the 95% confidence interval for σ, using CPUE based on total trawl effort, is 0.68-0.97. The extreme value of σ corresponds to an average fishing mortality of 20%.

There are fewer data available for Area 3D, and only the fishery model can be applied. The Area 3D parameter estimates are essentially identical to (3), although the confidence intervals differ. The 95% confidence interval for σ is 0.67-0.88. The extreme value of σ corresponds to an average fishing mortality of 10%.

2.3.5 Condition of the Stock

Based on nominal CPUE, Area 3C lingcod stocks are currently at low levels of abundance. Similar low levels of abundance occurred between 1976-81, after which the stock appeared to fully recover. If the "slow-mixing" hypothesis is true, then the lingcod stock will be relatively unaffected by the fishery, unless new methods are found to fish hard-bottom areas or the line fleet increases dramatically and expands into new areas. However, in a worst case scenario, the protected population in rocky areas could be gradually depleted, leading to a sudden, unexpected collapse of the fishery. Stock distribution studies are planned to test these hypotheses. Schnute et al. (1988b) noted a possible decline in recruitment over the last 10-15 y. Recruitment should continue to be monitored as an indicator of future stock sizes.

2.3.6 Yield Options

Because of the risk of stock collapse, it is recommended that a quota on the Area 3C stock be maintained while abundance is low. The low risk option is 900 t, the sustainable option is 1400 t, and the high risk option is unlimited yield. These options will be re-evaluated after studies are conducted on stock distribution. Due to the possible decrease in recruitment, it is also recommended that the winter fishing closure (Nov. 15-Apr. 30) be maintained to protect nesting lingcod. Yield options are not proposed for Area 3D.

2.4. Queen Charlotte Sound (Areas 5A and 5B)

2.4.1 Introduction

Commercially exploited lingcod stocks are located on the Cape Scott (Area 5A) and Goose Island (Area 5B) grounds. As few commercial samples are available for Area 5A lingcod, and as catch trends are similar in both areas, lingcod in Queen Charlotte Sound are treated as one stock for this assessment. The assessment is based on the analysis described in Schnute et al. (1988a,b) for the Area 3C lingcod stock.

2.4.2 The Fishery

Lingcod stocks in Queen Charlotte Sound are primarily exploited by commercial trawl vessels. There are also small catches by hook and line vessels. Lingcod have generally been a relatively minor component of the Queen Charlotte Sound trawl fishery.

2.4.3 Catch Statistics

The compilation of catch statistics for Area 5A/B is similar to that discussed for Area 3C (section 2.3.3). Nominal CPUE for Area 5A and 5B is calculated from 25% qualified interviewed trawl catch between May-September. Qualified effort is standardized for vessel horsepower class (Westrheim and Foucher 1985, Table 8). CPUE for Area 5A/5B combined is also corrected for a weight at recruitment to the fishery of V=2.25 kg, based on the average weight-frequency distribution of the 1956-87 commercial samples (Richards and Hand 1988). Effort is calculated from the ratio of nominal catch to CPUE.

Catch from Area 5A and Area 5B contributed about equally to the Area 5A/B total between 1956-70 (Table 2.8, Fig. 2.8). For every year since 1970, catch has been greater from Area 5B. However, the trends in catch and CPUE have remained similar in the two areas. The 1987 combined catch of 1520 t and the CPUE of 288 kg/h are lower than the corresponding 1986 values, but are still above average for the 1956-87 period.

2.4.4 General biological information

As discussed in Section 2.3.4, the first step in the application of Schnute's (1987) size-structured model is to describe fish growth. There are no tag-recapture data available for Area 5A/B. However, it is possible to base growth estimates on size-frequency data collected from the commercial fishery between 1956-86, and on size-at-age data for 1977-82. For both of these data sets, fish weight WT (kg) is estimated from fork length FL (cm) using the relationship

$WT = 1.050 \times 10^{-5}\ FL^{2.991}$ (Richards and Hand 1988). Von Bertalanffy parameters from combined weight-at-age data are

$$(6) \qquad (W_\infty, k, t_0) = (93.2\ \text{kg}, 0.0118, 1.60\ \text{y}) \quad .$$

Model parameters corresponding to (6) and V=2.25 kg are

$$(7) \qquad (V', \rho) = (3.32\ \text{kg}, 0.988) \quad .$$

Schnute et al. (1988a) describe how the growth parameters (7) may be checked by comparison with a time series of mean weights from commercial samples. With estimates for V and V', weight-frequency data for each year can be compiled into weight intervals (V,V') and (V,W_∞) representing the newly recruited and total recruited components of the fished population. Mean fish weight for the newly recruited component, Z_t, and for the total recruited component, X_t, can be computed for each year of sample data. A scatter plot relating Z_{t+1} to X_t should suggest a line through the point (V,V') with slope ρ.

Mean weights X_t and Z_t were computed for the Area 5A/B lingcod stock for each year between 1956-87. There were two years for which weight-frequency data were not available, 1975 and 1984. For these years, X_t and Z_t were defined as the mean of the preceding and following years. A line based on (7) did not appear to be the best line through the points (X_t, Z_{t+1}). Consequently, the errors-in-variables model of Schnute et al. (1988a) was applied to the fishery data to re-estimate the growth parameters. A line determined by estimates from the errors-in-variables model

$$(8) \qquad (V', \rho) = (3.02\ \text{kg}, 0.939)$$

did appear to pass reasonably through the fishery data, and these were accepted as the best available estimates. Although the estimates (8) fall within the 95% confidence region of the corresponding estimates (1) for the Area 3C lingcod stock, the estimates (8) pass more reasonably through the fishery data than do estimates (1).

Given (8), estimates of total annual survival, τ, survival from natural mortality, σ, and catchability, q, may be obtained as described in Schnute et al. (1988b). Estimates of τ from the equilibrium model are τ=0.839 over the time period 1956-87, and τ=0.821 for 1985-87 size-frequency samples. Estimates of the parameters (σ,q,τ) from the fishery model are

$$(5) \qquad (\hat{\sigma},\hat{q},\hat{\tau}) = (0.878, 0.020\text{x}10^{-3}\ h^{-1}, 0.820) \quad .$$

The estimate for q corresponds to a fishing mortality of 6.6%, based on a typical effort of $3.16\text{x}10^3$ h. The 95% confidence interval for σ is 0.786-0.992 with corresponding fishing mortalities of 0-15%. The estimates for σ and q are both higher than the corresponding estimates based on the Area 3C analysis. However, the estimate for τ is very close to the Area 3C estimate, and all of the estimates are within the 95% confidence region of the Area 3C estimates.

2.4.5 Condition of the stock

Although growth rates and the partitioning between natural and fishing mortality differ slightly between Area 5A/B and Area 3C, the estimate of total mortality is remarkably similar for the two areas. Hence, similar conclusions apply to lingcod stocks in the two areas. Stocks are probably sustainable at current rates of exploitation. Based on CPUE, lingcod stocks in Area 5A/B appear to be at above-average levels of abundance.

2.4.6 Yield options

Yield options are not proposed for this area.

Table 2.1. Nominal lingcod handline/troll catch (t), longline catch (t), trawl catch (t), and total catch (t) for Area 4B, 1951-87.

Year	Handline/troll[a]	Longline[a]	Trawl[b]	Total
1951	1279.5	27.4	48.1	1355.0
1952	1488.8	17.2	54.0	1560.0
1953	1179.2	6.3	28.1	1213.6
1954	1449.4	9.4	69.2	1528.3
1955	1220.1	8.5	50.6	1279.2
1956	1512.1	9.6	55.7	1577.4
1957	1539.7	4.5	42.0	1586.2
1958	1445.6	4.0	74.6	1524.2
1959	1183.0	6.7	336.4	1526.1
1960	1250.6	21.4	184.1	1456.1
1961	1157.7	30.7	102.1	1290.5
1962	1272.8	14.3	75.7	1362.9
1963	989.3	9.3	39.7	1038.3
1964	870.4	5.5	90.3	966.2
1965	779.7	6.5	93.8	880.0
1966	771.3	20.0	56.0	847.3
1967	781.0	14.5	54.4	849.9
1968	729.8	12.5	94.6	836.9
1969	747.9	19.9	65.6	833.4
1970	792.0	31.3	48.8	872.1
1971	564.9	34.3	60.5	659.7
1972	513.4	10.3	34.7	558.4
1973	373.1	31.2	15.0	419.3
1974	354.7	16.2	49.4	420.3
1975	331.4	37.3	33.9	402.6
1976	316.0	15.3	43.6	374.9
1977	408.7	24.9	32.1	465.7
1978	445.2	56.5	42.7	544.4
1979	505.5	56.0	26.6	588.1
1980	342.1	12.0	38.2	392.3
1981	334.5	9.2	67.1	410.8
1982	358.8	11.4	196.6	566.8
1983	274.7	12.6	135.4	422.7
1984	182.7	10.4	90.6	283.7
1985	129.2	8.6	34.0	171.8
1986	99.1	16.1	44.5	159.7
1987	71.3	9.2	17.2	97.7

[a]British Columbia Catch Statistics, Annual Reports.
[b]Groundfish data files.

Table 2.2. Nominal lingcod handline/troll and longline catch (t) for Area 4B by Statistical Area, 1951-87.

Year	Statistical Area 12	13	14	15	16	17	18	19	20	28	29	Total
1951	23.3	397.9	88.5	46.3	99.3	357.9	253.2	32.2	17.3	1.8	0.4	1318.1
1952	11.8	440.3	83.6	73.2	169.3	438.0	235.7	28.6	25.2	7.0	0.0	1512.7
1953	5.7	345.8	84.4	46.1	166.2	289.0	179.0	38.9	28.2	4.4	0.1	1187.8
1954	16.0	437.3	157.6	21.5	244.9	362.5	169.1	33.7	13.2	4.8	1.9	1462.5
1955	6.5	330.0	84.4	64.7	243.0	338.9	112.3	44.1	8.0	0.0	0.0	1231.9
1956	17.2	564.7	96.3	60.6	235.0	396.8	106.9	44.1	2.1	1.2	0.8	1512.3
1957	7.0	542.4	82.4	107.2	288.4	364.7	96.9	54.0	2.3	0.3	0.8	1546.4
1958	16.5	497.2	105.6	79.3	229.7	350.2	93.5	73.8	4.5	0.6	0.0	1450.9
1959	16.1	338.3	86.7	31.4	167.8	345.3	85.3	104.7	0.8	0.6	15.4	1192.4
1960	24.3	337.9	110.7	47.1	173.9	378.0	97.0	82.8	23.1	1.3	3.5	1279.6
1961	32.1	393.1	92.1	45.6	183.7	285.7	64.3	63.6	29.6	7.7	2.4	1199.9
1962	160.2	412.0	114.1	60.4	139.0	241.2	57.2	76.4	19.4	8.9	4.1	1293.0
1963	68.0	301.4	63.1	30.5	159.6	250.6	44.7	63.5	20.7	0.1	0.1	1002.3
1964	36.3	289.8	43.3	18.8	170.0	191.5	53.8	52.6	21.4	0.1	0.4	878.0
1965	30.3	303.2	52.4	6.6	135.8	155.3	50.1	39.3	11.2	0.0	4.6	788.8
1966	44.4	299.5	61.7	28.7	125.7	131.4	61.2	33.0	17.6	1.1	0.0	804.3
1967	49.3	332.8	55.7	19.8	133.3	109.6	69.9	17.8	7.0	0.0	0.4	795.6
1968	50.7	273.6	54.2	22.0	104.7	157.7	53.3	14.8	10.5	0.0	0.7	769.2
1969	61.9	227.7	81.9	56.0	109.5	143.5	52.3	31.7	13.8	0.0	0.1	778.4
1970	46.4	225.5	40.8	84.7	85.7	272.1	37.4	23.7	6.5	0.0	0.6	823.4
1971	50.1	119.2	30.0	66.5	89.7	199.9	22.7	18.9	2.2	0.1	0.1	599.4
1972	39.5	152.3	25.1	43.6	81.3	129.9	19.6	38.5	2.4	0.0	0.5	532.7
1973	22.2	85.9	8.4	62.0	38.2	123.7	34.4	27.7	1.1	0.6	0.2	404.4
1974	11.2	129.6	13.3	25.2	23.3	127.6	22.2	16.7	2.9	0.0	0.3	372.3
1975	8.6	93.9	15.1	76.0	26.5	123.0	10.9	8.9	5.0	0.0	0.9	368.8
1976	10.4	96.0	12.9	74.9	17.2	82.5	13.4	9.8	7.8	5.7	0.4	331.0
1977	25.7	128.0	31.4	63.4	19.0	104.1	40.6	15.7	2.6	2.2	0.3	433.0
1978	13.8	158.0	25.3	48.3	18.4	145.3	36.1	42.2	5.7	0.2	2.0	495.3
1979	29.2	215.5	36.8	28.7	15.6	157.4	26.9	30.2	13.7	7.1	1.5	562.6
1980	14.7	131.6	14.2	25.8	6.6	103.0	23.9	23.0	5.3	4.5	0.7	353.3
1981	17.5	137.4	28.9	34.6	12.9	83.6	16.4	16.3	3.3	0.1	0.5	351.5
1982	20.1	177.8	14.9	48.0	7.7	59.6	20.3	17.5	2.1	0.5	1.1	369.6
1983	16.8	112.3	17.9	32.9	13.2	56.5	18.0	14.1	4.6	0.3	0.3	286.9
1984	18.7	65.6	7.0	4.0	5.2	46.5	30.1	13.0	2.5	0.0	0.2	192.8
1985	20.1	46.0	8.2	4.0	0.3	29.8	15.9	10.5	2.6	0.0	0.3	137.7
1986	21.0	20.2	16.0	0.5	2.4	17.2	12.9	13.7	1.8	0.0	0.5	106.2
1987	15.6	22.6	2.2	0.9	0.1	10.0	8.0	8.4	5.9	6.7	0.0	80.4

Source: 1951-1966 British Columbia Catch Statistics, Annual Reports.
1967-87: Sales slip data files.

Table 2.3. Lingcod sport catch (t)[a] for the Strait of Georgia by Statistical Area from the creel survey (Shardlow and Hoyt, unpub. data), and the total for the same areas from the sport diary and visitors surveys (Bijsterveld, unpub. data), 1980-1987.

Year	Statistical Area 13	14	15	16	17	18	19	28	29	Creel total	Tidal Diary total
1980	41.8	12.6	2.4	22.6	12.6	9.6	13.8	4.6	6.7	126.7	179.4[b]
1981	43.4	17.1	8.0	15.4	9.1	12.6	23.0	7.4	9.8	145.8	170.2[b]
1982	24.0	9.1	2.1	31.4	14.2	9.6	20.3	9.8	5.9	126.4	210.9[b]
1983	25.8	3.7	1.8	32.2	11.4	10.1	15.7	10.9	6.9	118.3	193.3
1984	63.5	18.2	2.7	45.9	26.2	11.4	26.4	14.2	13.0	219.8	303.0
1985	37.1	9.9	1.4	22.4	14.2	4.5	20.8	5.0	4.3	123.7	311.8[c]
1986	41.3	15.5	2.1	15.0	10.1	6.9	17.1	3.0	2.6	113.6	344.8
1987	37.6	16.5	2.3	13.0	11.1	4.8	17.5	1.3	1.2	105.3	242.8[d]

[a]An average weight of 1.6 kg was used to convert numbers to weight.
[b]Sport diary component only, no visitors survey available.
[c]Sport diary component estimated as the mean of 1984 and 1986 totals.
[d]Visitor component estimated as the mean of 1983-1986.

Table 2.4. Lingcod nominal CPUE (kg/d) by Statistical Area and for Area 4B, nominal lingcod catch (t) by handline/troll and longline for Area 4B, the proportion of the nominal catch by these gears that satisfies the qualification criterion, effort (d), and the number of vessels that reported a qualified line catch.

	CPUE by Statistical Area													
Year	12	13	14	15	16	17	18	19	20	28/29	CPUE	Catch	Prop.	Effort	Vess.
1967	53	301	236	314	213	127	124	164	130	87	181.1	795.5	0.86	4313	
1968	37	318	179	375	194	127	110	168	157	227	156.8	742.3	0.89	4734	
1969	57	272	168	438	213	136	129	292	128	-	170.3	767.8	0.89	4509	
1970	50	254	168	351	196	175	154	228	161	257	182.0	823.3	0.90	4524	
1971	83	266	171	267	196	166	113	217	275	25	174.2	599.2	0.89	3440	
1972	50	301	201	283	178	143	150	191	245	147	164.9	523.7	0.85	3176	
1973	40	287	132	264	185	167	150	207	191	119	168.4	404.2	0.91	2401	
1974	36	312	253	269	135	139	135	170	156	327	172.1	370.9	0.90	2155	
1975	23	312	160	242	194	171	189	193	208	46	189.5	368.7	0.94	1966	
1976	38	275	150	250	123	174	126	128	168	140	181.2	331.3	0.89	1825	
1977	52	200	192	256	222	148	125	136	45	115	155.9	433.6	0.76	2781	
1978	74	192	126	206	278	155	105	131	33	210	150.8	501.8	0.88	3327	
1979	76	198	144	270	184	224	116	124	144	163	173.8	561.5	0.85	3231	253
1980	73	274	87	220	92	167	95	101	105	119	159.7	354.1	0.85	2217	205
1981	168	177	90	194	129	148	87	94	77	46	146.1	343.7	0.87	2352	206
1982	66	189	85	152	83	129	130	96	100	55	139.8	370.2	0.86	2648	226
1983	123	138	118	235	127	144	95	93	194	51	138.3	287.3	0.85	2077	174
1984	76	74	80	99	126	95	159	124	100	36	91.6	193.1	0.83	2108	156
1985	74	107	90	104	156	132	71	191	36	96	100.3	137.8	0.70	1374	96
1986	45	53	131	175	119	103	87	114	78	35	73.8	115.2	0.60	1561	83
1987	33	32	44	93	-	84	87	53	141	213	50.4	80.5	0.75	1596	89

Table 2.5. Mean length (cm) of lingcod, with sample size and standard error, from biological samples of the commercial handline fishery, by Statistical Area and sex, and for combined sexes. The 1988 sample is given for the total catch and for the kept catch.

	Male			Female			Combined sexes		
Year	N	Mean	SE	N	Mean	SE	N	Mean	SE
Area 13									
1981	72	71.0	0.7	244	76.0	0.6	316	74.8	0.5
1982	54	71.0	0.7	173	80.7	0.7	227	78.4	0.6
1983	137	70.3	0.5	527	80.2	0.4	667	78.1	0.4
1984	124	66.2	0.6	131	73.8	0.8	255	70.1	0.5
1988-total	93	55.9	0.6	71	61.1	0.9	164	58.2	0.5
1988-kept	43	60.6	0.5	46	65.5	0.7	89	63.1	0.5
Area 17									
1979	70	70.8	0.9	130	81.1	1.0	200	77.5	0.8
1981	360	69.6	0.4	271	81.6	0.8	633	74.5	0.5
1982	90	68.9	0.8	135	81.6	0.8	255	76.5	0.7
1983	591	65.9	0.3	614	73.2	0.4	1207	69.5	0.3

Table 2.6. Nominal lingcod trawl catch, line catch, total catch, nominal CPUE and effort for Area 3C, 1956-88.

Year	Trawl (t)	Line (t)	Total (t)	CPUE (kg/h)	Effort (h)
1956	1151	156	1307	292	4478
1957	1070	295	1365	307	4449
1958	1047	156	1203	442	2719
1959	1742	113	1855	408	4543
1960	1867	219	2086	293	7114
1961	1972	136	2108	426	4949
1962	890	228	1118	291	3847
1963	609	147	756	462	1637
1964	1127	101	1228	437	2811
1965	1812	122	1934	398	4861
1966	2030	158	2188	329	6641
1967	1779	246	2025	408	4960
1968	1661	156	1817	584	3114
1969	1054	171	1225	298	4113
1970	703	286	989	291	3398
1971	979	231	1210	346	3495
1972	625	267	892	278	3214
1973	876	185	1061	364	2917
1974	1029	224	1253	240	5218
1975	1630	216	1846	292	6325
1976	1205	253	1458	204	7138
1977	844	267	1111	236	4698
1978	360	91	451	184	2452
1979	602	82	684	220	3112
1980	623	97	720	242	2979
1981	603	240	843	179	4703
1982	1510	221	1731	331	5230
1983	970	170	1140	314	3626
1984	1731	128	1859	391	4749
1985	3416	207	3623	469	7729
1986	834	241	1075	325	3312
1987	492	173	665	190	4454
1988[a]	147				

[a]to Aug. 15, 1988.

Table 2.7. Nominal lingcod trawl catch, line catch, total catch, nominal CPUE and effort for Area 3D, 1956-88.

Year	Trawl (t)	Line (t)	Total (t)	CPUE (kg/h)	Effort (h)
1956	168	135	303	421	707
1957	130	146	276	583	470
1958	109	130	239	723	314
1959	64	102	166	563	276
1960	87	115	202	769	244
1961	200	125	325	544	550
1962	286	112	398	285	1334
1963	115	132	247	365	664
1964	226	92	318	536	578
1965	505	97	602	381	1457
1966	585	147	732	579	1177
1967	459	180	639	554	1098
1968	868	117	984	629	1400
1969	619	84	703	306	2053
1970	456	171	627	317	1922
1971	264	124	388	248	1548
1972	85	197	282	235	1168
1973	172	91	263	406	630
1974	242	123	365	509	677
1975	347	97	444	251	1553
1976	245	98	343	302	1108
1977	158	116	274	293	922
1978	197	94	292	458	625
1979	147	110	257	310	809
1980	127	94	222	199	1074
1981	87	122	209	170	1014
1982	49	175	224	188	1119
1983	447	153	600	299	1944
1984	322	153	475	204	2241
1985	380	194	574	456	1199
1986	246	229	475	306	1458
1987	88	232	320	315	993
1988[a]	84				

[a]to Aug. 15, 1988.

Table 2.8. Nominal lingcod trawl catch, line catch, total catch, nominal CPUE and effort for Area 5A and Area 5B, and Area 5A/B nominal catch, nominal CPUE and effort, 1956-88.

	Area 5A				Area 5B				Area 5A/B		
Year	Trawl (t)	Line (t)	Tot. (t)	CPUE (kg/h)	Trawl (t)	Line (t)	Tot. (t)	CPUE (kg/h)	Total (t)	CPUE (kg/h)	Effort (h)
1956	350	24	374	371	250	4	254	470	628	443	1418
1957	433	1	434	258	170	6	176	295	611	284	2136
1958	296	1	297	139	276	0	276	417	573	353	1614
1959	192	1	193	359	429	1	430	410	623	400	1546
1960	280	13	293	276	377	2	379	373	672	352	1904
1961	388	19	407	534	323	3	326	274	733	366	1965
1962	531	36	567	363	407	5	412	297	979	328	2940
1963	285	27	312	295	357	16	373	259	685	280	2420
1964	352	8	360	342	335	8	343	186	703	304	2275
1965	331	5	336	363	566	8	574	169	910	282	3149
1966	706	24	730	349	826	7	833	362	1563	351	4415
1967	759	22	781	322	901	5	906	477	1687	368	4547
1968	1227	17	1244	296	1043	11	1054	400	2298	302	7226
1969	617	28	644	139	517	9	526	233	1170	157	7267
1970	590	29	619	250	390	16	406	255	1026	249	4088
1971	230	27	257	141	415	14	429	174	685	156	4363
1972	164	47	211	197	476	27	503	157	714	173	4127
1973	232	38	270	178	349	20	369	131	639	173	3694
1974	339	40	379	203	532	31	563	205	942	202	4640
1975	82	31	113	112	451	23	473	203	587	162	3623
1976	258	42	300	244	345	28	373	174	673	194	3469
1977	122	50	172	117	257	18	275	195	446	156	2841
1978	128	20	148	224	162	12	174	168	322	189	1695
1979	100	32	132	186	242	12	254	179	386	166	2144
1980	108	33	141	103	302	12	314	174	455	137	2844
1981	183	33	216	227	548	12	560	237	776	216	3302
1982	468	35	503	249	580	9	589	239	1091	237	4490
1983	573	37	610	267	772	10	782	337	1392	307	4505
1984	261	47	308	190	455	10	465	198	773	188	3964
1985	408	45	453	255	469	23	491	236	944	227	3869
1986	640	41	681	346	1012	7	1019	403	1700	367	4462
1987	675	72	747	266	756	8	764	330	1511	288	5170
1988[a]	185				382						

[a]to Aug. 15, 1988.

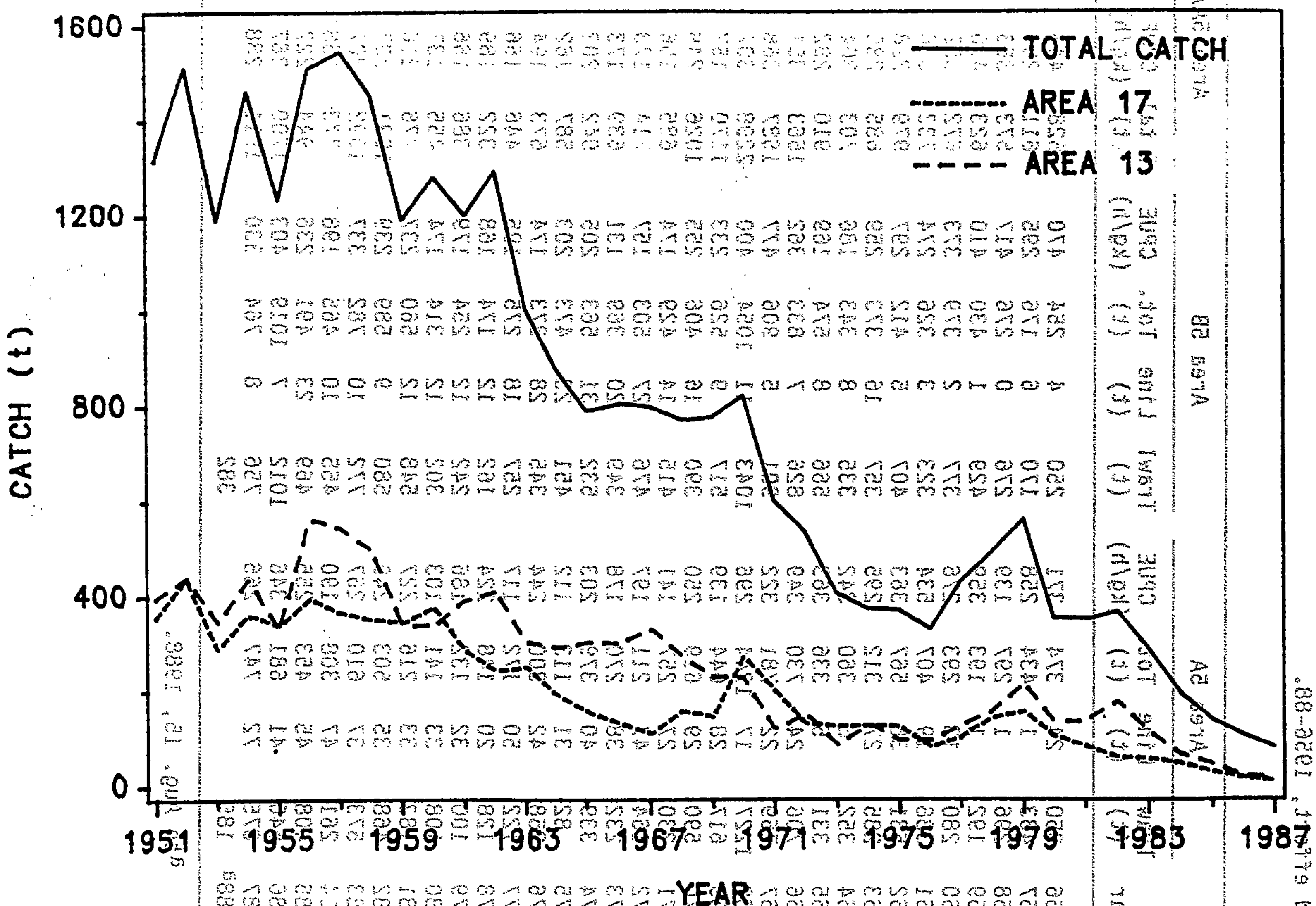

Fig. 2.1. Nominal lingcod handline/troll and longline catch from Area 4B combined, and from statistical areas 13 and 17, 1951-1987.

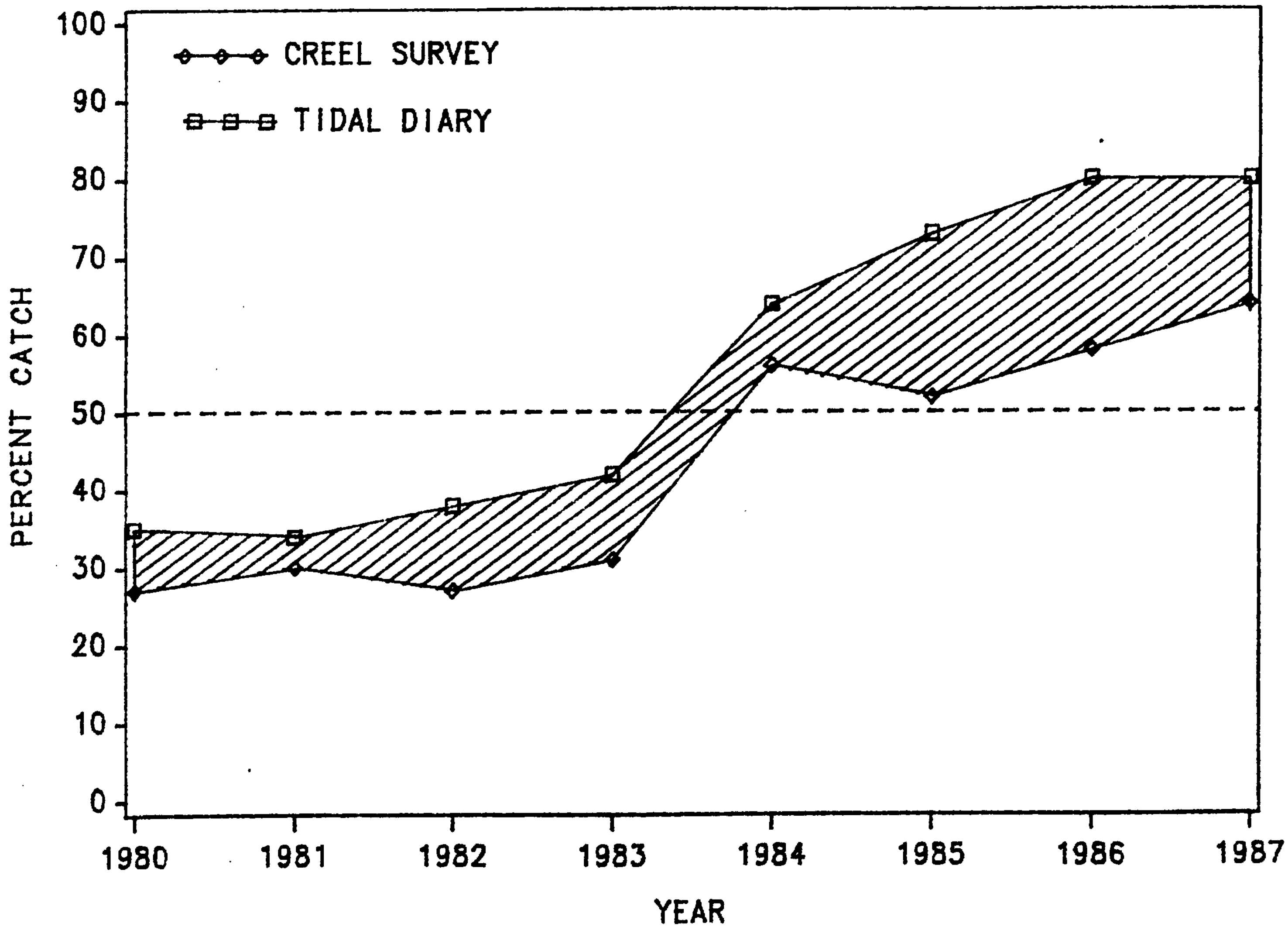

Fig. 2.2. Percent of the total lingcod line catch caught by the sport fishery in statistical areas 13-19, 28, and 29 between 1980-87, based on the creel survey and the tidal diary program. The shaded area between the two estimates is a measure of confidence in the percentages.

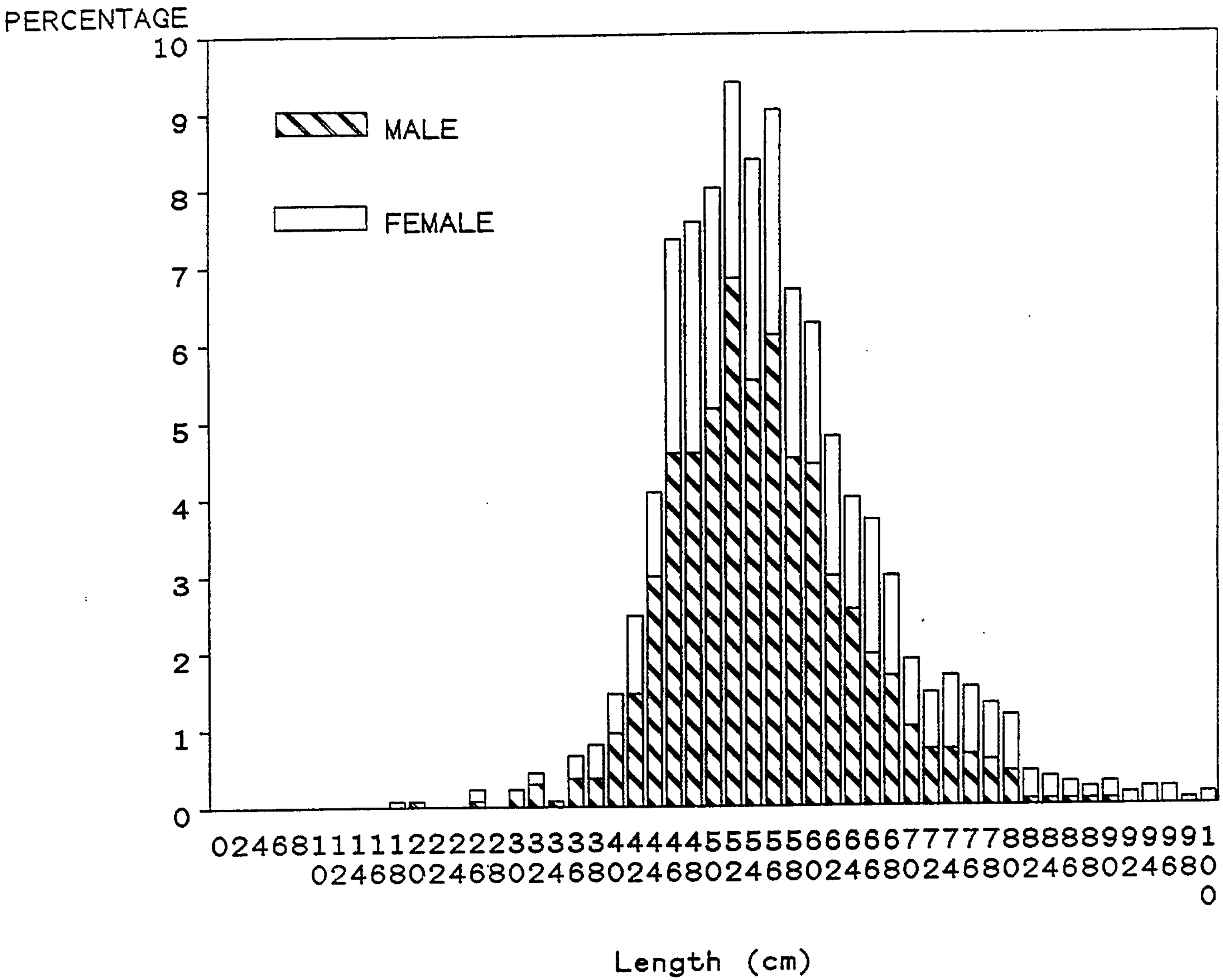

Fig. 2.3. Length-frequency distribution of lingcod caught in the sport fishery, 1983-87 (N=1376).

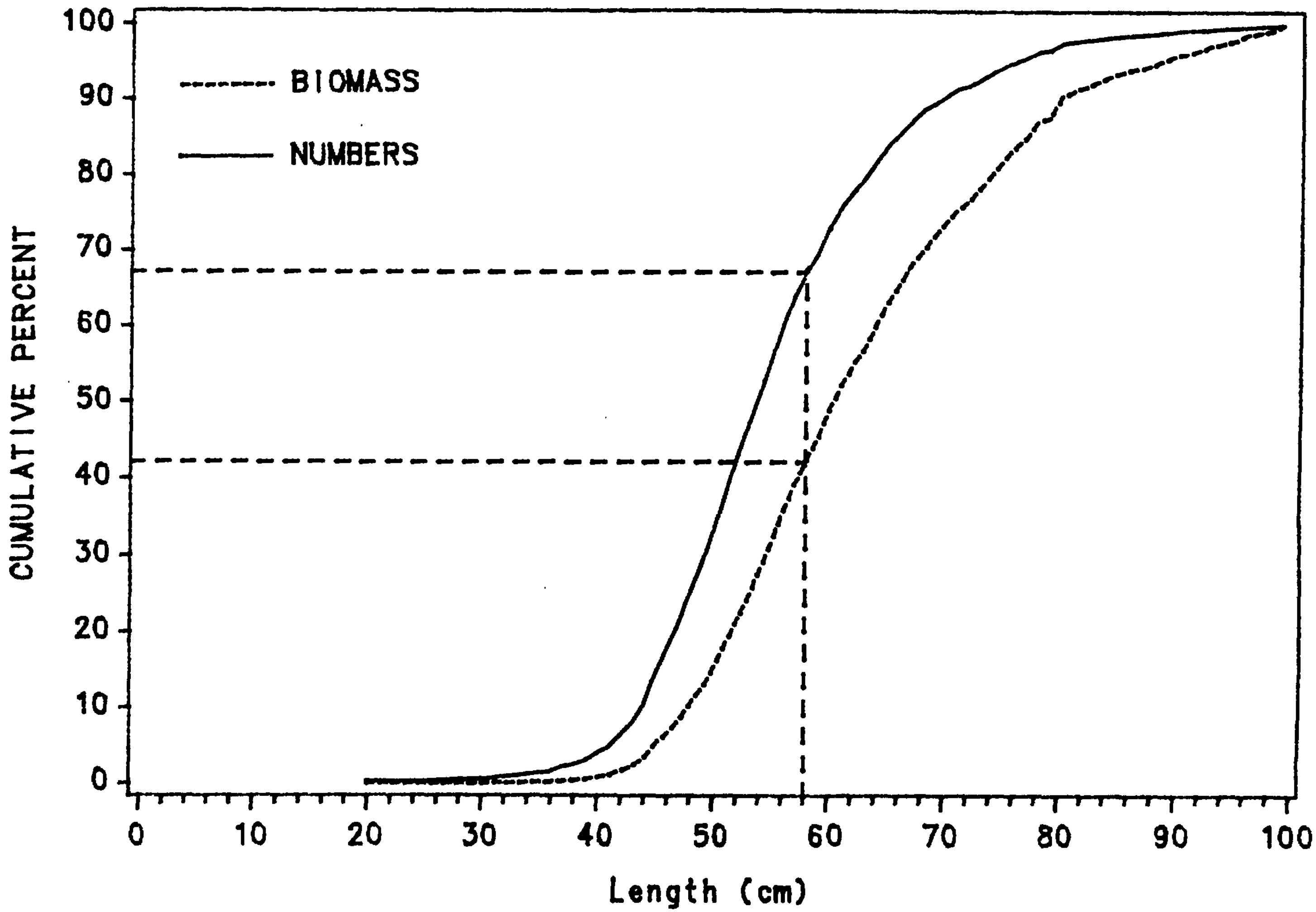

Fig. 2.4. Cumulative length-frequency distributions by number and biomass for lingcod caught in the sport fishery, 1983-87 (N=1376). The dashed lines indicate the proportions of the catch by number and biomass less than the commercial size limit of 58 cm.

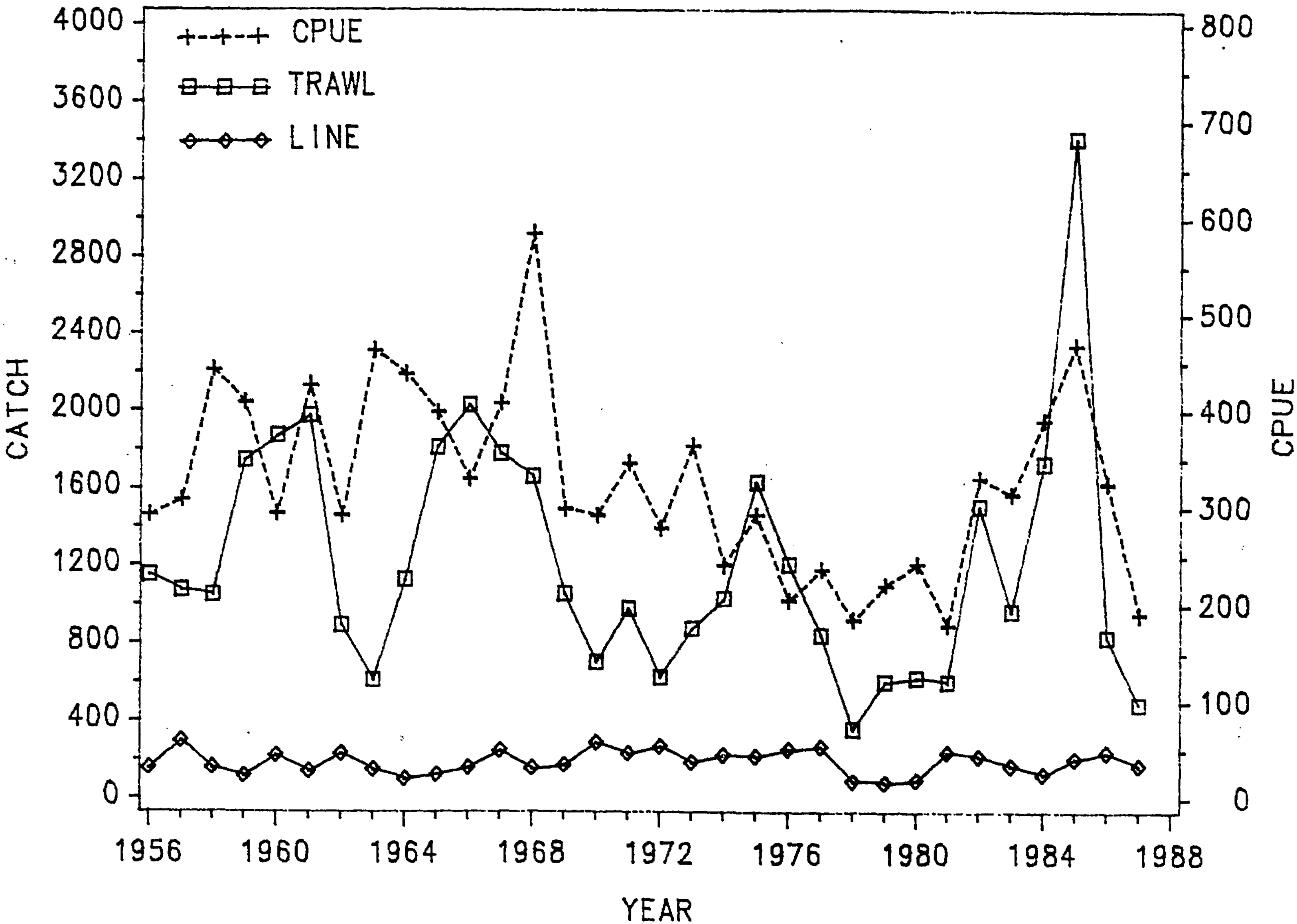

Fig. 2.5. Nominal lingcod trawl catch, line catch, and CPUE for Area 3C, 1956-87.

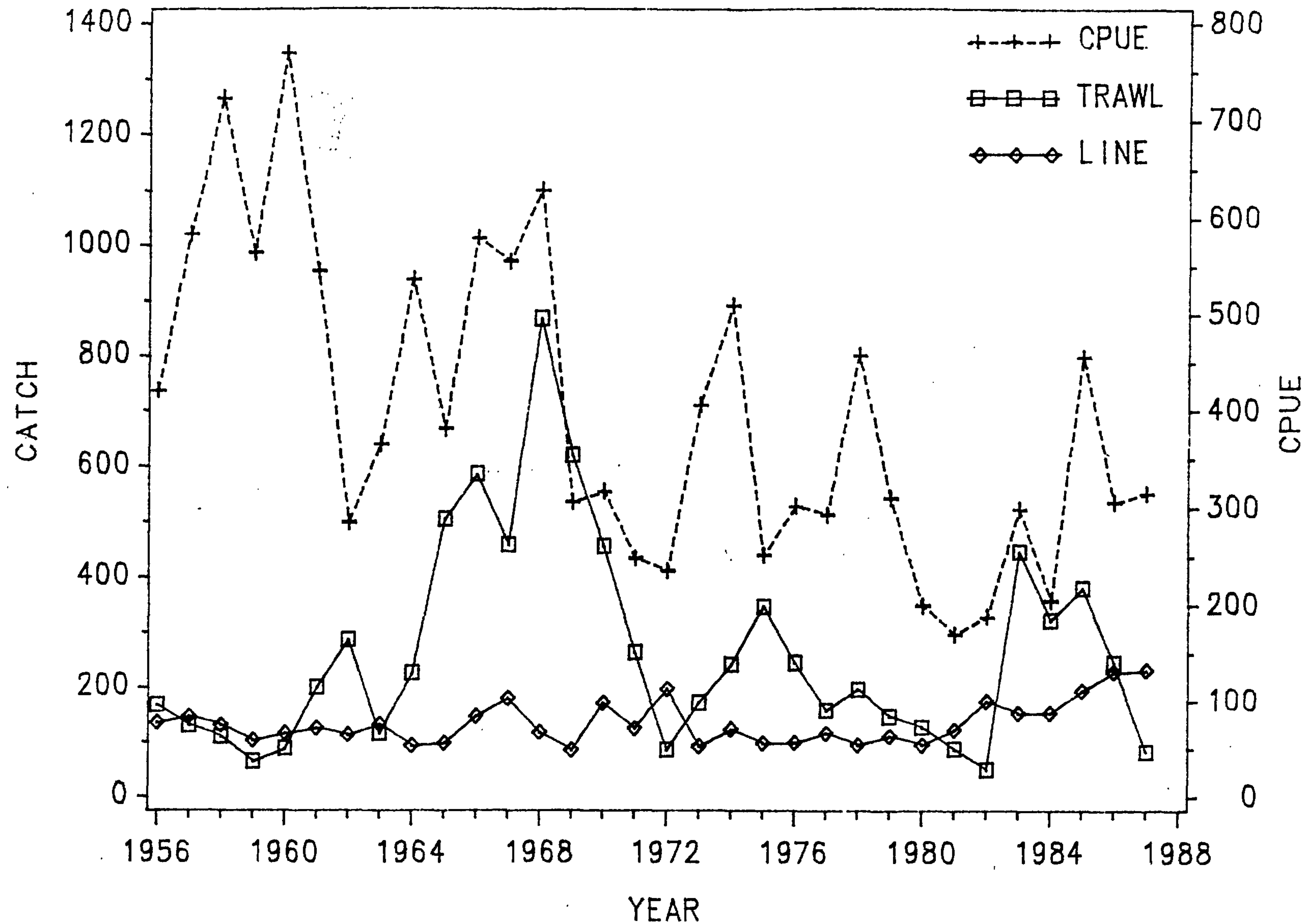

Fig. 2.6. Nominal lingcod trawl catch, line catch, and CPUE for Area 3D, 1956-87.

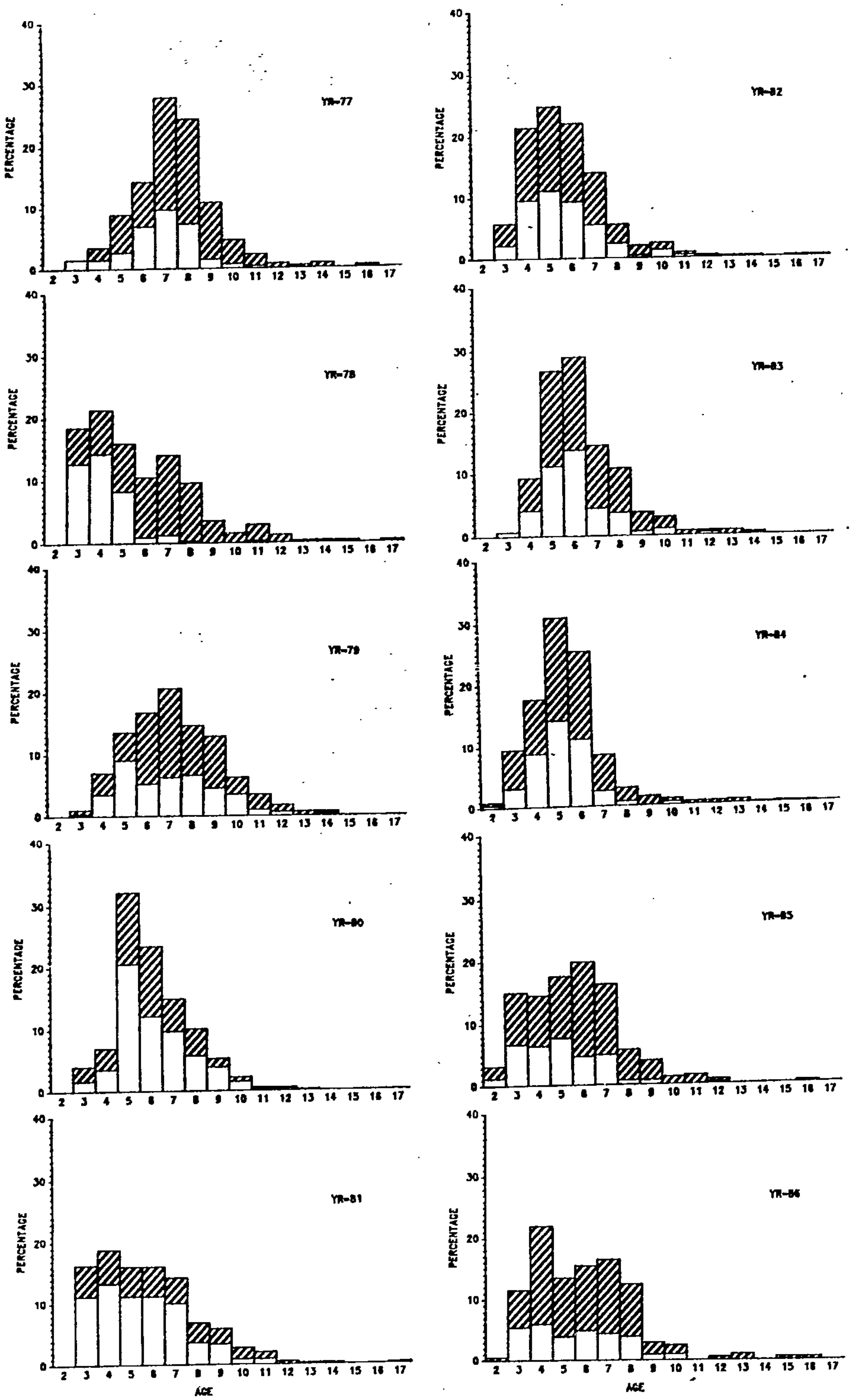

Fig. 2.7. Age-frequency distribution of the Area 3C lingcod catch, 1977-86. Open areas represent males and hatched areas females.

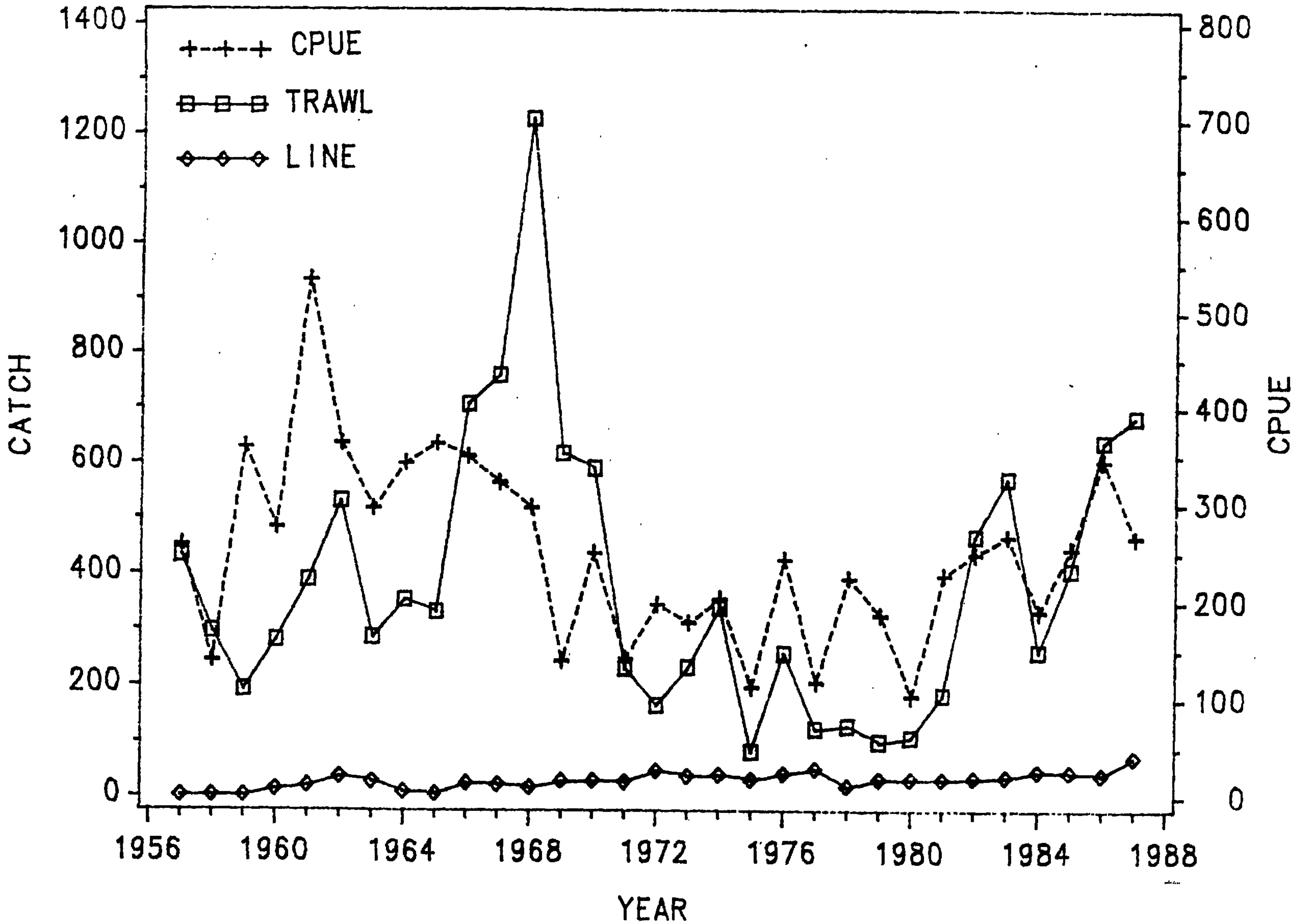

Fig. 2.8. Nominal lingcod trawl catch, line catch, and CPUE for Area 5A/B, 1956-87.

3.0. PACIFIC COD

A.V. Tyler and R.P. Foucher

3.0.1. General Introduction

Pacific cod (Gadus macrocephalus) continues to be a major component of the domestic, on-bottom trawl fishery. The 13,500 t of Pacific cod landed in 1987 was exceeded only by the landings of Pacific hake at 60,500 t. The landed value of $8.5 million for Pacific cod ranked third after sablefish ($11.8 million) and Pacific hake ($9.3 million). In Canadian waters, Pacific cod is close to the southern limit of its commercial abundance and exhibits rapid growth and a short life span. Recruitment begins at age 2, most are recruited and mature at age 3, and few survive to age 7. Year-class strength varies considerably resulting in a wide variation in annual landings (Fig. 3.1).

Among regions, cod production is greatest in the most northerly, Hecate Strait, and negligible off the west coast of the Queen Charlotte Islands. Cod production continues to be high due to the presence of the strong 1985 year-class. This is in spite of the presently poor market conditions.

3.1. Coastwide

Pacific cod were not treated as a coastwide stock.

3.2. Georgia Strait and vicinity (Area 4B)

3.2.1. Introduction

No new analyses have been conducted since a detailed stock assessment was carried out in 1986 (Westrheim and Foucher 1987). Nominal catch (landings) during 1987 were 1015 t, an increase of 26% over 1986 (Table 3.1). Landings during January-June 1988 were 425 t, up 23% over the same period in 1987.

3.2.2. Landing statistics

Landings were compiled and reported by calendar year as for the other areas. Equivalent effort was calculated by dividing the landings by the nominal CPUE. For each year the CPUE was calculated over a period including the previous fourth quarter and the first quarter of the year in question. Interviewed landings were divided by interviewed effort. These were selected using a 40% qualification level as described in Westrheim and Foucher 1987. This was done to avoid splitting the main period of the fishery (October-March) between two years. Also, the amount of fish present during the fishery in these quarters gives an indication of the parent stock that will produce the new year-class. This is the first year that the data have been compiled in this way.

By Minor Statistical Area, landings increased in all areas except Area 14 in 1987 compared to 1986. The largest increase (54%) occurred in Area 20 (Strait of Juan de Fuca). In January-June 1988 landings decreased, relative to January-June 1987, in all areas except Area 19 where they increased by 460%.

3.2.3. Yield options

Regulation does not appear to be necessary at this time. There are no symptoms of recruitment overfishing and current minimum mesh-size is reasonably satisfactory with respect to optimizing catch profitability (Westrheim and Foucher 1987).

3.3. West Coast of Vancouver Island (Areas 3C and 3D)

3.3.1. Introduction

Pacific cod is the principal shelf species sought by the on-bottom trawl fishery off the west coast of Vancouver Island. Area 3C produces approximately 90%, and Area 3D, 10% of the total nominal catch (landings) for the two areas combined. Within Area 3C, principal trawling grounds are Amphitrite Bank (53% of Area 3C landings), Big Bank (28%), and Swiftsure Bank (14%) (Foucher and Westrheim 1984). Amphitrite Bank is a major spawning ground for cod, and 77% of its production historically (prior to 1980) occurs during January-March. Big Bank and Swiftsure Bank are feeding areas with production occurring primarily during April-September -- 79% and 89%, respectively. The trawl fishery on spawning cod began about 1961, assumed considerable importance after 1971, and has been subject to various conservation regulations since 1977.

3.3.2. Landing statistics

Landing statistics are based on Foucher (1987) for detailed records by ground. Effort was allotted to the mixed-species fishery using the method of Westrheim (1983), and standardized according to the method of Westrheim and Foucher (1985a). Essentially, the standardization was a linear function utilizing vessel horsepower as the single factor in the regression. Representative nominal CPUEs for the region were derived from Canadian records for Big Bank, April-September. Landings, effort and CPUE have all fluctuated substantially (Table 3.2; Fig. 3.2). Landings to June 30, 1988 are 1000 t compared to 674 t for the same period in 1987.

3.3.3. Age composition

Age compositions are derived from length frequencies for Canadian cod landings using the method of Foucher and Fournier (1982). Age-classes 2-4 predominate in the landings, and few cod landed from the west coast of Vancouver Island are older than age 7 (Table 3.2). Recruitment is considered complete at age 3 under present fishery conditions. Year-class abundance during 1962-86, based on CPUE at age 2, fluctuates substantially--0.8 cod/h in 1985 to 125.6 cod/h in 1971. Data prior to 1962 are questionable due to the dissimilarity of the Canadian and U.S. trawl fleets at that time, and the absence of detailed records of the catches by U.S. vessels. Possible problems with accurately determining the proportions of older groups were pointed out by Westrheim and Foucher 1985b.

We plotted the length-frequency distributions of 3C cod for the second quarter of the year for the past three years (1986-88) in order to look at the relative abundance of the recruiting age-2 and age-3 fish (Fig. 3.3). The long-term mode of the age-2 fish was taken at approximately 44 cm, and the modal length of the age-3 fish at 55 cm (Ketchen 1964). It was clear that in 1986 there were few age-2 and age-3 fish as compared to 1987, when there was an abundance of 2-year-olds from the 1985 year-class. By 1988 the 1985 year-class was showing as an abundance of 3-year-olds.

3.3.4 Mortality rates

The derivation of mortality rates previously described (Foucher and Tyler 1988) resulted in best estimates for this area of:

Instantaneous fishing mortality rate	0.50
Instantaneous natural mortality rate	0.69
Instantaneous total mortality rate	1.19

The natural mortality rate was rounded to 0.7 for following analyses. The age determination process is still under study. A comparison of age compositions derived by the length-frequency method, which was used to produce the time-series of ages used, and the fin-ray method is in progress.

3.3.5 Virtual population analysis

A virtual population analysis (Gulland 1983) was undertaken utilizing the mortality rates estimated for ages 4-5: terminal F at age 7 = 0.5; M = 0.7 for all ages. Terminal F was allowed to vary around 0.50 by first calculating an overall q:

$$q = F / \bar{E}, \quad \text{where } \bar{E} = \text{mean effort}$$

and then calculating terminal F for each year:

$$F = q * E, \text{ where E is the effort for that year.}$$

This allowed the terminal F value to vary with effort which is more realistic than holding it constant for all years. Estimated numbers present (for age-classes represented by ages 2-7 -- 1954-79) at age 2 ranged from 0.8 million in 1982 to 9.1 million in 1971 (Table 3.3). Mean values of F by age-class were 0.08, 0.35, 0.55, 0.66, 0.68, and 0.50 for ages 2-7, respectively (Table 3.4). Mean exploitation rates for the time series were 0.06, 0.21, 0.30, 0.34, 0.33, and 0.28 for ages 2-7, respectively (Table 3.5).

3.3.6. Condition of the stock

The beginning of a fishery concentrating on spawning cod on Amphitrite Bank coincided with the start of a relatively steady decline in abundance after the early 1970s. In response to this heavy fishing pressure, a predictor was developed to forecast the probable January-March landings from Area 3C. This was based on the landings from the previous second and third quarters (Ketchen 1980). Since 1977, various conservation regulations have been imposed during January-March which have substantially reduced trawling effort and landings in most cases.

Later, Big Bank, April-September was chosen as the representative area-time cell from which to calculate CPUE for Area 3C as a whole (Foucher and Westrheim 1984), and this has subsequently been used as an abundance index for the Area 3C stock. The index increased from 37 kg/h in 1986 to 126 kg/h in 1987. Data for 1988 indicate it may be continuing to improve. CPUE for April-June 1988 is 268 kg/h, due in large part to the 1985 year-class.

There are problems which could potentially affect the usefulness of this abundance index. Because the index is based on data from a limited area (Big Bank) and time (April-September), the quality of information on the fishery in this area-time is very important. Only landings for which information on depth and effort is available can be included. This information is obtained during interviews with trawl captains. Due to time and distance and other factors it is often not possible for the port samplers to conduct interviews. This can lead to the use of a small proportion of the landings to estimate abundance. For example, during April-September 1987 interviews only accounted for 50% of the landings by weight from Area 3C. Of these interviewed landings, 46% were from Big Bank. A further problem--non-reporting of depth eliminated a further 22% of these, resulting in a CPUE estimate finally based on only 18% of the landings (122 t). This combination of low interview coverage and non-reporting of depth greatly reduces the certainty that can be placed in the abundance index. If this situation continues past the current high abundance period or if it increases in the future it could warrant more conservative recommendations to management in the future.

On the basis of the current condition of the stock and the state of the fishery and it's markets it would seem reasonable to re-assess the closure that has usually been imposed on the Area 3C winter fishery. A history of the closures and associated landings follows:

			Area 3C landings		Big Bank CPUE for	
Year	Closed period(s)	Total no. days open	Jan-Mar[a] (t)	Jan-Dec (t)	Previous Q2-3	Following Q2
1978	Feb 22 - Apr 3	53	895	1878	146	194
1979	Feb 1 - Mar 31	31	303	1677	167	212
1980	Jan 1 - Mar 31	0	1	977	220	131
1981	Jan 1 - Mar 31	0	5	856	124	39
1982	Jan 1 - Jan 31	59[b]	624	1086	60	24
1983	Jan 1-20, Feb 6-17	58	113	674	35	85
1984	No closure	91	290	643	66	42
1985	Jan 1 - Mar 31	0	124	449	33	11
1986	Jan 1 - Mar 31	0	44	424	13	26
1987	Jan 1 - Mar 31	0	18	747	37	200
1988	Jan 15-31, Feb 15-29, Mar 15-31	42	561	1289[c]	126	268

[a]The closure, in some years, did not include all of Area 3C.
[b]In February and March 1982 a trip limit of 50,000 lb per trip with two trips allowed per boat per month was imposed.
[c]Landings on record as of September 2, 1988 only.

The CPUE for the April-September index period reached its lowest point in 1985, one year after the last of three consecutive winter openings (1982-84) and then began to recover in response to a strong year-class, possibly contributed to by the more strict conservation measures starting in 1985. The higher CPUE in quarters 2-3 of 1987 (126) suggested that CPUE would be good for the first quarter of 1988. However, because this was from only one age-class and the stock was so low, only a partial opening was implemented. The resulting landings were 561 t. The CPUE of the following quarter 2, which was the highest since 1972, indicated that the recovery was being sustained and suggested that the stock was no longer in need of protection. The indicator will continue to be monitored and, due to the short life-span of a cod year-class in the fishery, regulations to limit catch may have to be imposed again in the future.

3.3.7. Yield-per-recruit analysis

The optimal yield-per-recruit was investigated using a minimum commercially acceptable size of 41 cm, a mesh size of 5.3 in. and natural mortality rates of 0.6, 0.7, and 0.8. The low minimum commercial size reflects the recent trend of plants to utilize the abundance of fish from the 1985 year-class which might otherwise be discarded at sea. The mesh size is an average of codend mesh sizes currently in use by the fleet. The resulting yield-per-recruit vs F curve for M = 0.7 (Fig. 3.4) rises rapidly from the origin as F increases and then levels out, showing very little variation in yield-per-recruit above F = 0.6. At a lower value of M (0.6) yield-per-recruit rises more rapidly to a higher level, peaks at F= 0.6 and then drops gradually as F increases. Higher values of M (eg. M = 0.8) lead to less yield per recruit as more fish die of natural causes.

3.3.8. Yield options

With the stock appearing to be strong it does not appear necessary to impose a spawning season closure for the first quarter of 1989 as has been done in recent years.

3.4. Queen Charlotte Sound (Areas 5A and 5B)

3.4.1. Landing statistics

Nominal catch (landings) in 1987 was 3264 t from 5A and 5B combined (Table 3.6), an increase of 1254% from 1986 landings. This is the highest recorded annual landing from Queen Charlotte Sound to date. Landings in 1988 are decreasing from these high levels. In 1988, January-June landings were 811 t compared to 1731 t in 1987.

3.4.2. Condition of the stock

The five samples collected during 1987 show that the 1985 year-class made up the majority of the landings. For five port samples collected and aged during 1987 the percentage at age 2 varied from 78 to 99%.

The 1984 assessment (Westrheim and Foucher 1985b) indicated that there was little danger of recruitment overfishing because of extensive, rough-bottom refuges from trawling. However, the dramatic drop in landings from 1987 levels indicates that the very high catch levels may have harvested much of the 1985 year-class during their first year in the fishery leaving few of them to contribute as age-3 fish. The increased use of sophisticated plotters is making it easier to fish previously unfished areas.

A recent study (Westrheim 1987) indicated differences between cod in Areas 5A and 5B in such measures as mortality rate and mean length at age. These differences may be related to the difference in rate of incidence of parabranchial lesions between the two areas. It has been suggested, but no cause and effect has been established, that the high concentration of sea lions in Area 5A may be a factor in the different rate of infection. (Westrheim 1987). The difference in parameters between the two stocks of cod may be simply a result of the effects of the infection.

3.4.3. Yield options

No recommendation is made for the fishery in Queen Charlotte Sound.

3.5. Hecate Strait (Areas 5C and 5D)

3.5.1. Introduction

With the strong 1985 year-class entering the fishery, 1987 nominal catch (landings) returned to a level exceeded only during the boom years 1965-66. Landings during 1988 are also at a high level and might have been higher still except for the poor market conditions for Pacific cod fillets.

3.5.2. The fishery

Landings from Hecate Strait are divided between two major areas and several important grounds (Fig. 3.5). The percentage distribution of landings (based on interviewed landings) historically (1956-87) and for 1987 were as follows:

	1956-87	1987
Horseshoe	18.6	21.4
Ole Spot	4.5	0.3
Reef Island-Cumshewa	3.6	3.7
Other Area 5C	3.8	3.3
Area 5C total	30.5	28.7
Two Peaks-Butterworth	33.6	34.9
White Rocks-Bonilla	17.8	31.1
Shell	3.8	4.6
Other Area 5D	14.3	0.7
Area 5D total	69.5	71.3
Areas 5C + 5D total	100.0	100.0

3.5.3. Landing statistics

Effort (Table 3.7; Fig. 3.6) was fairly constant up to the mid-1960s, after which there was a series of irregular oscillations, likely in response to strong year-classes. Since 1982, effort has remained fairly constant at below 8000 h. Landings have also oscillated and show a pattern similar enough to that for Areas 3C and 3D to suggest that factors with a coastwide influence may be involved. Interestingly, effort has generally peaked about two years after landings have peaked, suggesting a lag time in the response of the fishery to changes in abundance. Nominal CPUE also oscillated but not synchronously with landings. A long, low period in landings and CPUE has ended with the entry of the strong 1985 year-class. The higher level of production is continuing into 1988. Landings to June 30, 1988 are 4973 t compared to 5479 t for the same period in 1987. Mean landings for Jan 1-Jun 30 over 1956-87 is 2394 t.

3.5.4. Age composition

Annual age composition in numbers landed per hour trawled (Table 3.7) shows that ages 2-4 are most important to the fishery. Recruitment of age-2 fish begins historically in the spring, but more recently in the winter. In recent years, recruitment is complete by age 3, but in the past by age 4. Strong year-classes, based on CPUE at age 2 (>100/h), are 1960-62, 1965, 1970-72, 1977 and 1985, which, by this measure, is the strongest year-class observed in this time-series. There is evidence that the 1986 year-class is also strong.

We plotted the length-frequency distributions of the combined cod samples of 5C and 5D, for the first quarter of the year, for each of 1986-88 to look at the relative abundance of the recruiting age-2 and age-3 fish (Fig. 3.7). We used the first quarter in this case because in Hecate Strait there was a substantial fishery during this quarter (this was prevented by regulations for the SW Vancouver Island area, and so, in that area, we examined the second quarter data--section 3.3.3). Again the long-term mode was taken at 44 cm for age-2's, and 55 cm for age-3's (Ketchen 1964). In 1986 there were relatively few age-2 and age-3 fish due to the poor recruitment in 1984 and 1983. The 1987 length frequency was quite different from the 1986 data, and showed an enormous influx of age-2 fish from the 1985 year-class. By the first quarter of 1988, this year-class still dominated the catch, despite the record catches that were taken during 1987. Yet it was clear that there was a substantial, new recruitment of age-2 fish from the 1986 year-class, indicated by the relatively large number of fish at approximately 44 cm.

3.5.5. Mortality rates

The method of calculation of mortality rates was reported in Foucher and Tyler 1988. The best estimates of the parameters were considered to be those for ages 4-5: $M = 0.61$ and $F = 0.52$. These were rounded to $M = 0.6$ and $F = 0.5$ for the following analysis.

3.5.6. Virtual population analysis

Virtual population analysis was carried out as described in section 3.3.5. The VPA estimates of cod at age 2 ranged from 2.8 million in 1968 to 35.5 million in 1987 (Table 3.8). Mean values of F by age-class were 0.13, 0.38, 0.57, 0.60, 0.62 and 0.50 for ages 2-7, respectively (Table 3.9). Mean exploitation rates were 0.09, 0.23, 0.33, 0.34, 0.33, and 0.29 for ages 2-7, respectively (Table 3.10).

3.5.7 Calibration of nominal CPUE values using VPA

One of the most useful aspects of VPA is that the results are expressed in terms of absolute numbers-at-age. Because the procedure involves back-calcuations on the catches, however, these estimates are not available for the current year, last year, or over a series of recent years. The length of the series depends on the intensity of the fishery, and how many years it takes accumulated F on a cohort to reach a total of 2.0 or more (Pope 1972). Stock assessment biologists have sometimes moved around this obstacle to absolute estimates by regressing numbers at age (from VPA) on CPUE from either the commercial fishery or from research surveys. They then use the relationship to re-scale the most recent CPUE-at-age figures to number-at-age. To be sure, these estimates are not as good as true VPA estimates, and are worse than the original CPUE figures in that they incorporate extra measurement error and process error. Still the procedure gives the modeller some time-advance for yield estimation.

We have carried out a series of regressions to find which ages supply the tightest relationship between VPA numbers and CPUE (kg/h) for Hecate Strait Pacific cod.

Equation	Year range	No. years	r^2
VPA2 = 3918 + 21.4 CPUE2	1961 - 82	22	60.5*
VPA3 = 1334 + 12.7 CPUE3	1961 - 83	23	86.0*
VPA4 = 479 + 9.6 CPUE4	1961 - 84	24	78.5*
VPA5 = 233 + 6.6 CPUE5	1961 - 85	25	23.9

* Indicates significance at the 0.05 level.
VPA2 and CPUE2 are age-2 specific values.

Because of the high r^2 value, we chose the age-3 regression to scale CPUE at age-3 to numbers at age-3. The scatter plot with regression line (Fig. 3.8) gives some reason for optimism. The converted age-3 CPUE values, in thousands of fish, for 1984 to 1987 are, respectively: 1944, 1726, 1919, 2427. Note the increase in the age-3 fish from the 1984 year-class, perhaps indicating a somewhat larger 1984 year-class as compared to 1981 through 1983. Whether this re-scaling of CPUE values is at all accurate will be tested as true VPA values for these year-classes become available.

3.5.8. Evaluation of port sampling intensity

As has been mentioned, for each of the three regions, there is a degree of uncertainty with the age determination process. This uncertainty is difficult to resolve without growth data for fish of known age. Pacific cod grow, enter and pass through the fishery so quickly that it is difficult to anticipate tagging opportunities--an incoming strong year class--and launch a tagging program. Mortality rates are so high that many fish need to be tagged. From 1000 fish tagged at age-1 the number that could be expected to be caught at age-4 would be 4 fish. Mortality due to tagging procedures and non-reporting of tags would further reduce the number of tag returns. Other lines of investigation are looking for ways to provide a degree of validation for the age determination process aside from tagging. Up to this point, the ageing method has been used with recognition of possible inaccuracies but no way to measure them.

Another aspect of the age determination process that has not been examined is the representativeness of individual samples. The degree to which samples from different, individual landings vary from each other, or from an assumed, real distribution, gives some indication of the precision of sampling. This can be determined for time periods with multiple samples by comparing individual samples (using a chi-square test) to the sum of all samples which is assumed to represent the population length frequency. We chose samples from landings from Two Peaks-Butterworth ground. For each test, the individual sample is excluded from the total to which it is being compared. A chi-square test is used to test the hypothesis that there is no significant difference between the individual sample and total length frequency. Length frequencies were grouped by 3-cm intervals for the tests. For eight time periods summarized below, a total of 41 out of 54 samples (76%) were significantly different (at the 95% confidence level) from the total length frequency to which they were being compared.

Year	Month(s)	Number of samples	Number of individual samples significantly different from total
1959	Jul	6	5
1960	Aug	8	7
1961	Apr	8	6
1961	Jul	6	2
1965	Jul/Aug	6	4
1979	Jul/Aug	8	7
1984	Jul/Aug	7	6
1987	Aug	5	4
Total		54	41

This high degree of variability among samples in one time period leads to the question: what is the average number of samples, randomly selected within a time period, that are required to produce a combined length frequency not significantly different from the total? This was investigated for each of the sample sets above.

For each set, various numbers of samples were selected randomly with replacement and the length frequencies were combined. The resulting sample length frequency was compared to the original, total length frequency using a Chi-square test. This was repeated 1000 times for each level and, for instance, if in 800 tests the sample length frequency was not significantly different from that of the total, then that level of sampling was described as having an 80% probability of producing a sample distribution representative of the total.

The results for two of the time periods (July 1961 and 1965) showed a greater than 80% probability at all levels of sampling of a significant difference between the sample and total length frequencies. In these samples, the length frequency was unimodal with little contribution from smaller or larger fish from adjacent year-classes.

For the remaining six time periods, the average probability of samples being not significantly different from the total ranged from 33 to 61% for levels of sampling varying from one sample per time period to a number of samples equal to the number making up the total length frequency (e.g., 6 in July 1959, 8 in August 1960, etc.).

There is so much variablility in sample length frequencies that the actual level of sampling in the years examined would produce representative length-frequency distributions less than half the time. The present level of sampling for most important areas and time periods is generally much less than this. Recent levels of sampling by important grounds and quarters in Hecate Strait were:

Area	Time period (1988)	No. of samples
Horseshoe	April-September	1
Two Peaks-Butterworth	April-September	0
White Rocks-Bonilla	January-March	2

While it is important, as far as possible, to validate the age determination procedure, the validity of assessments based on age composition data depend heavily on the representativeness of samples included. Our study showed that there is a large variability among samples. It is quite possible that the degree of error due to the level of sampling often exceeds that due to error in the age determination method. Especially for the many years when sampling was minimal, the results of mortality rate calculations, virtual population analysis etc., could contain a high degree of measurement error.

3.5.9. Condition of the stock

The abundance index for Pacific cod in Hecate Strait, calculated from the CPUE from Horseshoe and Two Peaks-Butterworth during April-September indicates an increase in abundance. The index increased from 535 kg/h in 1986 to 1126 kg/h in 1987. Data for 1988 indicate a decline. CPUE for April-June 1988 is 622 kg/h. The 1987 CPUE is 165% of the long-term mean (1956-86) level and the 1988 CPUE is 91% of the long-term mean.

The problems noted in section 3.3.6 regarding the representativeness of the CPUE index do not exist to an appreciable extent in this area. Interview coverage for Areas 5C and 5D have each been over 97% for both 1987 and 1988. The percentage of interviews that lack information on depth of capture is only 3-4%.

3.5.10. Yield-per-recruit analysis

The optimal yield-per-recruit was investigated using natural mortality rates of both 0.4 and 0.6 and other parameters as described in section 3.3.7. The resulting yield-per-recruit vs F curve for M = 0.6 (Fig. 3.9) rises rapidly from the origin and then shows very little variation in yield-per-recruit above F = 0.5. At a lower value of M (0.4) yield-per-recruit rises even more rapidly from the origin to a higher peak at F= 0.4 and then drops off steadily. The mean historic F was estimated at 0.52, giving support to the hypothesis that the fishery has been self-regulating in terms of yield-per-recruit.

3.5.11. Yield options

The recommendation last year was that there be no quota or other restrictions to the fishery. The CPUE in 1986 was the highest for the previous ten years and in 1987 increased again, by 177% over 1986 levels due to the strong 1985 and 1986 year-classes entering the fishery. These year-classes are contributing strongly to the 1988 fishery and their effects should still be felt in 1989. Mortality rates are such, however, that by the 1990 fishery there will be little significant contribution from the 1985 year-class. We again recommend no quota for the 1989 fishing year.

Table 3.1. Canadian annual nominal catch (landings), standardized equivalent effort and nominal CPUE for Pacific cod from the Strait of Georgia and vicinity (Area 4B), 1954-87.

Year	Landings (t)	Effort (h)	Nominal CPUE (kg/h)
1955	967	4241	228
1956	578	2664	217
1957	607	2317	262
1958	650	2579	252
1959	1047	3573	293
1960	744	3429	217
1961	415	2207	188
1962	479	2957	162
1963	677	3063	221
1964	713	4818	148
1965	484	2327	208
1966	297	2034	146
1967	475	1218	390
1968	349	2424	144
1969	388	3104	125
1970	502	2758	182
1971	740	2671	277
1972	630	1848	341
1973	441	1909	231
1974	681	1946	350
1975	991	3871	256
1976	927	3708	250
1977	1148	3679	312
1978	1373	4702	292
1979	1197	3627	330
1980	1606	7333	219
1981	1742	6500	268
1982	1011	3663	276
1983	907	3961	229
1984	652	2739	238
1985	463	1498	309
1986	803	2136	376
1987	1015	2178	466

Table 3.2. Canada-U.S.[a] annual nominal catch (landings), standardized equivalent effort, nominal CPUE and CPUE by age (number per hour), for Pacific cod from the west coast of Vancouver Island (Areas 3C+3D), 1956-87.

Year	C-US land (t)	C-US eff (h)	C-US CPUE (kg/h)	Age 1	2	3	4	5	6	7	8	9
1956	1468	9009	163	-	8.6	21.1	19.9	9.0	0.8	0.6	0.3	-
1957	1814	13538	134	-	16.3	19.2	10.2	5.9	1.4	0.3	0.1	0.
1958	850	7659	111	-	1.8	34.7	6.3	2.7	0.5	0.2	-	-
1959	907	20155	45	-	1.3	6.4	5.5	1.3	0.1	0.1	-	-
1960	635	10079	63	-	0.4	13.7	7.2	2.2	0.4	-	-	-
1961	420	19998	21	-	0.5	1.6	3.8	1.7	0.1	0.1	-	-
1962	633	16230	39	-	13.9	3.5	2.2	0.9	0.2	-	-	-
1963	1231	9770	126	-	33.9	17.5	7.2	1.5	0.2	0.2	-	-
1964	1221	3569	342	-	23.1	47.8	38.9	19.0	7.2	0.9	0.5	-
1965	2768	12361	224	-	15.4	47.5	20.6	5.5	1.7	0.4	0.1	-
1966	3136	13108	239	-	16.2	49.7	23.7	6.3	2.3	0.4	-	-
1967	1941	24887	78	-	2.2	16.8	7.9	1.3	1.0	0.1	0.1	-
1968	1425	17378	82	-	3.7	15.0	6.7	2.8	1.0	0.4	0.1	-
1969	1092	15825	69	-	5.0	12.2	5.3	2.3	1.1	0.4	0.2	-
1970	1095	7879	139	-	28.9	19.2	13.0	3.5	0.7	0.2	0.1	-
1971	3328	6631	502	1.4	125.6	86.0	18.0	5.7	1.7	0.9	0.4	-
1972	5629	10846	519	0.9	113.3	86.8	27.6	7.6	1.4	0.7	0.4	-
1973	3712	17345	214	-	9.7	35.9	19.6	6.4	2.3	0.4	0.1	-
1974	3474	1 18094	192	-	27.2	13.0	23.2	8.9	2.4	0.9	0.4	0.
1975	4000	24847	161	-	13.8	36.2	9.2	4.3	2.1	0.3	0.2	-
1976	3797	21215	179	-	8.5	35.6	21.3	5.6	0.7	0.3	0.2	-
1977	2948	20192	146	-	11.5	21.0	16.0	5.3	1.8	0.5	0.2	-
1978	1998	1 11965	167	0.1	7.3	34.6	15.4	6.3	0.9	1.2	0.1	0.
1979	1861	1 8461	220	0.1	26.2	32.7	19.5	8.7	1.5	0.6	0.2	0.
1980	1152	1 9291	124	0.6	22.3	14.3	10.6	5.1	2.0	0.1	-	0.
1981	918	15298	60	0.3	4.8	19.4	2.7	0.6	0.6	0.3	-	-
1982	1123	32086	35	-	2.7	6.6	3.7	1.2	0.4	0.2	-	-
1983	694	10516	66	-	16.3	7.2	8.6	1.9	1.3	0.1	-	-
1984	675	20455	33	-	4.1	6.8	3.2	1.3	0.2	0.1	-	-
1985	493	37923	13	-	0.8	4.6	0.8	0.1	-	-	-	-
1986	498	13458	37	-	2.1	4.7	6.3	1.2	0.2	-	-	-
1987	810	6428	126	-	63.8	6.3	7.4	6.0	0.6	-	-	-

[a]No U.S. landings after March 31, 1981.

Table 3.3. Virtual population analysis estimates of numbers-at-age (thousands) of Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), for age-classes 2-7, 1956-87. (Asterisks indicate estimates considered inaccurate -- cumulative F for year-class less than 2.0 -- Pope 1972.)

	Age					
Year	2	3	4	5	6	7
1956	1577	766	513	202	36	27
1957	1990	729	252	135	47	13
1958	1542	838	190	36	16	11
1959	2398	755	238	62	5	5
1960	1733	1174	286	45	14	1
1961	2548	855	488	93	8	4
1962	3193	1257	401	191	24	2
1963	4403	1435	585	175	86	9
1964	4868	1956	594	242	77	41
1965	4403	2365	855	201	74	21
1966	3994	2049	778	254	55	22
1967	3009	1844	581	182	71	8
1968	2585	1451	634	159	68	19
1969	4622	1239	541	236	46	22
1970	6332	2241	483	213	91	11
1971	9143	2990	1007	170	86	42
1972	8129	3948	1094	418	59	35
1973	6230	3193	1320	343	151	19
1974	8025	2985	1163	428	96	49
1975	5526	3656	1321	298	106	20
1976	4213	2517	1202	500	76	18
1977	3500	1975	743	295	168	27
1978	1889	1573	691	156	75	58
1979	1799	879	504	219	28	30
1980	1990	740	251	140	60	6
1981	1486	850	276	59	38	17
1982	809	687	225	109	23	12
1983	1151	342	199	34	27	4
1984	1948*	453	118	39	4	5
1985	826*	907*	131	16	3	0
1986	417*	387*	330*	44	4	1
1987	7023*	188*	150*	107*	11	1

Table 3.4. Virtual population analysis estimates of fishing mortality rate (F) for Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), for age-classes 2-7, 1956-87.

	Age					
Year	2	3	4	5	6	7
1956	0.07	0.41	0.64	0.75	0.34	0.30
1957	0.17	0.64	1.24	1.45	0.80	0.45
1958	0.01	0.56	0.42	1.35	0.45	0.25
1959	0.01	0.27	0.97	0.78	1.32	0.66
1960	0.01	0.18	0.42	1.01	0.53	0.33
1961	0.01	0.06	0.24	0.65	0.59	0.66
1962	0.10	0.06	0.13	0.11	0.23	0.53
1963	0.11	0.18	0.18	0.12	0.04	0.32
1964	0.02	0.13	0.38	0.48	0.60	0.12
1965	0.06	0.41	0.52	0.60	0.50	0.41
1966	0.07	0.56	0.75	0.57	1.22	0.43
1967	0.03	0.37	0.60	0.28	0.61	0.82
1968	0.04	0.29	0.29	0.54	0.42	0.57
1969	0.02	0.24	0.23	0.25	0.71	0.52
1970	0.05	0.10	0.35	0.20	0.09	0.26
1971	0.14	0.31	0.18	0.36	0.20	0.22
1972	0.23	0.40	0.46	0.32	0.42	0.36
1973	0.04	0.31	0.43	0.57	0.44	0.57
1974	0.09	0.12	0.66	0.70	0.89	0.60
1975	0.09	0.41	0.27	0.66	1.07	0.82
1976	0.06	0.52	0.70	0.39	0.32	0.70
1977	0.10	0.35	0.86	0.67	0.35	0.66
1978	0.06	0.44	0.45	1.03	0.22	0.39
1979	0.19	0.56	0.58	0.60	0.90	0.28
1980	0.15	0.29	0.75	0.60	0.54	0.31
1981	0.07	0.63	0.23	0.22	0.43	0.50
1982	0.16	0.54	1.18	0.68	1.13	1.06
1983	0.23	0.36	0.93	1.38	1.08	0.35
1984	0.06	0.54	1.29	1.93	2.44	0.67
1985	0.06	0.31	0.39	0.60	0.64	1.25
1986	0.09	0.25	0.43	0.67	1.43	0.44
1987	0.08	0.35	0.55	0.66	0.68	0.21

Table 3.5. Virtual population analysis estimates of annual exploitation rates for Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), age-classes 2-7, 1956-87.

	Age					
Year	2	3	4	5	6	7
1956	0.05	0.25	0.35	0.40	0.21	0.19
1957	0.11	0.36	0.55	0.60	0.41	0.27
1958	0.01	0.32	0.25	0.58	0.27	0.16
1959	0.01	0.17	0.47	0.41	0.57	0.36
1960	0.00	0.12	0.25	0.49	0.31	0.21
1961	0.00	0.04	0.16	0.36	0.33	0.36
1962	0.07	0.05	0.09	0.07	0.15	0.31
1963	0.08	0.12	0.12	0.08	0.02	0.20
1964	0.02	0.09	0.23	0.28	0.34	0.08
1965	0.04	0.25	0.30	0.34	0.29	0.25
1966	0.05	0.32	0.40	0.32	0.54	0.26
1967	0.02	0.23	0.34	0.18	0.34	0.42
1968	0.03	0.18	0.18	0.31	0.25	0.32
1969	0.02	0.16	0.16	0.16	0.38	0.30
1970	0.04	0.07	0.21	0.13	0.06	0.17
1971	0.09	0.19	0.12	0.22	0.13	0.14
1972	0.15	0.24	0.27	0.20	0.25	0.22
1973	0.03	0.20	0.26	0.32	0.26	0.32
1974	0.06	0.08	0.36	0.37	0.45	0.33
1975	0.06	0.25	0.17	0.36	0.50	0.42
1976	0.04	0.30	0.38	0.24	0.20	0.38
1977	0.07	0.21	0.44	0.36	0.22	0.36
1978	0.05	0.26	0.27	0.49	0.14	0.24
1979	0.12	0.31	0.33	0.34	0.45	0.18
1980	0.10	0.18	0.39	0.34	0.31	0.19
1981	0.05	0.35	0.15	0.15	0.26	0.29
1982	0.11	0.31	0.53	0.37	0.52	0.50
1983	0.15	0.22	0.46	0.58	0.50	0.21
1984	0.04	0.31	0.56	0.68	0.74	0.37
1985	0.04	0.19	0.24	0.34	0.35	0.55
1986	0.07	0.16	0.26	0.36	0.59	0.26
1987	0.06	0.22	0.32	0.36	0.37	0.14

Table 3.6. Canada-U.S. annual nominal catch (landings), standardized equivalent effort, nominal CPUE and CPUE by age (number per hour), for Pacific cod from Queen Charlotte Sound (Areas 5A + 5B), 1956-87.

Year	C-US land (t)	C-US eff (h)	C-US CPUE (kg/h)	Age										
				1	2	3	4	5	6	7	8	9	10	11
1956	1753	10017	175	-	37.9	28.1	7.3	0.2	2.4	-	-	0.3	-	-
1957	2744	4126	665	5.4	169.1	90.4	27.7	4.6	1.1	0.2	0.2	0.3	-	-
1958	1178	8536	138	-	9.2	23.3	12.2	3.6	0.5	0.4	0.1	-	-	-
1959	946	4204	225	0.1	31.7	31.4	14.8	5.1	2.1	0.4	0.2	-	-	-
1960	618	4718	131	-	3.1	15.9	11.7	5.1	2.2	0.6	0.2	0.1	-	-
1961	240	3478	69	-	2.3	5.7	4.9	4.4	2.2	0.2	0.3	-	-	-
1962	422	4220	100	-	15.7	6.6	6.6	4.0	4.7	2.6	0.9	0.2	0.1	-
1963	677	7693	88	0.2	15.7	10.5	6.8	0.9	0.4	0.1	0.1	-	-	-
1964	1275	4208	303	-	68.6	25.8	9.3	4.6	1.6	0.3	-	-	-	-
1965	1940	4321	449	-	23.0	60.6	51.5	4.1	4.9	1.1	1.1	-	0.1	-
1966	1811	7273	249	0.2	41.5	26.0	12.1	6.5	1.9	0.8	0.2	0.1	-	-
1967	1501	9500	158	-	12.3	16.6	10.5	4.6	2.8	1.7	0.6	0.3	-	-
1968	960	7273	132	0.2	18.7	11.7	10.9	5.6	1.1	0.2	0.2	-	-	-
1969	699	9197	76	0.2	7.2	7.8	6.9	1.9	1.5	0.6	0.3	0.1	-	-
1970	299	6954	43	0.1	8.9	6.2	1.8	0.6	0.2	0.1	0.1	-	-	-
1971	928	11457	81	0.4	17.6	3.6	2.1	2.2	1.4	0.9	0.2	0.1	-	0.1
1972	2320	11101	209	0.1	75.0	18.9	6.3	0.6	0.1	-	-	-	-	-
1973	1914	8583	223	0.2	13.0	25.0	38.2	1.1	0.6	2.1	-	-	0.6	-
1974	2292	10967	209	-	27.3	22.3	9.0	7.3	3.0	0.6	-	-	-	-
1975	2444	8698	281	0.2	66.1	40.1	12.8	4.7	0.4	1.2	-	0.2	-	-
1976	2271	10712	212	0.7	51.0	44.9	8.3	2.0	0.2	0.5	-	0.4	-	-
1977	1268	8745	145	0.9	61.0	21.2	5.9	2.1	0.7	0.4	0.3	-	-	-
1978	1959	7593	258	0.7	26.9	64.5	13.7	2.2	2.2	0.4	0.1	-	0.1	-
1979	1904	6949	274	1.1	83.6	19.9	12.0	5.5	-	0.4	-	-	-	-
1980	1335	6357	210	1.0	59.9	29.9	8.3	1.3	0.7	0.1	-	-	0.1	-
1981	858	5169	166	1.4	36.2	19.3	8.3	1.9	0.9	0.5	0.2	0.1	0.1	-
1982	603	5244	115	-	19.4	22.2	9.0	1.1	1.0	-	-	-	-	-
1983	183	6310	29	-	3.6	5.9	1.5	0.2	0.1	0.1	-	-	-	-
1984	382	5536	69	0.2	12.6	8.1	3.7	0.9	0.4	0.2	0.1	-	-	-
1985	299	4823	62	0.1	8.7	8.7	4.0	0.8	0.4	0.2	-	-	-	-
1986	241	4820	50	0.1	12.4	7.3	6.1	1.7	0.4	0.2	-	-	-	-
1987	3264	9802	333	1.2	192.5	9.8	2.0	1.0	0.3	-	-	-	-	-

Table 3.7. Canada-U.S. annual nominal catch (landings), standardized equivalent effort, nominal CPUE and CPUE by age (number per hour), for Pacific cod from Hecate Strait (Areas 5C+5D), 1961-87.

Year	C-US land (t)	C-US eff (h)	C-US CPUE (kg/h)	Age 1	2	3	4	5	6	7	8	9	10
1961	1616	4391	368	-	21.5	140.6	60.5	11.2	2.0	1.1	1.1	-	-
1962	1690	2735	618	2.0	101.9	153.6	87.9	40.7	16.1	4.8	1.5	1.2	-
1963	2927	3157	927	14.7	170.8	378.7	190.4	60.0	10.4	12.0	3.8	1.6	0.1
1964	5228	3050	1714	1.9	469.9	290.9	122.9	52.8	9.4	1.6	0.5	0.3	-
1965	9119	5500	1658	0.5	58.3	425.2	178.8	39.1	10.9	0.8	0.9	0.1	-
1966	9519	6671	1427	1.1	66.1	228.9	167.9	46.4	11.9	1.6	0.2	0.1	0.1
1967	5112	4755	1075	-	200.1	142.7	86.7	38.4	14.3	4.6	1.3	0.2	0.1
1968	5165	14074	367	0.3	8.1	109.3	27.8	13.5	6.4	1.6	0.5	0.3	-
1969	2959	12078	245	0.2	36.7	24.4	35.0	13.2	3.4	1.8	0.2	0.1	0.1
1970	1339	8868	151	-	15.1	45.1	14.2	3.1	1.9	0.7	0.3	-	0.2
1971	1474	6856	215	0.8	70.4	24.0	15.7	7.9	1.1	0.7	0.5	-	-
1972	2694	4177	645	0.5	238.7	81.9	45.5	14.3	2.4	2.0	0.4	0.9	-
1973	4003	3552	1127	7.4	206.9	239.0	81.6	19.3	10.9	1.9	0.5	0.6	0.2
1974	4764	4630	1029	0.5	250.1	100.4	80.4	26.3	6.9	1.0	0.6	0.5	-
1975	4982	8649	576	0.1	68.3	107.0	42.1	21.6	2.6	4.2	1.7	0.8	0.1
1976	5016	10582	474	0.2	47.1	106.3	29.1	10.4	4.1	1.9	0.2	0.3	-
1977	3523	10124	348	0.1	93.3	54.3	27.3	5.1	3.2	1.0	-	-	-
1978	2102	5904	356	3.6	13.5	76.8	37.1	10.9	1.6	1.2	0.3	-	-
1979	4695	10274	457	0.7	133.6	34.1	44.6	10.5	3.3	0.6	0.3	-	0.1
1980	4540	12473	364	0.5	57.3	75.1	28.5	7.9	2.6	1.0	0.2	0.1	-
1981	3182	15752	202	0.9	26.0	28.2	28.1	9.9	1.4	0.9	-	-	-
1982	2077	5409	384	0.7	41.4	72.4	32.9	10.2	2.9	0.6	0.2	0.2	-
1983	2717	6967	390	0.3	32.9	63.3	37.4	12.8	3.0	0.9	0.2	-	-
1984	1748	5378	325	-	69.3	48.0	33.4	10.6	4.3	0.4	0.4	-	-
1985	1064	7093	150	0.4	10.7	30.9	10.6	3.7	1.9	0.2	0.1	-	-
1986	2099	3923	535	2.2	20.9	46.1	82.0	15.3	7.4	0.9	0.6	-	-
1987	8870	7877	1126	36.8	410.3	86.1	30.4	19.1	6.5	0.1	1.2	-	-

Table 3.8. Virtual population analysis estimates of numbers-at-age (thousands) of Pacific cod from Hecate Strait (Areas 5C and 5D), for age-classes 2-7, 1961-87. (Asterisks indicate estimates considered inaccurate -- cumulative F for year-class less than 2.0 -- Pope 1972.)

	Age					
Year	2	3	4	5	6	7
1961	6597	2588	960	1008	193	24
1962	9690	3545	981	336	519	99
1963	11337	5130	1638	366	105	253
1964	15859	5832	1961	477	69	34
1965	8135	7655	2568	805	148	18
1966	5664	4244	2548	714	288	39
1967	7848	2782	1246	607	174	102
1968	2767	3612	1036	391	202	47
1969	3464	1433	900	292	81	48
1970	4558	1576	577	197	50	16
1971	4964	2396	581	226	89	16
1972	7556	2372	1198	241	85	43
1973	5540	3418	1058	519	89	40
1974	5846	2502	1264	375	234	22
1975	6133	2374	1034	427	120	105
1976	4757	2952	647	312	102	50
1977	5664	2253	825	139	93	26
1978	4272	2420	838	256	40	27
1979	6716	2290	998	303	94	15
1980	3876	2704	1008	227	91	28
1981	3633	1607	823	304	54	27
1982	2761	1688	567	146	57	14
1983	3310*	1351	649	184	42	20
1984	5042*	1655*	430	172	38	8
1985	2924*	2504*	720*	109	54	5
1986	5293*	1548*	1213*	341*	41	20
1987	35483*	2844*	717*	437*	144*	3

Table 3.9. Virtual population analysis estimates of fishing mortality rate (F) for Pacific cod from Hecate Strait (Areas 5C and 5D), for age-classes 2-7, 1961-87.

	Age					
Year	2	3	4	5	6	7
1961	0.02	0.37	0.45	0.06	0.06	0.30
1962	0.04	0.17	0.39	0.56	0.12	0.19
1963	0.06	0.36	0.63	1.07	0.52	0.22
1964	0.13	0.22	0.29	0.57	0.77	0.21
1965	0.05	0.50	0.68	0.43	0.74	0.38
1966	0.11	0.63	0.83	0.81	0.44	0.46
1967	0.18	0.39	0.56	0.50	0.71	0.33
1968	0.06	0.79	0.67	0.97	0.84	0.97
1969	0.19	0.31	0.92	1.16	1.00	0.84
1970	0.04	0.40	0.34	0.20	0.56	0.61
1971	0.14	0.09	0.28	0.37	0.12	0.47
1972	0.19	0.21	0.24	0.39	0.17	0.29
1973	0.19	0.40	0.44	0.19	0.82	0.25
1974	0.30	0.28	0.49	0.54	0.20	0.32
1975	0.13	0.70	0.60	0.83	0.28	0.60
1976	0.15	0.67	0.94	0.61	0.78	0.73
1977	0.25	0.39	0.57	0.64	0.62	0.70
1978	0.02	0.29	0.42	0.40	0.38	0.41
1979	0.31	0.22	0.88	0.60	0.62	0.71
1980	0.28	0.59	0.60	0.83	0.62	0.86
1981	0.17	0.44	1.13	1.07	0.72	1.09
1982	0.11	0.36	0.53	0.66	0.43	0.37
1983	0.09	0.55	0.73	0.97	1.04	0.48
1984	0.10	0.23	0.77	0.56	1.39	0.37
1985	0.04	0.12	0.15	0.37	0.39	0.49
1986	0.02	0.17	0.42	0.26	1.88	0.27
1987	0.13	0.38	0.57	0.60	0.62	0.55

Table 3.10. Virtual population analysis estimates of annual exploitation rate for Pacific cod from Hecate Strait (Areas 5C and 5D), for age-classes 2-7, 1961-87.

	Age					
Year	2	3	4	5	6	7
1961	0.01	0.24	0.28	0.05	0.05	0.20
1962	0.03	0.12	0.25	0.33	0.08	0.13
1963	0.05	0.23	0.37	0.52	0.31	0.15
1964	0.09	0.15	0.19	0.34	0.41	0.14
1965	0.04	0.31	0.38	0.27	0.41	0.24
1966	0.08	0.36	0.44	0.43	0.27	0.28
1967	0.12	0.24	0.33	0.30	0.39	0.21
1968	0.04	0.43	0.38	0.49	0.45	0.49
1969	0.13	0.21	0.47	0.55	0.50	0.44
1970	0.03	0.25	0.22	0.14	0.33	0.36
1971	0.10	0.07	0.18	0.24	0.09	0.29
1972	0.13	0.14	0.16	0.25	0.12	0.19
1973	0.13	0.25	0.27	0.13	0.43	0.17
1974	0.20	0.19	0.29	0.32	0.14	0.21
1975	0.10	0.39	0.35	0.44	0.18	0.35
1976	0.10	0.38	0.48	0.35	0.42	0.40
1977	0.17	0.24	0.33	0.37	0.35	0.39
1978	0.02	0.19	0.26	0.25	0.24	0.26
1979	0.20	0.15	0.46	0.35	0.36	0.40
1980	0.18	0.35	0.35	0.44	0.35	0.45
1981	0.11	0.28	0.54	0.52	0.40	0.53
1982	0.08	0.23	0.31	0.38	0.27	0.24
1983	0.07	0.33	0.40	0.49	0.51	0.29
1984	0.07	0.16	0.42	0.33	0.60	0.24
1985	0.03	0.09	0.10	0.24	0.25	0.30
1986	0.02	0.12	0.27	0.18	0.70	0.18
1987	0.09	0.24	0.34	0.35	0.36	0.33

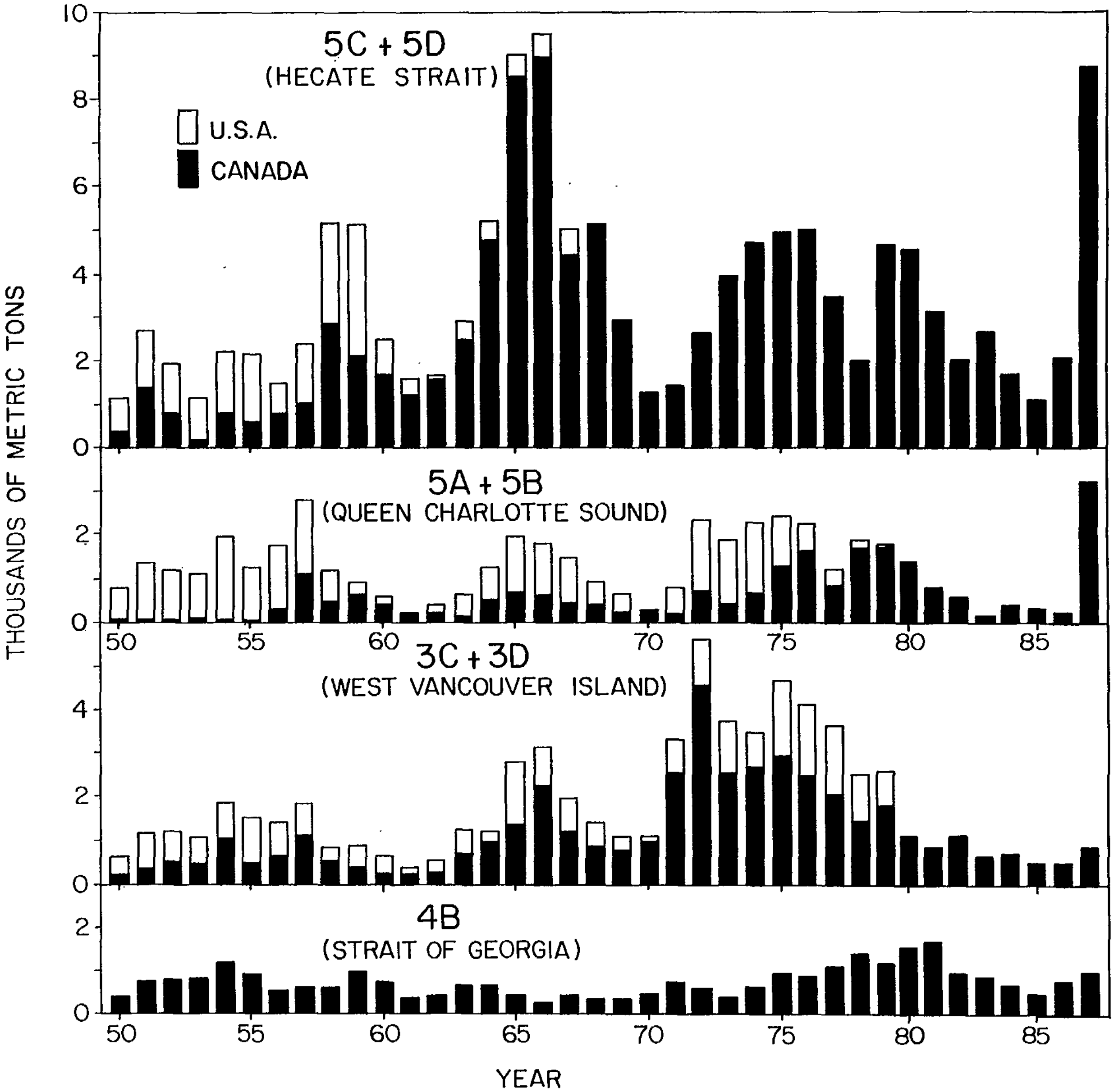

Fig. 3.1. Canada-U.S. annual nominal catch (landings) of Pacific cod, by region, 1950-87.

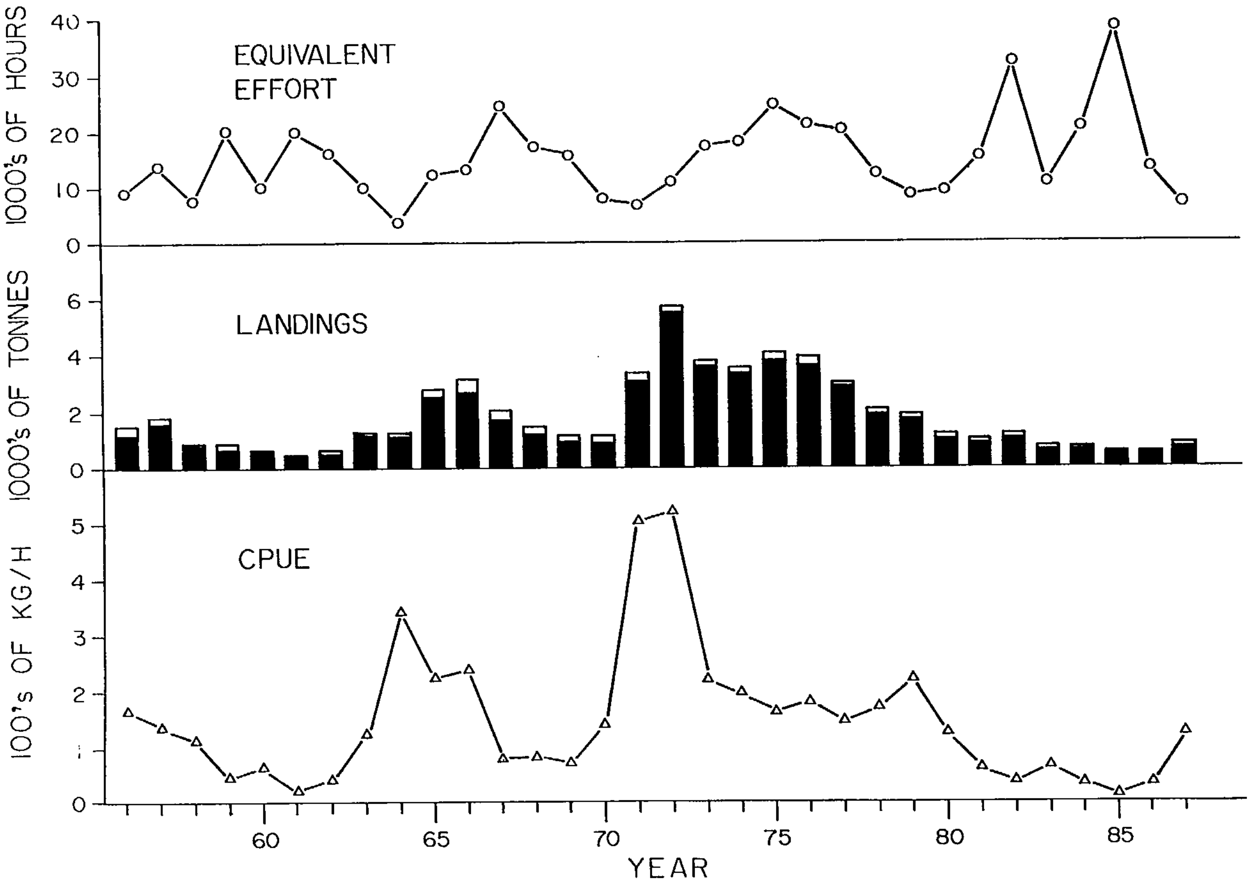

Fig. 3.2. Standardized Canada-U.S. landing statistics for Pacific cod from the west coast of Vancouver Island, 1956-87. Shaded portion of columns from Area 3C; clear portion from Area 3D.

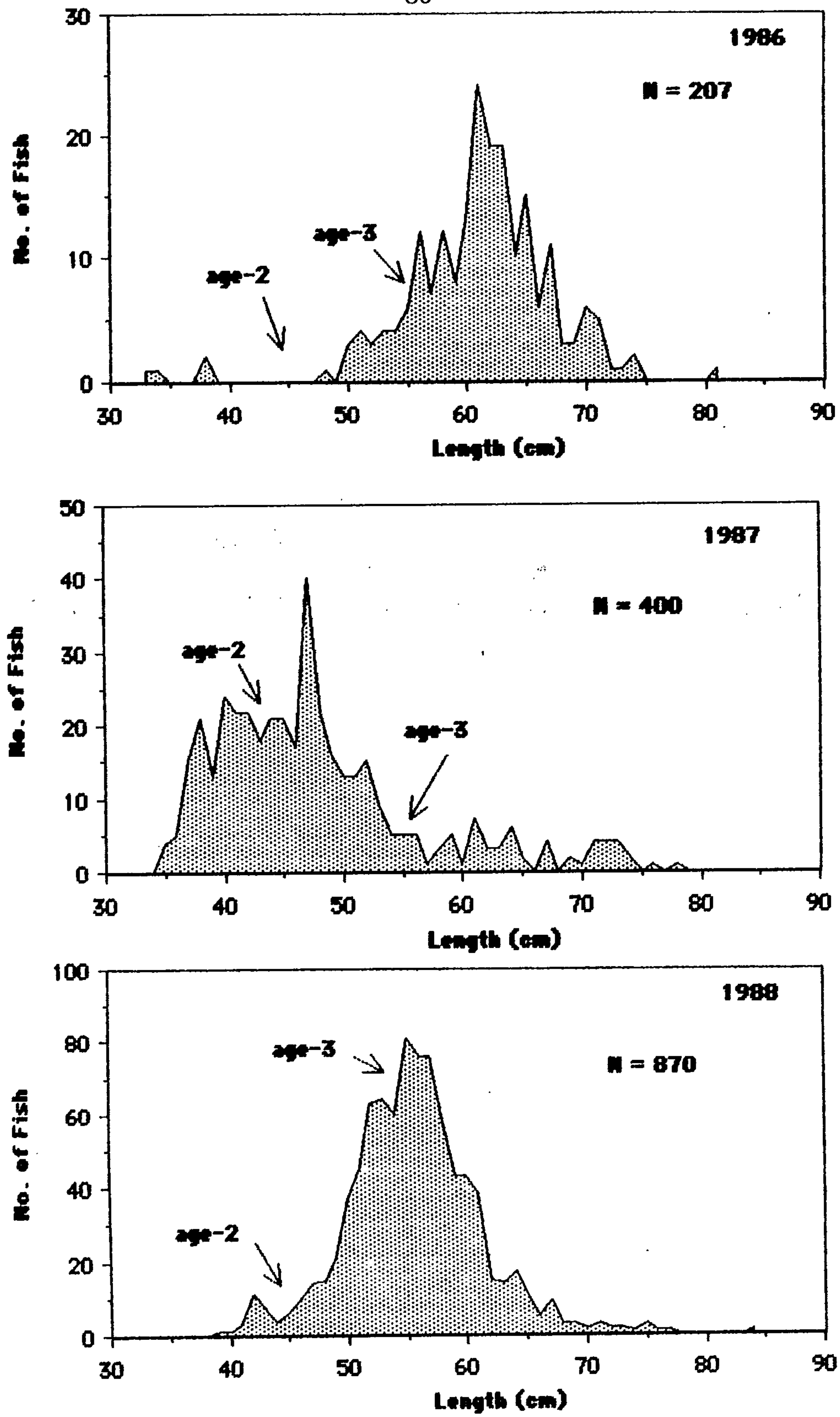

Fig. 3.3. Length frequency of Area 3C Pacific cod for the second quarter (April-June, inclusive) of 1986, 1987 and 1988. Long term size-at-age 2 and 3, and number of fish measured during each period (N) are given in the panels.

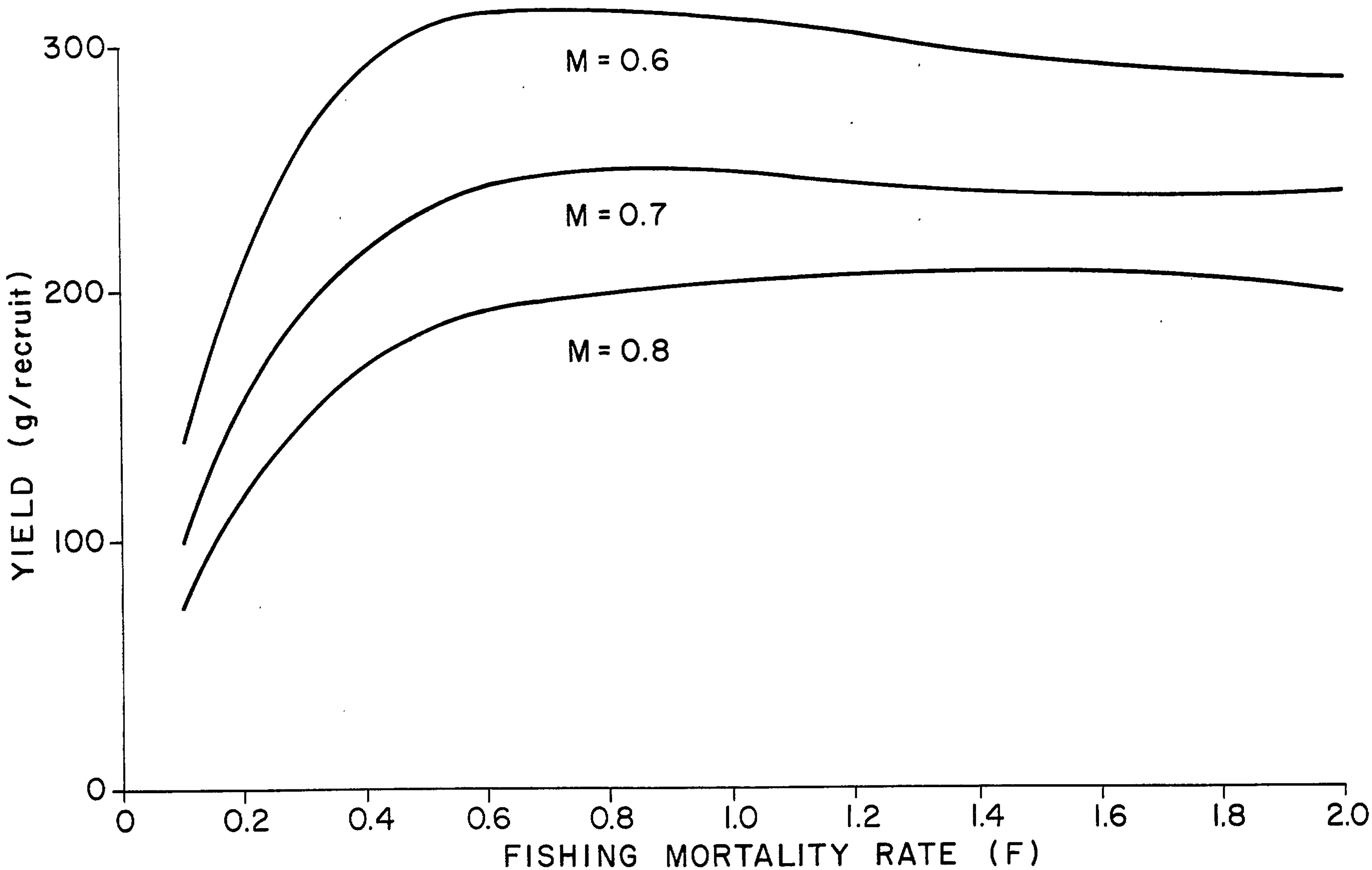

Fig. 3.4. Yield per recruit (g) vs fishing mortality rate (F) for Pacific cod from the west coast of Vancouver Island at three levels of M (0.6, 0.7 and 0.8), mesh size=5.3", and minimum commercial size=41 cm.

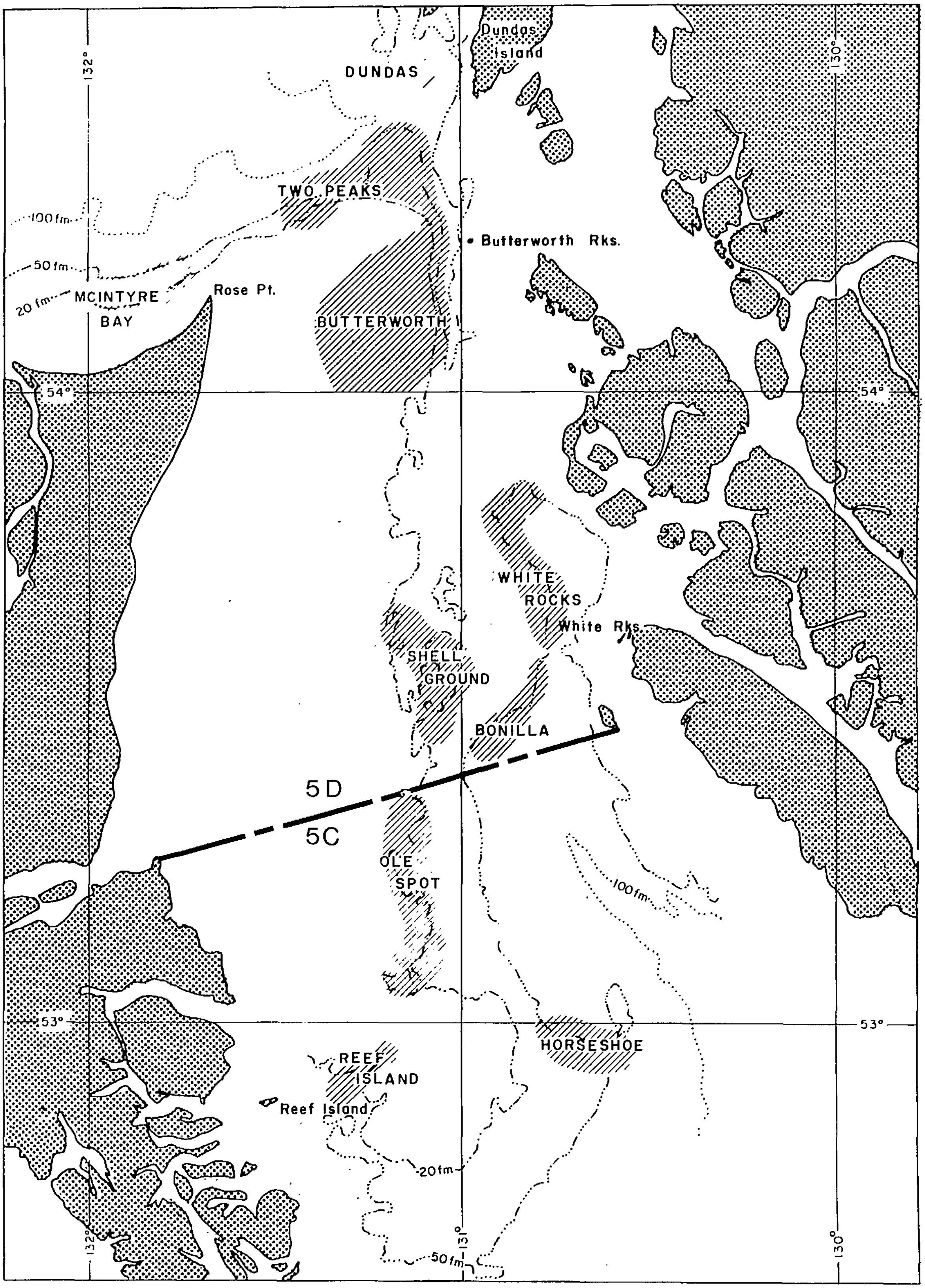

Fig. 3.5. Important trawling grounds for Pacific cod in Hecate Strait.

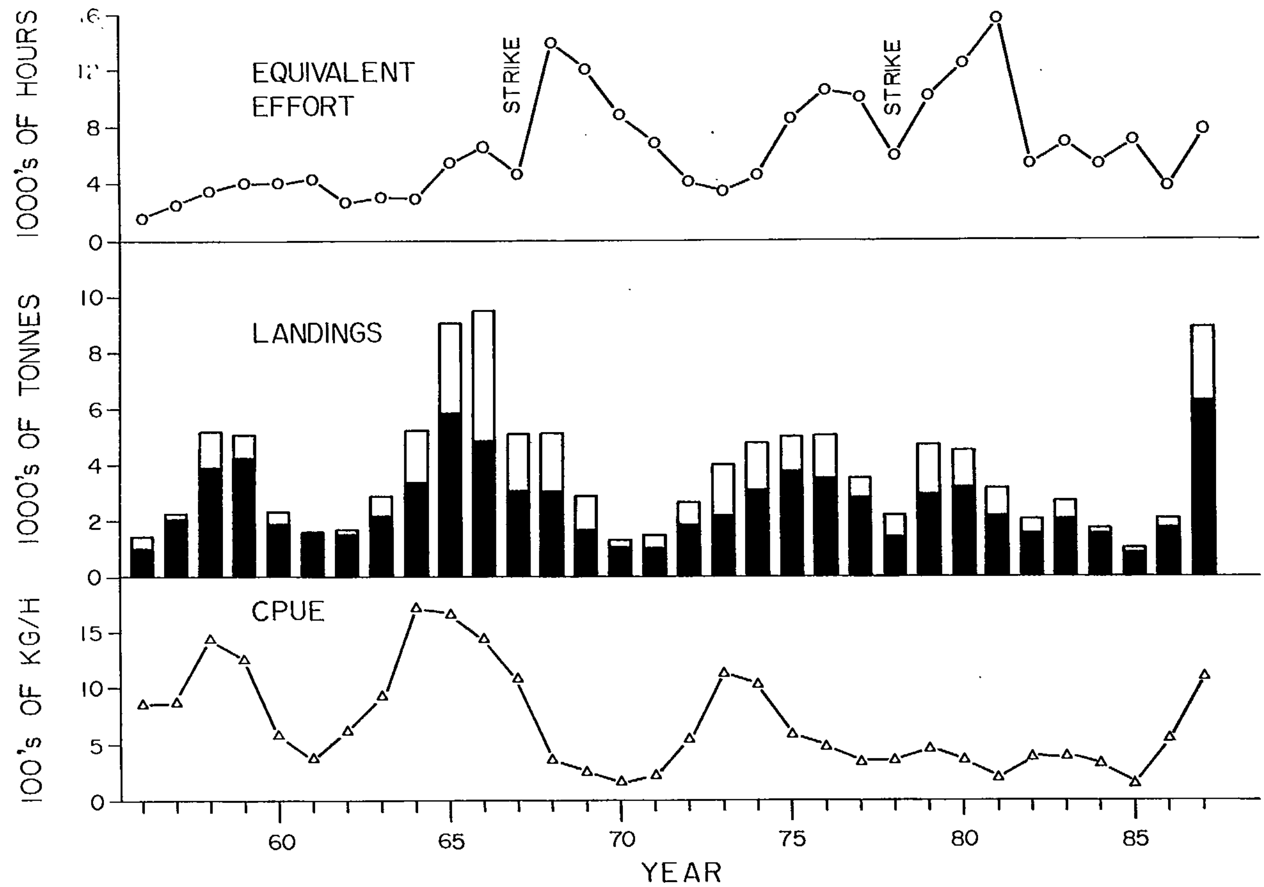

Fig. 3.6. Standardized Canada-U.S. landing statistics for Pacific cod from Hecate Strait, 1956-87. Shaded portion of columns from Area 5D; clear portion from Area 5C. "Strike" indicates years when a component of the industry was on strike. This reduced the total effort for the year but did not influence CPUE.

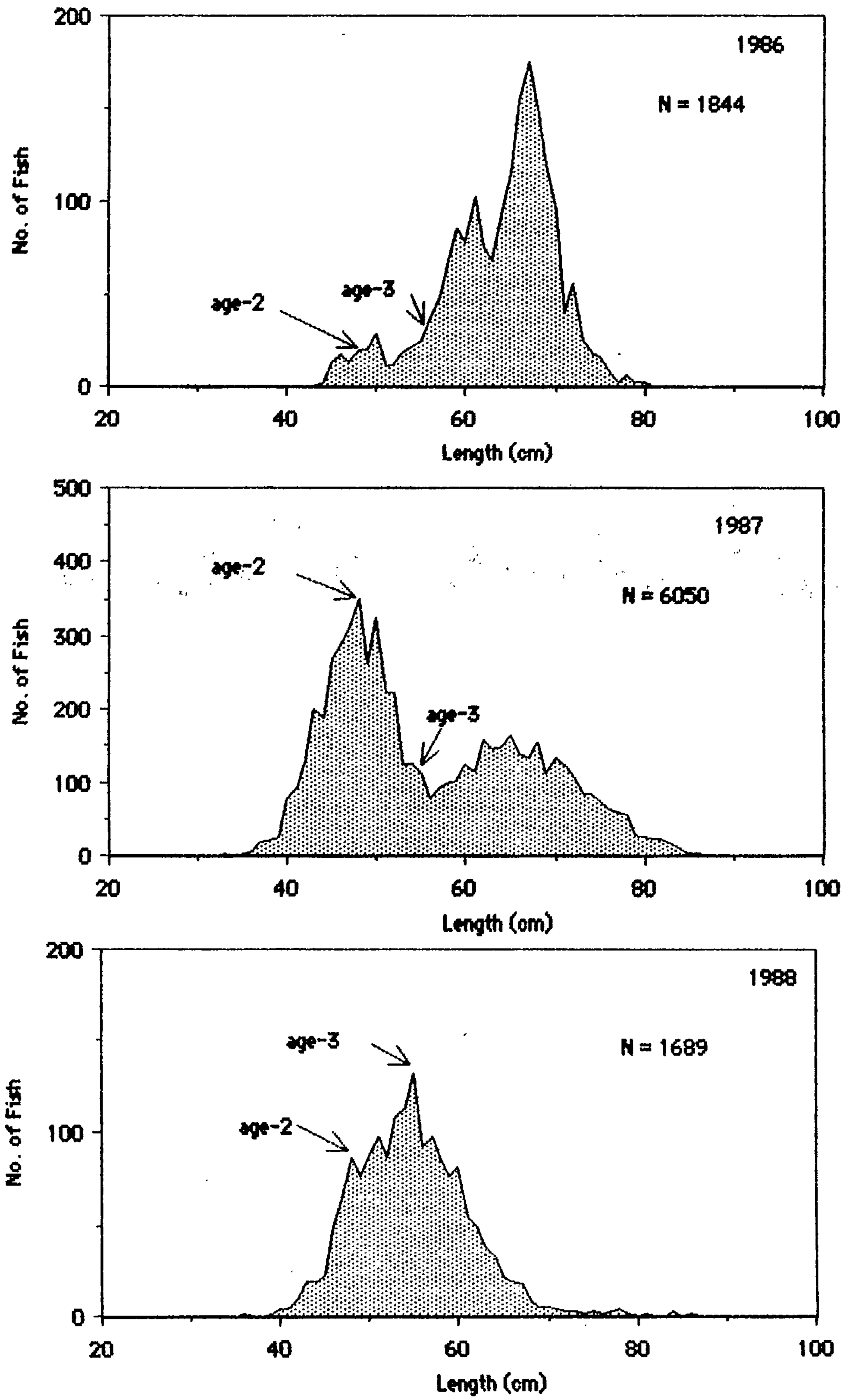

Fig. 3.7. Length frequency of Areas 5C and 5D Pacific cod for the first quarter (January-March, inclusive) of 1986, 1987 and 1988. Long term size-at-age 2 and 3, and number of fish measured during each period (N) are given in the panels.

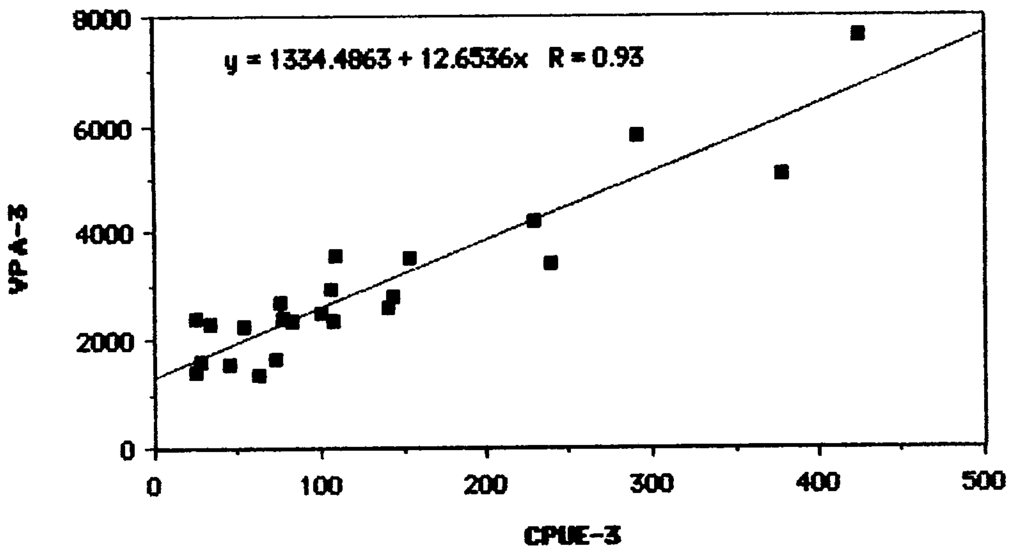

Fig. 3.8. Relationship between VPA estimates of numbers of age-3 fish (thousands) and nominal, standardized catch per unit effort of age-3 fish (number per hour) are fitted by linear regression. The r value shown is significant at the 5% level.

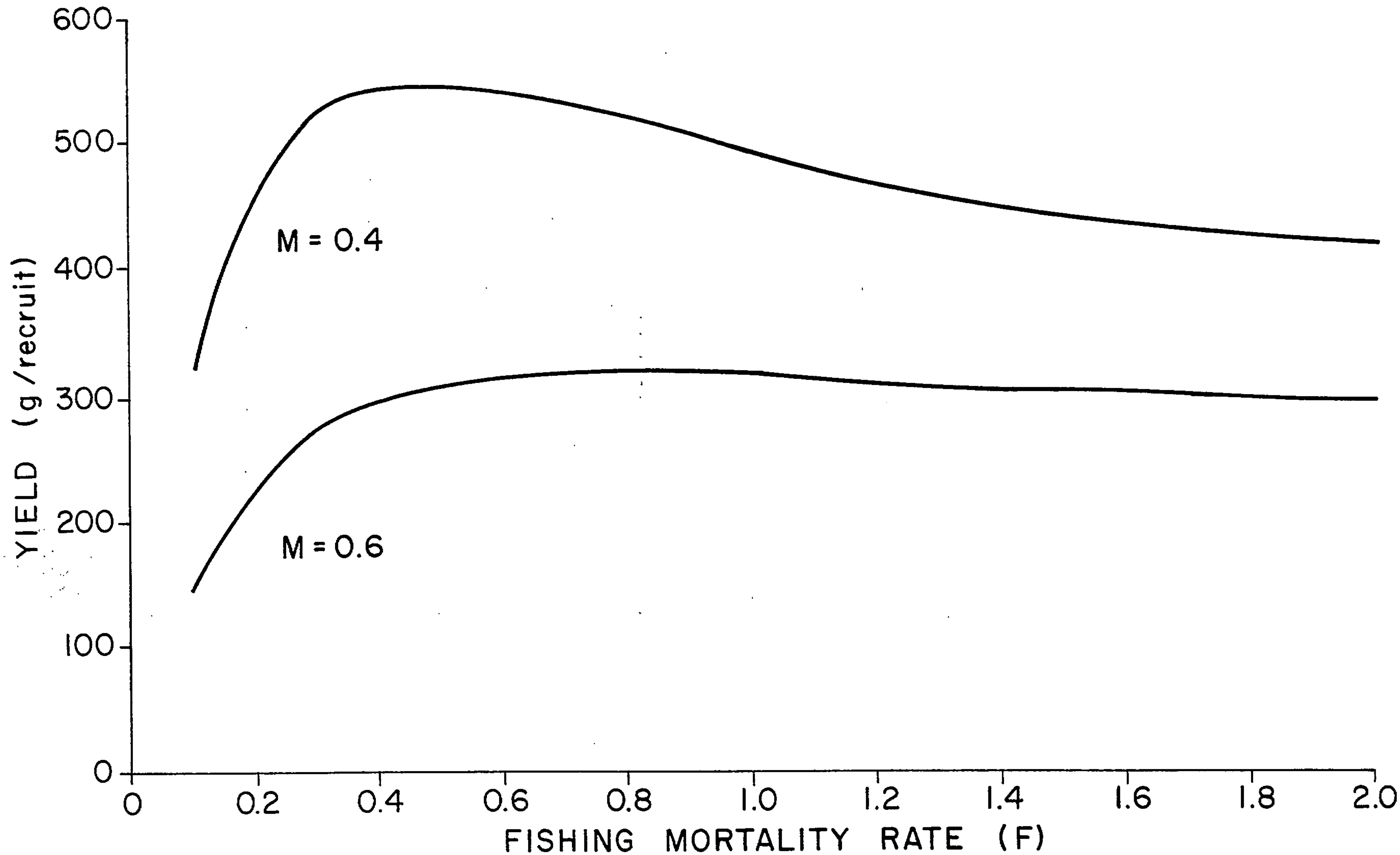

Fig. 3.9. Yield per recruit (g) vs fishing mortality rate (F) for Pacific cod from Hecate Strait at two levels of M (0.4 and 0.6), mesh size = 5.3", and minimum commercial size = 41 cm.

4.0. FLATFISH

by J. Fargo

4.0.1. General introduction

These stock assessments employ a variety of techniques, but they are dependent on two basic types of data, 1) landing statistics and 2) biological data in the form of length or age composition. Time series for these data sets varies from 20-45 years depending on the species/stock. Therefore, it is necessary to standardize the time series in order to be able to make comparisons of the data among years. The standardization procedure is described below.

Landing statistics have been standardized by using two methods to account for changes in CPUE due to increased vessel efficiency. The first method employs the use of a linear model of CPUE on vessel horsepower (Westrheim and Foucher 1985). Relative fishing powers for vessel horsepower classes are calculated from regression analysis and applied to individual data for each year in the time series. The second method employs a multiplicative log-linear model incorporating effects of vessel horsepower, depth, and other significant factors affecting CPUE. This model is similar to those used by Gavaris (1980) and Kimura (1981). Data are partitioned into matrix form according to pre-defined categories such as year and horsepower class, prior to analysis. The results of both methods of standardization help to account for changes in vessel efficiency over long periods of time and hopefully make the resultant landing statistics more comparable among years.

Biological samples in the form of length and age composition are obtained at ports of landing in conjunction with catch and effort data. When a suitable number of samples are obtained, they are combined to form a total sample that is considered to be representative of each species/stock. These samples are standardized by calculating the numbers of fish caught per standardized hour of trawling per centimeter interval. Then comparisons can be made among years with regard to the relative strength of recruitment and overall size composition. Age composition data derived from a subset of these biological samples is used to verify results from length frequency analysis and to obtain more refined estimates of recruitment and stock size using virtual population analysis. The results of virtual population analysis are used as a basis for projections of yield or potential yield for specific cases.

Estimates of sustainable yield are produced from results of the analysis of landing statistics and length/age composition on an individual stock basis. In most cases, several independent indices are derived from these data for the purpose of monitoring the condition of stocks. The yield estimates in these assessments are derived from both "short term" and "long term" equilibrium situations. English and rock soles are examples of species where the "short term" equilibrium approach is used. They are relatively short-lived and have fairly high turnover rates. Yield for these species is mainly a function of recruitment, which, in turn, is affected by stock size and environmental factors. The average period of contribution to the fishery for a recruiting year-class of these species is about 3-5 years and the amount of interannual variation in recruitment is high. The sustainable yield estimated for these species is a function of the current level of recruitment. This is somewhat analagous to the concept of annual surplus production applied to Pacific halibut (Quinn et al. 1985). The sustainable yield estimated using this approach will be lower than the maximum sustainable yield possible for the stock in cases where recruitment overfishing may have taken place. These cases are identified in the assessments for the managers' consideration. Dover sole is a species with biological characteristics more amenable to a "long term" equilibrium approach. They are relatively long-lived, and have a slow turnover rate. In addition, this species does not exhibit the extreme fluctuations in recruitment observed for rock and English soles. The estimate of sustainable yield for Dover sole is derived from 12 years of fishery equilibrium. Each new year's fishery observation increases the certainty of this estimate. The estimate of sustainable yield for Dover sole can be considered to be equivalent to the maximum sustainable yield in a "long term" sense.

4.1. Coastwide

Yield options are not proposed for flatfish species on a coastwide basis.

4.2. Strait of Georgia

Yield options are not proposed for flatfish for this region.

4.3. West Coast of Vancouver Island

4.3.1. Petrale sole

4.3.1.1. Introduction

The petrale sole (Eopsetta jordani) population off the west coast of Vancouver Island is thought to be composed of two stocks, on the basis of tagging experiments conducted in the 1960s (Ketchen and Forrester 1966). The "northern" stock occupies Areas 3D, 5A, 5B, 5C, and 5D while the "southern" stock occupies both the Canadian and U.S. portions of Area 3C. Both stocks are at levels significantly lower than the peak production levels of the 1940s and 50s. Analyses of Ketchen and Forrester (1966) and Pederson (1975a) have suggested that fishery effects on this species appeared to be overshadowed by environmentally induced variations in the production of year-classes. The fishery for these stocks is now largely incidental in nature with a target fishery on spawning aggregations occurring during the first quarter of the year in the deepwater areas of Estevan Deep and Clayoquot Canyon.

4.3.1.2. Landing statistics

Landings for the "southern" stock remained at very low levels in 1987 while landings for the "northern" stock increased to 303 t in 1987 from 169 t in 1986 (Table 4.1,4.2). The landings increase for the "northern" stock was the result of increased landings from Hecate Strait during the summer trawl fishery. No biological samples were obtained for this species in 1987.

4.3.1.4. Condition of the stock

Petrale sole stocks off the west coast of Vancouver Island are considered to be at low levels on the basis of landing statistics. The increase in landings in 1987 from the "northern" stock could be the result of an increase in recruitment or an increase in fishing effort in general in the Hecate Strait region. Although the current level of yield for petrale sole is sustainable it is not necessarily the maximum sustainable for the stock. The large removals from these stocks in the 1950s and 1960s and resultant decline in landings and presumably recruitment in the 1970s and 1980s may have resulted in recruitment overfishing.

4.3.1.5. Yield options

The yield options presented here are based on a "short term" equilibrium situation. Refer to Section 4.0.1. for an explanation of this.

(1) Sustainable option: A 44,000 lb trip limit regulation for petrale sole from January 1-March 31 is in effect, coastwide. The January-March period corresponds to the spawning time for petrale sole, a period when these stocks are particularly vulnerable to exploitation. This regulation is the result of a request by industry aimed at reducing a target fishery on petrale sole while stocks are depressed. Recently, some members of industry have presented arguments against a "coastwide" trip limit for this species, particularly in light of catches of petrale sole in the free-fishing area north of 54 degrees latitude. At present we have no evidence that the petrale sole in the northern portion of Area 5E are part of the "northern" or "southern" stocks. In fact, available evidence indicates that a number of discrete stocks of petrale sole exist along the Pacific coast (Ketchen and Forrester 1966, Pederson 1975b). Thus the trip limit for petrale sole could be considered applicable only to the west coast of Vancouver Island. However, area trip limits for individual species have created enforcement problems in the past.

(2) High risk sustainable option: Previous analyses have all indicated that petrale sole stock size has no effect on year-class production for the species and the trip limit should be removed and free-fishing allowed. As a caveat to this option, all previous analyses concerning stock and recruitment for the species were conducted when petrale sole stocks were at significantly higher levels of abundance than they are at present.

4.4. Queen Charlotte Sound

4.4.1. Rock sole

4.4.1.1. Introduction to Area 5A

The rock sole (<u>Lepidopsetta</u> <u>bilineata</u>) is a minor component of the shelf, on-bottom trawl fishery in Area 5A. Other principal members of this multispecies fishery are Pacific cod (<u>Gadus</u> <u>macrocephalus</u>) and lingcod (<u>Ophiodon</u> <u>elongatus</u>). Rock sole are caught primarily in the 40-50 fathom depths of Cook Bank. Pacific cod and lingcod are caught in the 40-70 fathom depths.

4.4.1.2. The fishery

The multispecies fishery in Queen Charlotte Sound has been dominated traditionally by Pacific cod and, in recent years, by lingcod and Pacific cod. Most catches of rock sole are taken incidentally to these species. Trip limit regulations are the basis for management of the rock sole fishery in British Columbia. Separate trip limits have been applied to stocks in Queen Charlotte Sound and Hecate Strait since 1986.

There has been some concern on the part of managers and segments of industry that area-specific trip limits for rock sole will allow fishermen to overrun limits in one area and claim that their catch was "split" between areas. Staff at Pacific Biological Station have monitored the landings of rock sole since the inception of the area-specific trip limit regulations. Landings in the 1987-88 trawl fishery are summarized with regard to rock sole in the following paragraphs.

In 1987, there were a total of 555 vessel landings containing rock sole. There were 8 landings where trip overages occurred. The overage for four of these landings was less than 4000 lb., probably within an acceptable margin of error for the captains' estimates. There were 4 landings where the overage was greater than 4000 lb., and 3 of these were reported as trips "split" between Hecate Strait and Queen Charlotte Sound.

In 1988, to the end of June, there were 405 landings containing rock sole. There were 13 landings where trip overages occurred. The overage for nine of these was less than 4000 lb. There were 4 landings where the overage was greater than 4000 lb. and 2 of these were reported as "split" trips.

4.4.1.3. Landing statistics

Landing statistics were standardized using the method of Westrheim and Foucher (1985). The standardization treated CPUE as a linear function of vessel horsepower. These statistics are presented in Table 4.3.

Once effort was standarized, allocation of effort followed the procedure outlined for multispecies fisheries by Westrheim (1983). That is, each species in each area/time cell (in this case rock sole in Area 5A) was allocated the standardized all-species effort expended in the depth intervals containing the rank-1 (most) and rank-2 (next-most) landings of that species. This is hereafter referred to as the "option-2" method. Problems with the option-2 method arise when species are caught over similar depth ranges but in different localities or when species are distributed in different relative abundances over the same depth range.

Landings of rock sole in Area 5A increased to 80 t in 1987 from 23 t in 1986 while effort increased to 2857 h in 1987 from 1769 h in 1986. CPUE for rock sole in Area 5A increased from 13 kg/h in 1986 to 28 kg/h in 1987 (Table 4.3). Pacific cod and lingcod continued to be the primary targets of this fishery.

4.4.1.4. Condition of the stock

On the basis of past trends in landings and CPUE, the Area 5A rock sole stock is considered to be at low levels of abundance, although length frequency samples collected in 1988 (there were none collected in 1986-87) indicate a modest increase in the numbers of smaller (younger) fish in the landings. Average annual yield for this stock with similar levels of recruitment/abundance in the past has been approximately 100 t. Significant removals occurred from this stock in the 1960s and the increase in recruitment observed in recent years does not appear to be of the same magnitude as that for rock sole stocks in other areas. For this reason we feel that recruitment overfishing may have occurred.

4.4.1.5. Yield options

The yield options presented here are based on a "short-term" equilibrium situation. Refer to Section 4.0.1. for an explanation.

Sustainable Yield option: A yield of 100 t is considered to be sustainable for the current stock level and low recruitment mode. The 30,000 lb trip limit regulation is consistent with this option.

Non-sustainable Yield option: Yields of 200 t are considered to be non-sustainable at this time. This is assuming that recruitment to the stock will not increase significantly in the next year.

4.4.1.6. Introduction to Area 5B

Rock sole is a minor component of the shelf, on-bottom trawl fishery in Area 5B. Pacific cod and lingcod are the major components in this multispecies fishery.

4.4.1.7. The fishery

Catches of rock sole in Area 5B have traditionally come from the 40-50 fathom depth range on the outer edges of Goose Island Bank, which is considered to have good "trawlable" bottom. There has been speculation among fishermen over the years that rock sole also occupy the top of the bank (10-39 fathom depths) which is composed mainly of rough bottom type, not amenable to trawl capture of flatfish. This speculation exists because of suitable habitat available for rock sole, and the fact that rock sole in Hecate Strait and other areas along the Pacific coast are most abundant at shallow (10-39 fathom) depths.

Trip limit regulations are the basis for management of the rock sole fishery in British Columbia. Separate trip limits have been applied to stocks in Queen Charlotte Sound and Hecate Strait. A discussion of rock sole landings for 1987-88 with regard to the area-specific trip limit regulations currently in effect is contained in Section 4.4.1.2.

4.4.1.8. Landing statistics

Problems with interpretation and derivation of landing statistics for rock sole in Area 5B using the option-2 method are the same as those discussed in Section 4.4.1.3. Landings increased to 205 t in 1987 from 135 t in 1986, while effort increased to 4457 h from 2596 h over the same period. CPUE for 1987 was 46 kg/h and was consistent with the trend established over the period 1973-86 (Table 4.4).

4.4.1.9. General biological information

Length frequency samples from Area 5B rock sole in 1987 have been analyzed and a significant increase in the numbers of smaller (younger) fish was noted. This is consistent with results of analysis of length frequency data obtained from the 1986 fishery and is indicative of an increase in recruitment/abundance for the stock. At present, however, Pacific cod and lingcod continue to be the primary targets of the fishery. Rock sole catches are largely incidental to those species.

4.4.1.10. Condition of the stock

On the basis of CPUE trends, the Area 5B stock has been at a stable, albeit low, level of abundance since the early 1970s with recruitment varying from low to average levels over this time period. The average annual yield over this time period has been approximately 250 t. Similarly, for the period 1977-87 annual yields have averaged 200 t. The significant increase in recruitment observed in 1986-87 is taken as an indication that recruitment overfishing is not a problem for the Area 5B stock and that yields in recent years have been sustainable. The increase in recruitment could increase the level of sustainable yield for this stock to as much as 400 t, over the next few years if the present year-class(es) recruiting are similar in size to those of the 1960s. However, it is too early to accurately determine the size of these year-classes. Removals greater than 500 t have consistently resulted in declines in CPUE/abundance for Area 5B rock sole, as indicated by the CPUE time series, and are considered to be non-sustainable.

4.4.1.11. Yield options

The yield options presented here are based on a "short term" equilibrium situation. Refer to Section 4.0.1. for an explanation.

Low risk sustainable yield option: A yield of 200 t is considered to be sustainable for the Area 5B stock. The 30,000 lb trip limit currently in effect for Queen Charlotte Sound is consistent with this option.

High risk sustainable option: Yields of 400 t could be sustained with a significant increase in recruitment. However, the size of the recruiting year-classes cannot be accurately determined at this time.

Non-sustainable yield option: Based on trends in CPUE, yields of 500 t can be considered to be non-sustainable for the stock.

4.5. Hecate Strait

4.5.1. Rock sole

4.5.1.1. General Introduction

The rock sole (Lepidopsetta bilineata) is one component in a multi-species on-bottom trawl fishery in Hecate Strait along with English sole (Parophrys vetulus) and Pacific cod (Gadus macrocephalus). Two stocks of rock sole have been identified using abundance trends from landing statistics, length-frequency analysis and results of a 1982 tagging experiment (Fargo and Westrheim 1987).

4.5.1.2. Introduction to Area 5C

The fishery for rock sole in Area 5C is seasonal. The majority (84%) of the landings occur during April-September. The spring fishery is predominantly on a spawning population at Reef Island-Cumshewa grounds while summer and fall landings come from the multispecies fisheries at Horseshoe and Ole Spot grounds. Analysis of landing statistics and annual length frequency compositions are the basis for this assessment.

4.5.1.3. Fishery

Trip limit regulations are the basis for management of the rock sole fishery in British Columbia. Separate trip limits have been applied to stocks in Queen Charlotte Sound and Hecate Strait. A discussion of rock sole landings for 1987-88 with regard to the area-specific trip limit regulations currently in effect is contained in Section 4.4.1.2.

4.5.1.4. Landing statistics

A description of the method used for deriving the landing statistics used in this assessment is contained in Section 4.4.1.3. Landings increased significantly to 209 t in 1987 from 86 t in 1986. CPUE for rock sole in Area 5C rose to 214 kg/h in 1987, from 131 kg/h in 1986. Effort increased to 977 hours from 656 hours in 1986 (Table 4.5). CPUE has shown an increasing trend in recent years and is now above the average for the last 10 years.

4.5.1.5. General biological information

Length frequency data has been compiled and a time series of length frequency anomalies for numbers of fish caught per hour of standardized fishing effort have been calculated for the period 1966-86. The anomaly for 1987 indicates that recruitment has increased but the majority of the catch was still composed of larger size groups. Fishermen complained on numerous occasions of discards of rock sole just under the industry-imposed minimum size limit of 35 cm. In 1988, some fish processing plants decreased their minimum size limit to 30 cm, and samples collected in 1988 show high CPUEs for both sexes in the 30-35 cm range. Catch rates in numbers of fish per standardized hour of trawling per centimeter interval were compared for annual periods when a 30 cm minimum size limit was used by processors. Results of this analysis indicate that the current level of recruitment is higher than the recruitment level of the late 1970s (last major surge in recruitment), but is lower than the 1960s level.

4.5.1.6. Condition of the stock

The Area 5C rock sole stock is considered to be at average to above average levels, with recruitment currently increasing. This is based on trends in standardized CPUE and length frequency composition data.

4.5.1.7. Yield options

The yield options presented here are based on a "short term" equilibrium situation. Refer to Section 4.0.1 for an explanation.

Low risk sustainable yield option -- The sustainable yield with recruitment at above average levels in the past has ranged between 500 and 1000 t for the Area 5C stock. A yield of 500 t is equivalent to the average yield sustained during the late 1970s recruitment surge for the stock. A trip limit of 30,000 lbs is consistent with this option.

High risk sustainable yield option -- A yield of 700 t could be sustained if the current recruitment level is mid-way between 1970s and 1960s levels. The exact level of recruitment cannot be determined at this time and 700 t can be considered to constitute a high risk for the stock until additional years' data are analyzed.

Non-sustainable option -- Yields of 900 t have not been observed for the Area 5C stock since the mid-late 1960s. Both the stock size and recruitment at that time were higher than they are currently, based on analysis of standardized CPUE and length frequency data. Also, the current recruiting year-classes have not had time to make a significant reproductive contribution to the stock. This contribution may be important to stability in the long term for the stock. For these reasons, yields of 900 t are considered to be non-sustainable at this time.

4.5.1.8. Introduction to Area 5D

The rock sole population in Area 5D is one of the most intensively studied marine fish populations in British Columbia (Forrester and Thomson 1969; Stocker 1981; Fargo 1985). For the past 40 years the stock has been characterized by cyclic abundance trends attributed to major surges in recruitment about once a decade. Ocean temperature at the time of spawning and stock size have been shown to be important determinants of year-class production for the stock (Fargo and McKinnell in press).

4.5.1.9. The fishery

The fishery for rock sole in Area 5D is mainly a seasonal one. The majority (80%) of the landings occur during the months April-September. Principal grounds are Two Peaks and Butterworth. Rock sole occupy depths of

10-40 fathoms, but are most concentrated at the shallower (10-29 fathom) depths. They are caught incidentally along with Pacific cod and English sole at depths of 30-49 fathoms.

Trip limit regulations are the basis for management of the rock sole fishery in British Columbia. Separate trip limits have been applied to stocks in Queen Charlotte Sound and Hecate Strait. A discussion of rock sole landings for 1987-88 with regard to the area-specific trip limit regulations currently in effect is contained in Section 4.4.1.2.

4.5.1.10. Landing statistics

Past analysis (Fargo 1985) has shown that 50% of the variation in the option-2 CPUE for rock sole in Area 5D could be accounted for by fishing effort directed at Pacific cod, the major target species in Hecate Strait. A new approach toward compiling landing statistics for Area 5D rock sole was adopted for the 1987 assessment (Fargo 1988). This method was used for this year's assessment, and is briefly described in the paragraph below.

A log linear model similar to those of Gavaris (1980) and Kimura (1981) was used to standardize CPUE for rock sole (Table 4.6). Independent variables included in the model were vessel horsepower, and depth. Year effects were taken into account as well. The model was applied to a data set for rock sole from Two Peaks-Butterworth areas for the months April-September. Landings of rock sole less than 1000 lbs were not considered because of the problem of non-reporting of exact locations of small catches. Overall, the model accounted for 61% of the variation in the log of CPUE for rock sole over time.

Landings in 1987 were 327 t up from 133 t in 1986. Similarly, CPUE increased to 577 kg/h in 1987 from 280 kg/h in 1986. The effort level was similar for the two years, and was considerably lower than the long-term average.

4.5.1.11. General biological information

Length frequency anomalies in numbers caught per hour of standardized fishing effort were calculated for the time period 1956-87. The anomaly for 1987 indicates that the catch in Area 5D is composed of a variety of sizes of fish. However, the length frequency samples for analysis for 1987 were graded to a 35 cm minimum size. Samples for 1988, graded to a minimum size of 30 cm indicate high CPUEs for fish in the 30-35 cm range in the catch. Fishermen had complained of discards of fish just under the industry-imposed minimum size limit in 1987. A comparison of standardized catch rates for samples taken during 1988 and samples collected under the same minimum size limit in the past indicates that the current level of recruitment is higher than that in the late 1970s (last major surge) but not as high as that of the 1960s.

Rock sole age composition data has recently been updated for Area 5D. The results of virtual population analysis for age composition data from 1945-85 are presented in Tables 4.7, 4.8. The analysis was limited to age groups 4-11 because ageing imprecision becomes a problem at ages greater than

11 and discrepancies between surface and burnt cross-section techniques become apparent at ages greater than 11 as well. Approximately 95% of the rock sole in the catch fall within this age range. The results of the VPA are considered to be reliable only for the years 1945-79. This is because the cumulative fishing mortality for cohorts after that time is less than 2.0 (Pope 1972). Exploitation rates calculated for the Area 5D stock from results of this analysis are presented in Table 4.9. Exploitation rates for the stock ranged from 7% to 35% per year from 1945-79. Explotitation rates were relatively low in the late 1970s and presumably through the mid-1980s when fishing effort in the Hecate Strait region decreased significantly.

4.5.1.12. Condition of the stock

Recruitment for the rock sole stock in Area 5D has increased significantly based on analysis of fishery data and length composition. Results of catch-at-age analysis for the stock indicates that exploitation rates have not been excessive since the mid-1960s. However, the stock has been at relatively low levels for nearly a decade and the reproductive contribution of current recruiting year-classes has been minimal. An increase in abundance or stability for the stock in the long term may be dependent on the reproductive contribution of these strong recruiting year-classes. Therefore, unlimited harvest at this time is deemed undesirable.

4.5.1.13. Yield options

The yield options presented here are based on a "short term" equilibrium situation. Refer to Section 4.0.1. for an explanation.

Low risk sustainable yield option -- CPUE increased significantly in 1987. This increase is due, presumably, to an increase in recruitment. Yields of 500-1200 t were sustained in the past, depending on the size of recruiting year-classes. Analysis of standardized anomalies indicates that the current recruiting year-class is intermediate in strength to strong year-classes of the 60s and 70s. Therefore 500 t would constitute a low risk for the stock. The 30,000 lb trip regulation currently in effect for rock sole in Hecate Strait is consistent with this option.

High risk sustainable yield option -- If the current level of recruitment is intermediate in strength to that of the 60s and 70s, yields of 850 t annually would be sustainable. However, the size of the recruiting year-class(es) cannot be accurately determined at this time. Therefore 850 t is considered to be a high risk for the stock.

Non sustainable yield option -- Yields of over 1000 t have only occurred during one period in the past when several consecutive strong year-classes were produced. VPA results suggest excessive exploitation rates during this period (mid-1960s). The current stock size is lower than in the mid-1960s as indicated by CPUE. Therefore, yields of 1000 t are considered to be non-sustainable for the Area 5D stock at this time.

4.5.2. English sole - Area 5D

4.5.2.1. Introduction

Detailed stock assessments were last conducted in 1987 and are summarized in Fargo (1988). Catch/effort and length frequency time series have been updated for this assessment. Also, a series of yield simulations for English sole have been done using updated reproductive potentials estimated from a research project designed to study the reproductive biology of this species. A preliminary analysis of factors affecting English sole year-class production was conducted as well.

4.5.2.2. The fishery

Area 5D in Hecate Strait contains the only significant fishery for English sole (*Parophrys vetulus*) in British Columbia. The principal fishing grounds are Two Peaks-Butterworth (April-September) and White Rocks (October-March). Approximately 80% of the landings come from the former. In recent years, small landings of English sole have occurred from locations in Area 5C (Horseshoe and Bonilla). It is not known whether these landings derive from another stock of English sole in Hecate Strait, but these landings are of minor importance at present and are ignored in this assessment.

4.5.2.3. Landing statistics

Landing statistics for English sole in Area 5D have been standardized using the option-2 method described in Section 4.4.1.3. and are presented in Table 4.10.

Landings of English sole in 1987 were 528 t, up from 322 t in 1986. CPUE for 1987 was 132 kg/h up from 115 kg/h in 1986 and close to the average for 1956-87. Effort was up 25% to 4000 h in 1987, probably as a result of the intensive fishery for Pacific cod.

4.5.2.4. General biological information

In order to monitor recruitment for English sole in Area 5D, a series of length frequency anomalies (see section 4.3.1.3) have been calculated in numbers per hour. In 1987, recruitment has increased. Preliminary analysis shows that length composition from 1988 samples is consistent with this observation. The length frequency composition also indicates some sign of juvenation over the last few years. Results of the length frequency analysis have to be viewed with some caution, however, because of the low number of samples taken in the last two years (2 in 1987, and 1 in 1988).

Reproductive potentials for fish in the age range of 3-12 years have been estimated from data collected since 1986 for the purpose of studying the reproductive biology of English sole. The algorithm for calculating reproductive potentials is as follows:

$$f_i(r) = P_i * w_i$$

where: $f_i(r)$ = reproductive potential of fish at age i

P_i= proportion of fish sexually mature at age i
w_i= average weight of individual at age i during the spawning season.

These reproductive potentials were used as input for yield simulations similar to those performed in previous assessments for the Area 5D stock (Fargo 1985). In previous assessments reproductive potentials were assumed to be equal for all age groups where 100% of the individuals were mature.

The yield simulations were 50-year simulations using the last year of reliable age composition data (1974) from cohort analysis (Fargo 1985). A maximum annual yield of 600 t was obtained from the simulations, assuming that females represent approximately 70% of the total weight of the fishery yield for the species. Additional simulations were performed with recruitment fixed at low, average, and high levels for the stock. Maximum annual yields of 450 t, 650 t, and 1000 t were obtained for the three levels of recruitment, respectively. As in the previous yield simulations for the species (Fargo 1985) the greatest yield is achieved at an age of first capture of 6 years (Fig. 4.1). The current age of first capture for English sole is 3 years.

An investigation of factors affecting English sole year-class production was also undertaken. Ocean temperature, Ekman transport and stock size were all found to be correlated with year-class production for English sole. Stock size appears to exert the greatest effect of the three factors. A flat-topped Ricker stock-recruit relationship was implied by the analysis with relatively constant production achieved from average to large stock sizes. These results are considered to be preliminary at the present time.

4.5.2.5. Condition of the stock

On the basis of trends in CPUE in recent years and analysis of length composition, the Area 5D English sole stock is considered to be near average levels. Some increase in recruitment for the stock has been noted in 1987-88 but this is considered suspect because of the low number of samples taken in 1987-88. It also appears that larger (older) fish make up less of the population now as compared to the early 1980s. Age at which the species is first fished is well below the age of first-fishing where maximum yield was obtained in the yield simulations.

4.5.2.6. Yield options

The yield options presented here are based on a "short term" equilibrium situation. Refer to Section 4.0.1. for an explanation.

Low risk sustainable yield option -- Yields of 400 t are sustainable with recruitment at low levels. This is based on CPUE trends for the Area 5D English sole stock.

High risk sustainable yield option -- Yields of 600t have been sustainable with recruitment at average levels in the past and CPUE trends have remained fairly stable with yields at this level. However, length composition for the stock indicates some signs of juvenation with removals near this level for 3 of the last 4 years. Therefore, the risk of recruitment overfishing for the stock is assumed to be a possibility with yields at this level.

Non-sustainable yield option -- Analysis of CPUE and yield simulations indicate that yields of 800 t are possible for short periods if recruitment is at high levels and age composition for the stock is not truncated. Recruitment is currently not high and indications are that the proportion of older fish in the stock has decreased, at least since the early 1980s. Therefore, yields of 800t are deemed to be non-sustainable for the Area 5D English sole stock at this time.

4.5.3. Dover sole

4.5.3.1. Introduction

The last detailed stock assessment for Dover sole is contained in Fargo (1988). As in the past, estimates of yield for this assessment are determined by surplus production analysis of standardized catch/effort data.

4.5.3.2. The fishery

The fishery for Dover sole takes place at depths of 50-80 fathoms at Dundas ground in north Hecate Strait (May-October) and 100-200 fathoms at Langara Deep and Frederick Island (December-April). The seasonal shift in the fishery is related to the annual bathymetric migrations Dover sole undergo for the purpose of spawning.

4.5.3.3. Landing statistics

Standardized landing statistics for Dover sole for 1970-87 are presented in Table 4.11. CPUE for Dover sole was standardized using a log-linear multiplicative model similar to Gavaris (1980), and Kimura (1981). The CPUE time series shows a declining trend from 1970-79. Within this, the brief upward trend from 1972-74 may be an artifact of the initial period of exploitation. An upward trend in CPUE is also observed from 1980-87. Landings in 1987 declined to 503 t from 1040 t in 1986 while effort declined to 756 h in 1987 from nearly 2000 h in 1986. This decline is attributed largely to the intensive fishery for Pacific cod in Hecate Strait in 1987. The majority of fishing effort in this region was expended obtaining catches of Pacific cod on grounds south of the area where Dover sole are concentrated during the summer months.

4.5.3.4. General biological information

Annual length frequency compositions compiled from 1970-87 indicate no change in mean length and no observable change in the overall length composition over this time period.

4.5.3.5. Condition of the stock

The CPUE time series indicates that the 5CDE Dover sole stock is presently increasing in abundance, with no apparent sign of overfishing. The length frequency data indicate no obvious sign of overfishing as well. MSY estimated from standardized effort and CPUE using Gulland's (1961) method is 864 t, while the optimum effort level is estimated at 1712 hours using a lag period of 3 years.

4.5.3.6. Yield options

The yield options presented here are based on a "long term" equilibrium situation. Refer to Section 4.0.1. for an explanation.

Low risk sustainable option -- The analysis estimates MSY at 800 t for the Area 5CDE Dover sole stock. However, the rising trend in CPUE with removals of 800 t over the last several years indicates that the true MSY may well be higher than 800 t.

High risk sustainable option -- With effort at an optimum level and CPUE at 1987 levels, a catch of 1165 t would be observed. An estimate of 1000 t is therefore provided as a high risk option for sustainable yield.

Table 4.1. Canada-U.S. landings (t) of petrale sole from southwest Vancouver Island (Area 3C)--the area occupied by the "southern stock" 1942-87.

Year	Flattery Spit	Northern section Area 3C	Total Area 3C	Year	Flattery Spit	Northern section Area 3C	Total Area 3C
1942	?	-	1,561	1964	71	530	601
1943	?	-	2,264	1965	140	658	798
1944	?	-	1,489	1966	118	512	630
1945	?	-	718	1967	106	259	365
1946	?	-	906	1968	114	233	347
1947	?	-	627	1969	255	142	397
1948	?	-	1,321	1970	80	198	278
1949	?	-	1,178	1971	74	523	597
1950	?	-	854	1972	22	561	583
1951	?	-	794	1973	211	452	663
1952	?	-	948	1974	230	684	914
1953	?	-	748	1975	474	465	939
1954	?	-	664	1976	304	453	757
1955	?	-	415	1977	157	311	468
1956	40	585	625	1978	287	126	413
1957	9	629	638	1979	256	92	348
1958	19	609	628	1980	147	115	262
1959	33	1,072	1,105	1981	125	180	305
1960	233	974	1,207	1982	45	232	277
1961	375	1,109	1,484	1983	179	183	362
1962	215	850	1,065	1984	237	218	455
1963	90	658	748	1985	122	147	269
				1986	75	197	272
				1987	113	123	236

Table 4.2. Canada-U.S. landings (t) of petrale sole from the "northern stock" 1942-87.

Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total	Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total
1942	-	-	-	-	1964	183	421	163	767
1943	-	-	-	-	1965	300	418	202	920
1944	499	303	-	802	1966	264	469	260	993
1945	270	1,535	193	1,998	1967	169	485	176	830
1946	623	1,258	494	2,375	1968	293	266	137	696
1947	469	986	769	2,224	1969	262	114	22	398
1948	943	920	3,011	4,874	1970	136	56	22	214
1949	316	429	1,644	2,390	1971	127	97	55	280
1950	694	569	700	1,963	1972	50	154	33	237
1951	305	326	642	1,273	1973	197	211	24	432
1952	265	305	574	1,144	1974	196	283	14	493
1953	235	450	46	731	1975	234	156	27	417
1954	712	234	300	1,237	1976	153	132	30	315
1955	452	462	94	1,008	1977	58	73	24	155
1956	291	528	53	872	1978	21	63	13	97
1957	1,320	333	216	1,869	1979	10	57	39	106
1958	174	227	171	572	1980	31	40	33	104
1959	227	160	216	603	1981	15	41	42	98
1960	93	212	120	425	1982	30	61	16	107
1961	277	171	102	550	1983	29	161	35	225
1962	295	343	165	803	1984	77	79	24	180
1963	202	537	82	821	1985	50	81	22	153
					1986	24	120	25	169
					1987	37	165	101	303

Table 4.3. Standardized Canada-U.S. landing statistics for rock sole from Area 5A, January-December 1956-87.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	551	1328	415
1957	511	1780	287
1958	501	1920	261
1959	212	1293	164
1960	397	1640	242
1961	237	1139	208
1962	196	1719	114
1963	161	1288	125
1964	156	1642	95
1965	157	1040	151
1966	330	1803	183
1967	252	1292	195
1968	435	2042	213
1969	293	2203	133
1970	167	1144	146
1971	135	1000	135
1972	58	763	76
1973	57	722	79
1974	74	1451	51
1975	37	597	62
1976	182	3309	55
1977	83	1766	47
1978	79	1129	70
1979	202	1474	137
1980	238	1384	172
1981	114	726	157
1982	189	1512	125
1983	124	1824	68
1984	142	1214	117
1985	56	737	76
1986	23	1769	13
1987	80	2857	28

[a]Effort = (Landings)(1000)/CPUE.
[b]CPUE -- Area 5A, April-September, option-2 method (Westrheim 1983). Standardized using the method of Westrheim and Foucher 1985.

Table 4.4. Standardized Canada-U.S. landing statistics for rock sole from Area 5B, January-December 1956-87.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[a]
1956	307	853	360
1957	206	619	333
1958	379	1606	236
1959	344	1339	257
1960	503	1863	270
1961	416	1770	235
1962	531	2091	254
1963	517	1958	264
1964	482	2472	195
1965	568	2021	281
1966	772	2339	330
1967	741	2487	298
1968	392	1774	221
1969	652	2751	237
1970	245	1161	211
1971	368	2079	177
1972	382	2748	139
1973	324	5586	58
1974	371	7275	51
1975	408	4250	96
1976	368	4182	88
1977	188	3133	60
1978	217	2932	74
1979	208	2667	78
1980	410	1925	213
1981	220	2588	85
1982	155	3039	51
1983	206	2424	85
1984	87	2071	42
1985	170	1717	99
1986	135	2596	52
1987	205	4457	46

[a]Effort = (Landings)(1000)/CPUE.
[b]CPUE -- Area 5B, April-Sept, option-2 method (Westrheim 1983). Standardized using the method of Westrheim and Foucher 1985.

Table 4.5. Standardized Canada-U.S. landing statistics for rock sole from Area 5C, January-December 1956-87.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	397	570	699
1957	726	1396	520
1958	368	944	390
1959	249	1078	231
1960	471	1186	397
1961	110	350	314
1962	322	651	495
1963	155	451	344
1964	244	1179	207
1965	539	4115	131
1966	961	2921	329
1967	948	1992	476
1968	811	1940	419
1969	1053	4066	259
1970	694	2410	288
1971	376	1301	289
1972	134	388	345
1973	186	565	329
1974	288	1269	227
1975	383	2176	176
1976	277	1689	164
1977	272	1470	185
1978	356	1240	287
1979	647	2451	264
1980	482	2634	183
1981	126	2377	53
1982	70	1842	38
1983	60	1132	53
1984	64	362	177
1985	28	318	88
1986	86	656	131
1987	209	977	214

[a]Effort = (Landings)(1000)/CPUE.
[b]CPUE -- Area 5C, April-September, option-2 method (Westrheim 1983). Standardized using the method of Westrheim and Foucher 1985.

Table 4.6. Standardized Canada-U.S. landing statistics for rock sole from Area 5D, January-December 1956-87.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	763	2430	314
1957	425	1146	371
1958	888	1039	855
1959	167	241	694
1960	656	761	862
1961	634	744	852
1962	507	658	771
1963	726	1021	711
1964	499	929	537
1965	340	668	509
1966	1583	2812	563
1967	1214	1082	1122
1968	1555	3756	414
1969	1356	2383	569
1970	709	1795	395
1971	1127	3113	362
1972	381	1206	316
1973	321	768	418
1974	334	530	630
1975	821	1512	543
1976	1161	3071	378
1977	574	2000	287
1978	518	1302	398
1979	666	1930	345
1980	495	1349	367
1981	458	1585	289
1982	221	773	286
1983	187	654	285
1984	124	667	186
1985	84	542	155
1986	133	475	280
1987	327	567	577

[a]Effort = (Landings)(1000)/CPUE
[b]CPUE -- Two Peaks-Butterworth, April-September.
Standardized by log linear model (see Section 4.0.1).

Table 4.7. Rock sole, Area 5D, annual estimates of numbers at age from virtual population analysis. 1945-85.

Year	Age 4	5	6	7	8	9	10	11
1945	543	337	315	162	122	76	22	9
1946	1439	414	251	234	106	70	46	11
1947	2578	991	276	169	146	53	35	26
1948	1411	1551	432	154	95	65	22	11
1949	1099	970	794	214	68	47	21	9
1950	1859	832	614	436	118	30	20	9
1951	3204	1387	571	346	177	56	7	11
1952	2509	2039	724	295	188	56	20	3
1953	2084	1336	836	342	130	83	21	9
1954	1099	1612	963	487	191	74	51	11
1955	542	785	940	527	301	125	49	37
1956	654	405	383	353	168	124	54	14
1957	2038	456	247	155	147	54	54	28
1958	2889	1542	317	116	45	57	10	23
1959	3759	2203	555	117	32	6	10	0
1960	1795	2909	1597	343	77	22	3	6
1961	1243	1389	1972	805	187	39	9	0
1962	1216	962	1043	1097	313	89	26	3
1963	1870	941	745	735	595	136	49	11
1964	2695	1426	679	494	373	284	38	17
1965	2857	2013	1005	474	305	197	182	20
1966	2921	2179	1469	708	314	184	127	131
1967	2297	2211	1055	568	290	74	39	34
1968	2029	1752	1352	515	139	126	13	14
1969	1719	1403	1021	469	213	61	77	0
1970	956	949	773	580	246	140	37	57
1971	969	734	639	388	223	123	38	9
1972	1378	738	373	184	145	43	32	14
1973	1240	1022	523	226	102	79	15	20
1974	1495	926	768	390	153	61	51	6
1975	1312	1029	561	586	302	118	43	34
1976	1093	1000	736	243	258	90	11	0
1977	1438	770	643	340	123	177	59	9
1978	2196	1049	454	402	194	79	131	43
1979	1335	1603	722	281	249	106	33	74
1980	2350*	1003	1113	424	161	147	63	0
1981	1053*	1353*	598	729	290	110	103	44
1982	429*	519*	775*	330	360	99	38	49
1983	162*	202*	244*	358*	112	122	24	7
1984	39*	75*	87*	92*	136*	35	44	9
1985	44*	18*	36*	39*	35*	51*	15	18

*Numbers marked with an asterisk are considered unreliable because the cumulative fishing mortality for these cohorts is less than 2.0 (Pope 1972).

Table 4.8. Rock sole, Area 5D, annual estimates of fishing mortality rates (F) 1945-85.

	Age							
Year	4	5	6	7	8	9	10	11
1945	0.02	0.04	0.05	0.18	0.30	0.24	0.43	0.50
1946	0.12	0.16	0.14	0.22	0.44	0.46	0.35	0.50
1947	0.26	0.58	0.33	0.33	0.56	0.62	0.86	0.50
1948	0.12	0.42	0.45	0.57	0.45	0.88	0.70	0.50
1949	0.03	0.21	0.35	0.35	0.56	0.59	0.65	0.50
1950	0.04	0.13	0.32	0.65	0.50	1.20	0.33	0.50
1951	0.20	0.40	0.41	0.36	0.89	0.78	0.65	0.50
1952	0.38	0.64	0.50	0.57	0.57	0.73	0.59	0.50
1953	0.01	0.08	0.29	0.33	0.31	0.23	0.38	0.50
1954	0.09	0.29	0.35	0.23	0.18	0.16	0.07	0.50
1955	0.04	0.47	0.73	0.89	0.64	0.58	0.99	0.50
1956	0.11	0.25	0.66	0.63	0.89	0.58	0.40	0.50
1957	0.03	0.12	0.51	0.98	0.70	1.39	0.61	0.50
1958	0.02	0.77	0.75	1.05	1.71	1.54	5.66	0.50
1959	0.01	0.07	0.23	0.17	0.11	0.43	0.27	0.50
1960	0.01	0.14	0.43	0.35	0.43	0.62	4.48	0.50
1961	0.01	0.04	0.34	0.70	0.50	0.16	0.93	0.50
1962	0.01	0.01	0.10	0.36	0.59	0.35	0.57	0.50
1963	0.02	0.08	0.16	0.43	0.49	1.02	0.80	0.50
1964	0.04	0.10	0.11	0.23	0.39	0.19	0.40	0.50
1965	0.02	0.06	0.10	0.16	0.26	0.18	0.08	0.50
1966	0.03	0.47	0.70	0.64	1.19	1.29	1.07	0.50
1967	0.02	0.24	0.47	1.16	0.58	1.53	0.77	0.50
1968	0.12	0.29	0.81	0.64	0.58	0.24	5.84	0.50
1969	0.34	0.35	0.31	0.40	0.17	0.23	0.06	0.50
1970	0.01	0.15	0.44	0.70	0.44	1.04	1.23	0.50
1971	0.02	0.43	0.99	0.73	1.40	1.09	0.74	0.50
1972	0.05	0.09	0.25	0.34	0.36	0.79	0.24	0.50
1973	0.04	0.04	0.04	0.14	0.26	0.19	0.73	0.50
1974	0.12	0.25	0.02	0.01	0.01	0.12	0.14	0.50
1975	0.02	0.09	0.59	0.57	0.96	2.12	7.06	0.50
1976	0.10	0.19	0.52	0.43	0.13	0.17	0.01	0.50
1977	0.06	0.28	0.22	0.31	0.19	0.05	0.08	0.50
1978	0.06	0.12	0.23	0.23	0.35	0.62	0.32	0.50
1979	0.04	0.11	0.28	0.30	0.27	0.27	6.77	0.50
1980	0.20	0.17	0.07	0.03	0.04	0.01	0.01	0.50
1981	0.21	0.06	0.09	0.21	0.57	0.57	0.24	0.50
1982	0.01	0.01	0.02	0.33	0.34	0.66	0.94	0.50
1983	0.02	0.09	0.22	0.22	0.42	0.26	0.19	0.50
1984	0.26	0.23	0.29	0.46	0.49	0.34	0.41	0.50
1985	0.08	0.22	0.35	0.44	0.51	0.61	1.18	0.50

Table 4.9. Rock sole, Area 5D, annual estimates of numbers in stock, numbers landed, and exploitation rates.

Year	Nos. in stock	No. landed	Exploitation rate
1945	1586	109	0.07
1946	2571	342	0.13
1947	4274	1123	0.26
1948	3741	897	0.24
1949	3222	508	0.16
1950	3918	564	0.14
1951	5759	1314	0.23
1952	5834	2057	0.35
1953	4841	429	0.09
1954	4488	825	0.18
1955	3306	1219	0.37
1956	2155	606	0.28
1957	3179	401	0.13
1958	4999	1097	0.22
1959	6682	259	0.04
1960	6752	980	0.15
1961	5644	980	0.17
1962	4749	553	0.12
1963	5082	730	0.14
1964	6006	539	0.09
1965	7053	421	0.06
1966	8033	2208	0.27
1967	6568	1360	0.21
1968	5940	1579	0.27
1969	4963	1230	0.25
1970	3738	840	0.22
1971	3123	1045	0.33
1972	2907	305	0.10
1973	3227	172	0.05
1974	3850	361	0.09
1975	3985	863	0.22
1976	3431	631	0.18
1977	3559	474	0.13
1978	4548	518	0.11
1979	4403	547	0.12
1980	5261	571	0.11
1981	4280	546	0.13
1982	2599	219	0.08
1983	1231	153	0.12
1984	517	128	0.25
1985	256	74	0.29

Table 4.10. Standardized Canada-U.S. landing statistics for English sole, Area 5D, January-December 1956-87.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	935	1300	719
1957	539	1653	326
1958	674	2332	289
1959	901	2468	365
1960	1079	1505	717
1961	865	1676	516
1962	436	1232	354
1963	369	3101	119
1964	420	2308	182
1965	391	3491	112
1966	329	5141	64
1967	511	2077	246
1968	632	3144	201
1969	725	2571	282
1970	920	2402	383
1971	482	2708	178
1972	356	2211	161
1973	598	2265	264
1974	459	2318	198
1975	922	3415	270
1976	946	6757	140
1977	972	7594	128
1978	495	4714	105
1979	744	8651	86
1980	796	7044	113
1981	1148	7705	149
1982	401	3457	116
1983	396	2829	140
1984	606	3367	180
1985	547	2509	218
1986	322	2800	115
1987	528	4000	132

[a]Effort = (landings)(1000)/CPUE.
[b]CPUE -- Two Peaks-Butterworth, April-September, option-2 method (Westrheim 1983).
Standardized using the method of Westrheim and Foucher 1985.

Table 4.11. Standardized Canada-U.S. landing statistics for Dover sole, Areas 5C, D, E, 1970-87.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1970	965	1290	748
1971	903	1402	644
1972	922	1372	672
1973	768	869	884
1974	767	908	845
1975	882	1432	616
1976	1022	2355	434
1977	577	1775	325
1978	483	1081	447
1979	697	2437	286
1980	807	2267	356
1981	840	2079	404
1982	512	1450	353
1983	693	1537	451
1984	953	1765	540
1985	830	1853	448
1986	1040	1981	525
1987	503	756	665

[a]Effort (h) = landings (1000)/CPUE.
[b]CPUE -- Dundas 25% qualified, June-September.
Standardized by log-linear model (see Section 4.0.1).

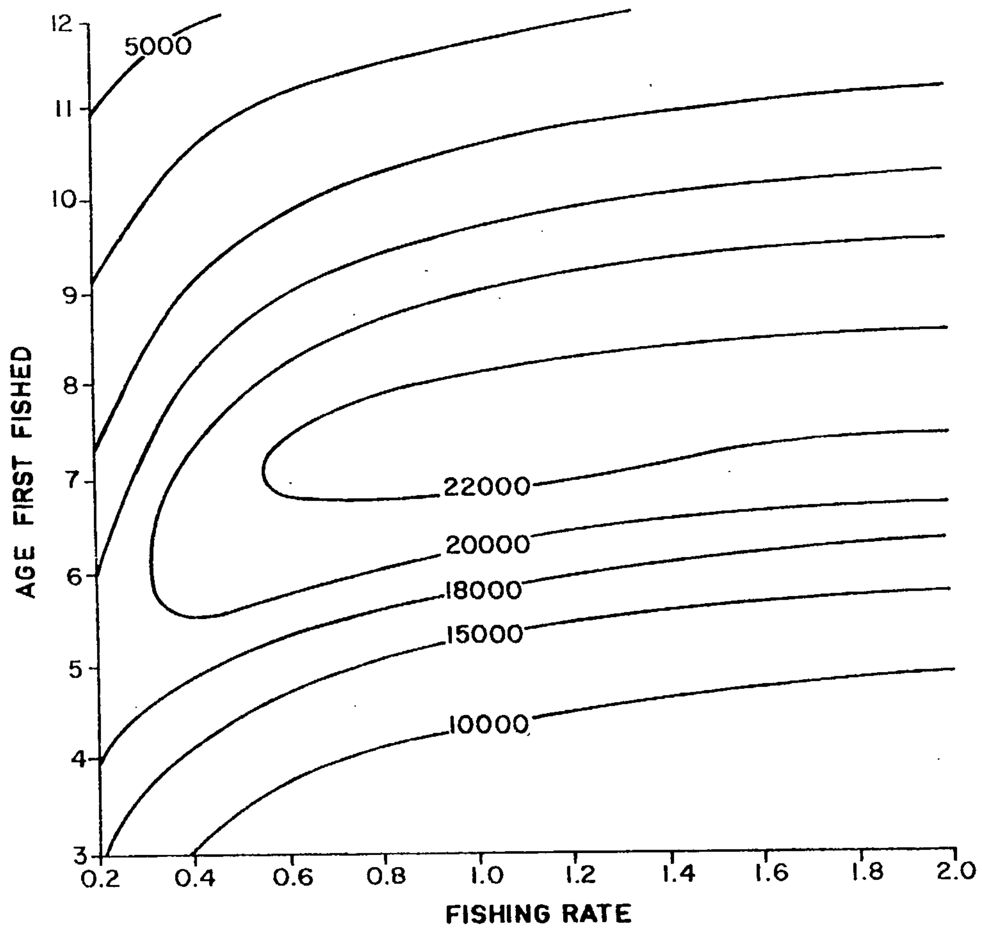

Fig. 4.1. Potential yield isopleths from 50-yr forward simulations for English sole females in Area 5D. Numbers in the body of the graph are tons of production summed over 50 years in relation to age of recruitment and fishing rate.

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5.1 Coastwide

5.1.2. Landing Statistics

In 1987 a total of 5189 t of sablefish were caught coastwide by trap, trawl, and longline. Nominal catch from the west coast of the Queen Charlotte Islands, Queen Charlotte Sound, and Hecate Strait increased from 2560.0 t in 1986 to 2635.1 t in 1987, with the majority (87.4%) caught by trap (Table 5.1).

Catch from the west coast of Vancouver Island increased to 2554.2 t in 1987 from 1851.2 t in 1986. The majority of fish were trap-caught (59.25%) (Table 5.2). Longline catch increased to 770.4 t in 1987 from 459.2 in 1986.

Trawl catch from the west coast of Vancouver Island decreased to 271.5 t in 1987 from 365.4 t in 1986. Similarily, landings from all other areas combined, decreased to 167.9 t in 1987 from 184.8 t in 1986 (Tables 5.1 and 5.2).

5.1.3 General biological information

Length frequencies collected in 1987 remain consistent with those presented in the previous assessment (Saunders et al. 1988).

The age frequencies for 1979 to 1986 are presented in Figure 5.1. The 1979 frequency shows few young fish. In 1980, the strong 1977 year-class is evident and persists as the strongest component of the fishery, by number, until 1984. The coincidental decline in older age classes in the fishery may indicate a fishing down of these older age classes or may be a masking by the dominant 1977 year-class.

5.1.4 Condition of the stock

Nominal CPUE was standardized to account for variation due to trap type, and records from vessels with skippers having one or more years of experience were selected. Standardized CPUE values off the Queen Charlotte Islands in 1987 decreased to 15.0 kg/trap from 16.8 kg/trap in 1986. In Queen Charlotte Sound, standardized CPUE in 1987 increased to 22.2 kg/trap from 20.3 kg/trap in 1986. Off Vancouver Island, standardized CPUE increased to 17.4 kg/trap in 1987 from 15.0 kg/trap in 1986.

The approach taken in this assessment is similar to that reported in the 1987 assessment (Saunders et al. 1988). A forward simulation model (Tyler 1982) was used to make projections of sablefish biomass and yield. The numbers-at-age used as the starting vector for the forward simulation were calculated using Virtual Population Analysis (VPA) (Gulland 1983).

The VPA was run using eight years of age composition data from 1979 to 1986. The catch-at-age data used in the VPA are presented in Table 5.4. The catch-at-age indicates that the fishery is becoming increasingly dependent on younger fish. The cause of this age frequency truncation is believed to be the result of a number of factors. First of all, the increasing price for small fish (< 60 cm) since 1984 and the shorter duration of the fishery has led to more smaller fish being landed. To reduce the error in estimating recruitment in the forward simuluations, numbers at age 5 from the VPA were used rather than numbers at age 4 which had been used in previous assessments.

Secondly, the truncation could be the result of a masking of the older age-classes by the strong 1977 year-class. The sample sizes required to sample the population were derived prior to the arrival of the strong 1977 year-class and may be inadequate for older ages.

Thirdly, the truncation could be the result of fishing down the older ages. If true, then the rapid loss of the older ages and the dependence of the fishery on 10-15 year-classes is cause for concern for a species with documented low periods of recruitment.

As in previous assessments, a natural mortality rate of 0.1 and a Terminal F value of 0.1 were used in the VPA (see Saunders et al. 1988) for a discussion of the sensitivity of the analysis to varying rates of M and Terminal F). The annual estimates of numbers-at-age, fishing mortality rates (F), total mortality rates (Z), and exploitation rates from the VPA (using M=0.1 (McFarlane et al. 1985)) are presented in Tables 5.5, 5.6, 5.7, and 5.8, respectively, with totals presented in Table 5.9. It must be noted that because the cumulative F values for all cohorts in the VPA are less than two, the numbers-at-age, cannot be considered accurate (Pope 1972).

The numbers at age 5 in 1983, 1984 and 1985 (Table 5.5) indicate that the 1978, 1979 and 1980 year-classes are moderate to strong in strength.

In all runs of the forward simulation model, the numbers-at-age in 1979 from the VPA were used. The numbers-at-age in 1988 were estimated by running the simulation from 1979 and incorporating catches from 1979 to 1988 with the catch in 1988 assumed to be equal to the quota.

The numbers recruiting at age 5 were taken from the VPA up to 1984. Beyond 1984 recruitment was assumed to be constant and a range of recruitment levels was employed. The average of the numbers at age 5 in 1980 and 1981 (1975 and 1976 year-classes) was used as a low level of recruitment. These year-classes are recognized as weak to moderate in strength. The number at age 5 for the 1979 year-class was used for the moderate to strong recruitment level and the mean of the high and low levels was used as an average level.

Equilibrium yields

Using the starting population in 1979, 50-year runs of varying constant catches assuming the constant recruitment values above were conducted. At low levels of recruitment 1000 t was sustainable over the long term. At average and high recruitment levels, yields of 2600 t and 4400 t were sustainable, respectively. This would suggest that the current levels of exploitation are of high risk with respect to maintaining a long-term yield in the event that recruitment since the arrival of the 1977 year-class has been low.

Variable yields

If the goal is to manage to an F 0.1 level, a projection to 1989 can be utilized and the F 0.1 level of F applied to the stock. Beyond 1987, F levels of 0.205 and 0.1025 under low, average and high recruitment assumptions result in the following yields, in tonnes, for 1989:

F	Recruitment		
	Low	Average	High
0.205	1276	2871	4481
0.150	954	2146	3348

These correspond to the F0.1 and F0.05 levels from yield per recruit analysis (McFarlane et al. 1985). While F0.1 is assumed to be conservative for most species, it is not known if it is conservative for a long-lived species with low recruitment. It is likely that the acceptable catch level is somewhere between the two.

The projections indicate that biomass is in the order of 26 thousand t and that with average and low recruitment the recruited biomass will continue to decline at F's of 0.205 and 0.15. Appropriate levels of recruitment introduce the most uncertainty into this assessment. Work is currently underway on determining the factors that influence year-class strength. As well, an index of year-class strength based on the abundance of 0+ fish has been under development since 1984. In 1988, the first year-class surveyed will begin to recruit to the fishery as age 4-5 fish, and the ability of the survey to predict year-class strength will be demonstrated. In the past, strong year-classes have been approximately ten years apart. Although there is indication that moderate to strong year-classes have occurred since 1977 it is possible that persistently poor recruitment could occur again as it did in the mid-1970s. Should this happen, available yields would decline.

5.1.5 Yield options

Risk in the yield options below is a function of the uncertainty regarding recruitment. There exists a strong possibility that the high-risk level may interfere with the future yield.

Given a commitment to optimizing return from the existing stock, the following levels are appropriate from variable catch simulations. Again, risk is associated with the uncertainty regarding appropriate recruitment levels from 1985 to the present.

Sustainable - low risk -	2800 t
Sustainable -	3600 t
High risk - high risk -	4500 t

Table 5.1. Canadian sablefish nominal catch, by gear, from Queen Charlotte Sound, Hecate Strait, and the west coast of the Queen Charlotte Islands, 1973 to 1987 (Major Areas 5A, 5B, 5C, 5D and 5E) (round wt, metric tonnes)[a], excluding dumped and discarded fish.

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1973	116.6	21.6	31.7	5.9	392.4	72.6	-	-	540.7
1974	39.0	16.1	38.1	15.7	165.6	68.2	-	-	242.7
1975	149.9	22.7	82.0	12.4	427.9	64.9	-	-	659.8
1976	47.7	10.4	154.2	33.7	255.8	55.9	-	-	457.7
1977	49.8	16.9	98.3	33.4	145.7	49.4	.9	.3	294.7
1978	39.0	8.2	40.4	8.5	395.1	83.0	1.4	.3	475.9
1979	158.7	11.7	132.7	9.8	1067.6	78.5	-	-	1359.0
1980	179.7	9.5	228.6	12.0	1488.3	78.5	-	-	1896.6
1981	238.1	8.7	90.4	3.3	2412.6	88.0	-	-	2741.1
1982	181.8	6.3	88.3	3.1	2595.2	90.1	16.5[d]	.5	2865.3
1983	108.4	3.5	116.5	3.7	2901.2	92.3	15.6[e]	.5	3141.7
1984	153.9	6.7	64.8	2.8	2082.2	90.5	-	-	2300.9
1985	298.9	13.0	135.1	5.9	1864.1	81.1	-	-	2298.1
1986	159.3	6.2	184.8	7.2	2215.9	86.6	-	-	2560.0
1987	164.4	6.2	167.9	6.4	2302.5	87.4	.3	-	2635.1

[a]Fisheries Research Board of Canada Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1973-1981. Statistics from 1982 to 1987 from Department of Fisheries and Oceans, Pacific Biological Station groundfish data base.

[b]Includes troll and handline.

[c]Percent of total landed by all gears within a year.

[d]Incidental to halibut longline.

[e]Includes troll, handline, sunken gillnet and catch incidental to halibut longline fishery.

Table 5.2. Canadian sablefish landing, by gear, from west coast Vancouver Island (Major Areas 3C and 3D), 1973-1987 (round wt, metric tonnes)[a], excluding dumped and discarded fish.

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1973	3.2	0.8	50.9	12.5	353.4	86.7	Tr	Tr	407.5
1974	2.3	0.9	83.7	33.6	161.5	64.8	1.8	0.7	249.3
1975	2.3	0.9	200.3	81.8	41.5	16.9	0.9	0.4	245.0
1976	41.7	13.3	224.8	71.5	47.6	15.1	0.1	0.0	314.2
1977	27.3	3.5	688.4	87.1	68.9	8.7	5.9	0.7	790.5
1978	18.2	5.1	89.9	25.4	239.5	67.7	6.4	1.8	354.0
1979	118.3	17.5	143.4	21.2	409.8	60.5	6.0	0.9	677.5
1980	69.1	3.6	106.8	5.6	1722.5	90.6	3.0	0.2	1901.4
1981	94.8	8.6	140.2	12.8	862.4	78.6	-	-	1097.4
1982	161.9	13.2	153.2	12.5	913.3	74.2	1.9[d]	0.2	1230.3
1983	343.1	27.1	146.7	11.6	777.0	61.3	-	-	1266.8
1984	211.2	13.9	120.0	7.9	1188.9	78.2	-	-	1520.1
1985	159.4	8.4	93.9	5.0	1637.2	86.6	-	-	1890.5
1986	459.2	24.8	365.4	19.7	1026.6	55.5	-	-	1851.2
1987	770.4	30.2	271.5	10.6	1512.3	59.2	-	-	2554.2

[a]Fisheries Research Board of Canada Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1973-1981. Statistics from 1982 to 1987 from Department of Fisheries and Oceans, Pacific Biological Station groundfish data base.

[b]Includes troll and handline.

[c]Percent of total landed by all gears within a year.

[d]Incidental to halibut longline.

Table 5.3. Sablefish trap nominal and standardized CPUE (kg/trap) for the three major areas, 1978-1987.

	Vancouver Island		Queen Charlotte Sd.		Queen Charlotte Is.	
Year	Nom.	Stand	Nom.	Stand	Nom.	Stand.
1978	25.2	-	11.6	-	20.1	-
1979	14.1	12.0	14.0	22.7	20.9	17.5
1980	15.0	16.8	18.4	15.8	13.5	13.8
1981	10.3	9.9	17.9	18.0	18.5	19.2
1982	11.8	15.7	16.6	19.1	24.8	24.7
1983	13.7	11.1	17.0	16.5	17.9	18.9
1984	11.7	13.4	14.9	14.9	12.7	13.7
1985	15.2	15.6	20.3	17.4	19.6	18.2
1986	10.8	10.3	20.2	20.3	16.4	16.8
1987	12.4	12.1	18.9	22.2	17.4	15.0

Table 5.4. Catch-at-age in numbers for sablefish from 1979-1985.

	Year							
Age	1979	1980	1981	1982	1983	1984	1985	1986
5	2019	10701	40098	141704	100093	184255	88206	131641
6	2019	28026	24059	60987	333276	178349	195707	195024
7	2019	34650	33312	36472	87994	287012	290804	160895
8	2019	35670	15422	44245	38497	47245	237053	183648
9	2019	41784	22825	51420	36297	34253	88206	86136
10	18175	42294	30228	41256	53896	24804	22051	27628
11	26252	63186	32078	63976	26398	25985	16539	14627
12	30291	74396	47501	48430	49496	11811	4135	11376
13	38369	82040	36397	54410	35197	23622	4135	21128
14	64621	65224	40715	41854	43997	15355	17917	11376
15	50485	58090	43799	59193	47297	16536	11026	16252
16	60583	71339	36397	31091	28598	9449	4135	16252
17	92893	60129	33929	22720	38497	7087	2756	9751
18	76738	47390	27760	26906	26398	2362	5513	8126
19	74718	45861	28377	19133	29698	14173	2756	6501
20	68660	42803	22208	20329	28598	3543	5513	13002
21	80777	39236	24676	19731	24198	2362	2756	8126
22	78757	30574	22208	9567	20898	1181	1378	8126
23	68660	16816	24059	10164	17599	3543	1378	8126
24	64621	15797	17273	8969	14299	1181	1378	11376
25	32311	15797	9253	10164	4400	1181	1378	13002
26	32311	18344	11104	4783	6600	2362	1378	13002
27	20194	9682	6169	7773	3300	2362	1378	13002
28	20194	10701	8636	2392	3300	1181	1378	1625
29	6058	5096	4935	2392	4400	1181	1378	9751
30	12117	10701	5552	2392	1100	1181	1378	3250
31	8078	6624	1851	598	2200	1181	1378	1625
32	4039	2548	4935	1196	4400	1181	1378	8126
33	8078	2548	1851	1794	1100	1181	1378	3250
34	2019	2038	1851	598	1100	1181	1378	4876
35	4039	1529	5552	598	1100	1181	1378	3250

Table 5.5. Annual estimates of sablefish numbers-at-age from Virtual Population Analysis (M=0.1, Terminal F=0.1).

	Year							
Age	1979	1980	1981	1982	1983	1984	1985	1986
5	429424	416087	759389	2120246	2648545	2022934	2495187	2864965
6	552703	387110	365344	647109	1788933	2299149	1656239	2166823
7	333418	498309	324853	308267	525599	1301717	1901303	1315720
8	501543	298110	418252	263440	244834	391473	908177	1436974
9	476192	452162	236341	363129	196034	185042	309978	595470
10	471364	429295	370199	191866	280404	143304	135296	196600
11	443027	409131	348378	306139	135071	201695	105594	101178
12	431536	375039	309214	285227	215517	97395	157538	79806
13	509942	361613	267608	233699	211364	147964	77070	138316
14	415360	424557	249067	208600	160031	157550	111258	65675
15	447632	313922	324098	187279	148600	102972	127879	84087
16	370267	358067	229593	250298	113114	89399	77127	105751
17	425496	276727	255334	173523	196891	75271	72153	65723
18	516746	296859	193066	199194	135446	141967	61626	62631
19	452781	394473	223215	148381	153841	97687	125769	50456
20	505020	337955	313422	175587	115892	111456	75077	111335
21	223216	393668	265845	262247	139510	77391	97768	62506
22	538125	125357	319399	217655	218336	103729	67901	85813
23	184859	412193	84260	268088	187060	177281	92682	60123
24	156312	101954	357606	53327	232718	153152	156981	82772
25	238699	79965	77055	307172	39660	196816	136907	140311
26	139987	184324	57094	61057	266831	31725	175976	122349
27	177520	96015	149554	41184	50491	234323	26413	157307
28	142651	141911	77885	129740	29967	42604	209406	22507
29	54909	110163	118149	62302	114909	23971	37397	187219
30	50681	43922	94652	102489	54078	99742	20587	32469
31	29480	34396	29542	80127	90706	47883	89115	17370
32	18819	19005	24924	24930	71630	79660	42050	78960
33	83472	13129	14822	17954	21415	60585	71143	36879
34	22181	67762	9472	11659	14566	18386	53651	63002
35	42820	18160	59458	6830	10010	12127	15514	47108

Table 5.6. Annual estimates of sablefish fishing mortality rates (F) from Virtual Population Analysis (M=0.1, Terminal F=0.1).

	Year							
Age	1979	1980	1981	1982	1983	1984	1985	1986
5	0.00	0.03	0.06	0.07	0.04	0.10	0.04	0.05
6	0.00	0.08	0.07	0.11	0.22	0.09	0.13	0.10
7	0.01	0.08	0.11	0.13	0.19	0.26	0.18	0.14
8	0.00	0.13	0.04	0.20	0.18	0.13	0.32	0.14
9	0.00	0.10	0.11	0.16	0.21	0.21	0.36	0.16
10	0.04	0.11	0.09	0.25	0.23	0.21	0.19	0.16
11	0.07	0.18	0.10	0.25	0.23	0.15	0.18	0.16
12	0.08	0.24	0.18	0.20	0.28	0.13	0.03	0.16
13	0.08	0.27	0.15	0.28	0.19	0.19	0.06	0.17
14	0.18	0.17	0.19	0.24	0.34	0.11	0.18	0.20
15	0.12	0.21	0.16	0.40	0.41	0.19	0.09	0.23
16	0.19	0.24	0.18	0.14	0.31	0.11	0.06	0.18
17	0.26	0.26	0.15	0.15	0.23	0.10	0.04	0.17
18	0.17	0.19	0.16	0.16	0.23	0.02	0.10	0.15
19	0.19	0.13	0.14	0.15	0.22	0.16	0.02	0.15
20	0.15	0.14	0.08	0.13	0.30	0.03	0.08	0.13
21	0.48	0.11	0.10	0.08	0.20	0.03	0.03	0.15
22	0.17	0.30	0.08	0.05	0.11	0.01	0.02	0.10
23	0.50	0.04	0.36	0.04	0.10	0.02	0.01	0.15
24	0.57	0.18	0.05	0.20	0.07	0.01	0.01	0.16
25	0.16	0.24	0.13	0.04	0.12	0.01	0.01	0.10
26	0.28	0.11	0.23	0.09	0.03	0.08	0.01	0.12
27	0.12	0.11	0.04	0.22	0.07	0.01	0.06	0.09
28	0.16	0.08	0.12	0.02	0.12	0.03	0.01	0.08
29	0.12	0.05	0.04	0.04	0.04	0.05	0.04	0.06
30	0.29	0.30	0.07	0.02	0.02	0.01	0.07	0.11
31	0.34	0.22	0.07	0.01	0.03	0.03	0.02	0.10
32	0.26	0.15	0.23	0.05	0.07	0.01	0.03	0.11
33	0.11	0.23	0.14	0.11	0.05	0.02	0.02	0.10
34	0.10	0.03	0.23	0.05	0.08	0.07	0.03	0.08
35	0.10	0.09	0.10	0.10	0.12	0.11	0.10	0.08

Table 5.7. Annual estimates of sablefish total mortality rates (Z) from Virtual Population Analysis (M=0.1, Terminal F=0.1).

	Year							
Age	1979	1980	1981	1982	1983	1984	1985	1986
5	0.10	0.13	0.16	0.17	0.14	0.20	0.14	0.15
6	0.10	0.18	0.17	0.21	0.32	0.19	0.23	0.20
7	0.11	0.18	0.21	0.23	0.29	0.36	0.28	0.24
8	0.10	0.23	0.14	0.30	0.28	0.23	0.42	0.24
9	0.10	0.20	0.21	0.26	0.31	0.31	0.46	0.26
10	0.14	0.21	0.19	0.35	0.33	0.31	0.29	0.26
11	0.17	0.28	0.20	0.35	0.33	0.25	0.28	0.26
12	0.18	0.34	0.28	0.30	0.38	0.23	0.13	0.26
13	0.18	0.37	0.25	0.38	0.29	0.29	0.16	0.27
14	0.28	0.27	0.29	0.34	0.44	0.21	0.28	0.30
15	0.22	0.31	0.26	0.50	0.51	0.29	0.19	0.33
16	0.29	0.34	0.28	0.24	0.41	0.21	0.16	0.28
17	0.36	0.36	0.25	0.25	0.33	0.20	0.14	0.27
18	0.27	0.29	0.26	0.26	0.33	0.12	0.20	0.25
19	0.29	0.23	0.24	0.25	0.32	0.26	0.12	0.25
20	0.25	0.24	0.18	0.23	0.40	0.13	0.18	0.23
21	0.58	0.21	0.20	0.18	0.30	0.13	0.13	0.25
22	0.27	0.40	0.18	0.15	0.21	0.11	0.12	0.20
23	0.60	0.14	0.46	0.14	0.20	0.12	0.11	0.25
24	0.67	0.28	0.15	0.30	0.17	0.11	0.11	0.26
25	0.26	0.34	0.23	0.14	0.22	0.11	0.11	0.20
26	0.38	0.21	0.33	0.19	0.13	0.18	0.11	0.22
27	0.22	0.21	0.14	0.32	0.17	0.11	0.16	0.19
28	0.26	0.18	0.22	0.12	0.22	0.13	0.11	0.18
29	0.22	0.15	0.14	0.14	0.14	0.15	0.14	0.16
30	0.39	0.40	0.17	0.12	0.12	0.11	0.17	0.21
31	0.44	0.32	0.17	0.11	0.13	0.13	0.12	0.20
32	0.36	0.25	0.33	0.15	0.17	0.11	0.13	0.21
33	0.21	0.33	0.24	0.21	0.15	0.12	0.12	0.20
34	0.20	0.13	0.33	0.15	0.18	0.17	0.13	0.18
35	0.20	0.19	0.20	0.20	0.22	0.21	0.20	0.18

Table 5.8. Annual exploitation rates (nos. caught/nos. in the stock) by age for sablefish from Virtual Population Analysis (M=0.1, Terminal F=0.1).

	Year							
Age	1979	1980	1981	1982	1983	1984	1985	1986
5	0.00	0.03	0.05	0.07	0.04	0.09	0.04	0.05
6	0.00	0.07	0.07	0.09	0.19	0.08	0.12	0.09
7	0.01	0.07	0.10	0.12	0.17	0.22	0.15	0.12
8	0.00	0.12	0.04	0.17	0.16	0.12	0.26	0.13
9	0.00	0.09	0.10	0.14	0.19	0.19	0.28	0.14
10	0.04	0.10	0.08	0.22	0.19	0.17	0.16	0.14
11	0.06	0.15	0.09	0.21	0.20	0.13	0.16	0.14
12	0.07	0.20	0.15	0.17	0.23	0.12	0.03	0.14
13	0.08	0.23	0.14	0.23	0.17	0.16	0.05	0.15
14	0.16	0.15	0.16	0.20	0.27	0.10	0.16	0.17
15	0.11	0.19	0.14	0.32	0.32	0.16	0.09	0.19
16	0.16	0.20	0.16	0.12	0.25	0.11	0.05	0.15
17	0.22	0.22	0.13	0.13	0.20	0.09	0.04	0.15
18	0.15	0.16	0.14	0.14	0.19	0.02	0.09	0.13
19	0.17	0.12	0.13	0.13	0.19	0.15	0.02	0.13
20	0.14	0.13	0.07	0.12	0.25	0.03	0.07	0.12
21	0.36	0.10	0.09	0.08	0.17	0.03	0.03	0.13
22	0.15	0.24	0.07	0.04	0.10	0.01	0.02	0.09
23	0.37	0.04	0.29	0.04	0.09	0.02	0.01	0.14
24	0.41	0.15	0.05	0.17	0.06	0.01	0.01	0.14
25	0.14	0.20	0.12	0.03	0.11	0.01	0.01	0.09
26	0.23	0.10	0.19	0.08	0.02	0.07	0.01	0.11
27	0.11	0.10	0.04	0.19	0.07	0.01	0.05	0.08
28	0.14	0.08	0.11	0.02	0.11	0.03	0.01	0.07
29	0.11	0.05	0.04	0.04	0.04	0.05	0.04	0.05
30	0.24	0.24	0.06	0.02	0.02	0.01	0.07	0.10
31	0.27	0.19	0.06	0.01	0.02	0.02	0.02	0.09
32	0.21	0.13	0.20	0.05	0.06	0.01	0.03	0.10
33	0.10	0.19	0.12	0.10	0.05	0.02	0.02	0.09
34	0.09	0.03	0.20	0.05	0.08	0.06	0.03	0.08
35	0.09	0.08	0.09	0.09	0.11	0.10	0.09	0.07

Table 5.9. Annual estimates of numbers in stock, numbers landed, exploitation rates, mean F and Z values ages 5-35, from Virtual Population Analysis (M=0.1, Terminal F=0.1).

Year	Nos. in stock	No. landed	Exploitation rate	Mean F Z	Mean
1979	9386182	1054133	0.11	0.17	0.27
1980	7871340	991614	0.13	0.15	0.25
1981	6927090	665010	0.10	0.13	0.23
1982	7708745	847237	0.11	0.13	0.23
1983	8812003	1114221	0.13	0.16	0.26
1984	8926350	909461	0.10	0.09	0.19
1985	9690762	1018500	0.11	0.08	0.18
1986	10638205	1023876	0.10	0.13	0.23

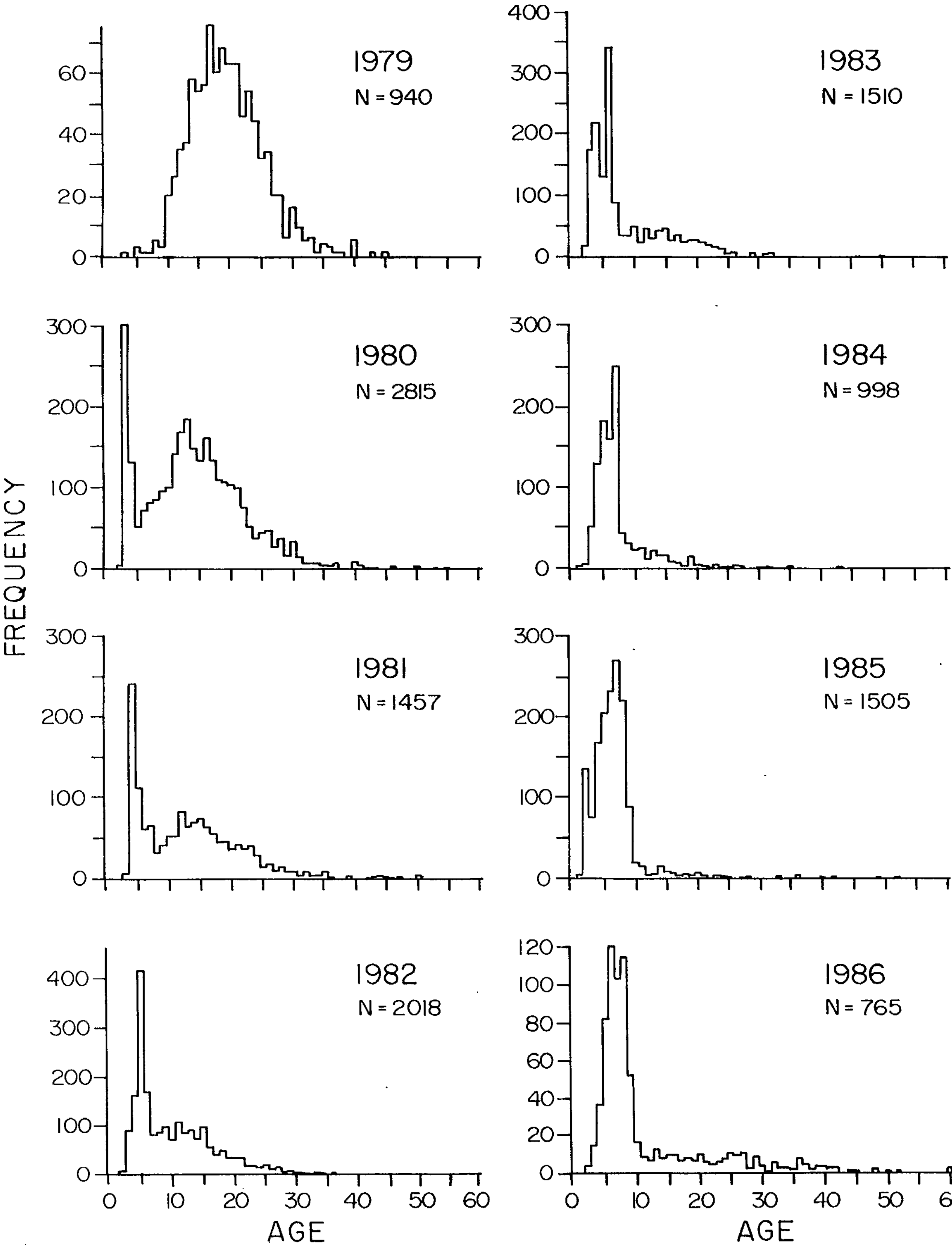


Fig. 5.1. Age frequencies of commercial catches of sablefish 1979-1986 off the west coast of Canada.

6.0 PACIFIC HAKE

by M. W. Saunders and W. Shaw

6.1. Coastwide

Yield options are not proposed on a coastwide basis.

6.2. Strait of Georgia

6.2.1. Introduction

Pacific hake are the most abundant resident fish in the Strait of Georgia. Exploitation of the resident stocks has been increasing since the inception of the fishery in 1978. The proximity of the stocks to land-based processing, absence of the parasite Kudoa paniformes which is responsible for the rapid degradation of the flesh found in offshore Pacific hake, and the potential for harvesting roe from the large spawning concentration has made this an increasingly important fishery.

The 1988 assessment is based on results from catch-at-age analysis incorporated into a forward simulation model (Tyler 1982) to simulate hake biomass and yield into the future.

6.2.2 Landing Statistics

During 1987, a total of 9127 t was landed from the Strait of Georgia, an increase of 81.4 % over 1986 landings (Table 6.1). In 1987, as in previous years, the majority (63.7%) of landings took place in the second quarter (Table 6.1). Prior to 1986, most of the catch came from Minor Area 17. In 1986, exploitation shifted from Minor Area 17 to Minor Area 29, a trend which continued in 1987 with 64.1% of the catch taken from Minor Area 29 (Table 6.1).

6.2.3. General biological information

Biological port sample data collected in 1988, indicate no change in the size composition from previous years (Figure 6.1), with the length of fish captured averaging 41.15 cm. The fishery continues to be supported by a number of strong year-classes, including those of 1977, 1978 and 1983 (Figure 6.2).

CPUE increased slightly from 7.45 t/hr in 1986, to 8.02 t/hr in 1987 (Table 6.2).

6.2.4. Condition of the stock

The approach taken in this assessment is similar to that reported in the 1987 assessment (Shaw et al. 1988). A forward simulation model was used to project hake biomass and yield from numbers-at-age for 1979. The numbers-at-age used as the starting vector for the forward simulation were calculated using Virtual Population Analysis (VPA) (Gulland 1983).

The catch-at-age data used in the VPA are presented in Table 6.3. The relative strength of most cohorts is inconsistent between years. These discrepancies may be the result of a number of factors that bear examination for future assessments, namely age-specific catchability, partial recruitment factors and behavioral segregation by size or age.

The catch-at-age was calculated as the ratio of number-at-age to weight-at-age in the age sample, multiplied by the total catch. The weight-at-age in the sample was the sum of the weights of individual fish determined from length-weight relationships for males and females in the appropriate quarter (Table 6.4 in Shaw et al. 1988).

The VPA was run using nine years of age composition data, 1979-1987. The rate of natural mortality for this stock is reported to range between 0.16 and 0.29 (McFarlane et al. 1983). In the VPA a midpoint of this range (0.23) was used. A Terminal F value of 0.35 was used. Terminal F was allowed to vary around 0.35 by first calculating an overall q:

$$q = F / E, \text{ where } E = \text{mean effort}$$

and then calculating terminal F for each year:

$$F = q * E, \text{ where } E \text{ is the effort for that year.}$$

This allowed the terminal F value to vary with effort, which is more realistic than holding it constant for all years.

To confirm the appropriateness of the assumed values of M and F, the relationship between fishery CPUE data and biomass, calculated from the VPA, was examined using linear regression. The CPUE time series (Table 6.2) was regressed on biomass estimates for each year from the VPA. This was repeated for VPA runs conducted at M levels of 0.16, 0.23 and 0.29 and Terminal F values of 0.05, 0.10, 0.20, 0.30, 0.35, and 0.4. The R-square value over all of the runs ranged from 0.1906 to 0.2103 indicating a poor fit between the two series. No one combination of M and F explained significantly more of the variation than any other. It is possible that the CPUE statistic of t/hr is inappropriate as an index of abundance given the schooling behavior of this species. Future work will include fitting of VPA age-specific biomass and CPUE data from the 1988 survey.

The numbers-at-age in the population, fishing mortality rates (F), total mortality rates (Z) and exploitation rates from the VPA using M=0.23 and Terminal F=0.35, are presented in Tables 6.4, 6.5, 6.6, and 6.7 respectively, with totals by year reported in Table 6.8. The numbers-at-age for the majority of the cohorts modelled by the VPA do not have a cumulative F of greater than 2.0 and are considered inaccurate (Pope 1972).

In the previous assessment, a general forward simulation model (Tyler 1982) was adapted for Pacific hake and was used to investigate constant catch and variable catch management scenarios. For this assessment, the model was updated with numbers-at-age in 1979 from the VPA runs. Catches from 1979 to 1987 were included and numbers recruiting at age 2 were taken from the VPA up to 1982.

Beyond 1982, recruitment was assumed to be constant and runs using low, average and high recruitment from the VPA were conducted. The recruiting numbers (in thousands) at age-2 used were 87277, 126917 and 166704 respectively, for low, average and high recruitment.

Assuming average recruitment, biomass of the spawning stock has been increasing from 1977 to the present (Figure 6.3). Spawning biomass in 1981 from the model compares favorably with fishery independent biomass estimates of 85-130 thousand t (Thompson and McFarlane 1982) and 40-250 thousand t (Kieser 1983). The spawning biomass in 1987 estimated from the model is between 101 thousand t and 172 thousand t.

Under the constant catch scenario, equilibrium yields of 8000 t, 11000 t and 14000 t are sustainable assuming low, average and high constant recruitment, respectively. It is recognized that the assumption of constant recruitment is not consistent with the actual life history of hake and in future assessments a stochastic recruitment function will be incorporated to provide a more realistic model of stock dynamics.

In the previous assessment (Shaw et al. 1988), variable catch scenarios based on optimal levels of F from yield-per-recruit analysis were presented. This type of projection relies heavily on accurate estimates of recruitment. Given the inaccuracy of the VPA numbers-at-age for the recent years we recommend that this approach not be taken until an appropriate stock-recruitment relationship or fishery independent measure of recruitment can be established.

6.2.5. Yield options

The risks associated with the harvest levels result from the inability to predict the strength of incoming year-classes. The three levels of harvest presented are capable of sustaining a spawning stock biomass assuming low, average and high recruitment respectively. Higher risk implies a greater likelihood of depleting the stock below a critical spawner biomass in the event of poor recruitment.

Constant yield	- Low risk sustainable	- 8000 t
	- Sustainable	- 11000 t
	- High risk sustainable	- 14000 t

6.3 West Coast Vancouver Island

6.3.1 Introduction

Offshore Pacific hake (<u>Merluccius productus</u>) are a highly migratory fish that range from southern California to Queen Charlotte Sound. Hake are present in the Canadian zone from late spring until late fall when they migrate south to spawn off California. The portion of stock in Canadian waters is composed predominantly of larger, older females.

Since 1968, more Pacific hake have been landed than any other species in the groundfish fishery on Canada's west coast. Prior to 1977 the USSR caught the major percentage of hake in the Canadian zone with Poland and

Japan accounting for much smaller quantities. Since 1977, and the declaration of the 200 mile extended fishing zone, the fishery has been divided into domestic, joint venture, and foreign operations. These are the most rapidly developing fisheries on Canada's west coast with the projected yield in 1988 to be close to the quota for the first time.

6.3.2 Catch statistics

Coastwide catches of Pacific hake have increased from 208,843 t in 1986 to 233,819 t in 1987 (Table 6.9). Catch by all nations in the Canadian zone was 77,371 t in 1987, up considerably from 55,652 t in 1986. As in the past, most of the catch was sold directly to foreign processing vessels. Canadian catch from joint venture fisheries with Russian and Polish fishermen increased to 48,000 t in 1987 t from 30,136 qt in 1986. Domestic catches reported during 1987 totalled 4170 t up from 1774 t in 1986 (Table 6.10).

6.3.3 General biological information

Biological data collected in 1987 indicate little change in the size composition of the offshore hake stock in the Canadian zone. The fishery continues to be supported by a series of strong year-classes (Fig. 6.4). In particular, the 1984 and 1977 year-classes contributed 74.13% and 10.88% in number respectively to the 1987 catch. The U.S. fishery was supported by the strong 1980 and 1984 year-classes (Fig 6.4).

In a fishery dominated by a small number of year-classes it is desirable to have the ability to forecast the relative strength of recruitment based on pre-recruit abundance. Measures of catch per unit effort and percent occurrence of 0-age hake in mid-water trawl surveys, conducted by the California Department of Fish and Game off the California coast over the last 20 years, appear to be good indicators. Figure 6.5 presents the two indices and the abundance of three-year-olds obtained from cohort analysis. The strong 1970, 1973, 1977, 1980, 1984 and 1986 year-classes are identifiable.

The surveys indicate that the 1986 year-class is above average (Figure 6.5), however, catch-at-age data from the 1986 and 1987 fishing seasons in U.S. waters do not show large catches of one- and two-year-olds, which may indicate that the 1985 year-class was poor and the 1986 year-class may be no better than average (Figure 6.4).

6.3.4 Condition of the stock

The approach taken in this assessment is similar to the previous one (Shaw et al. 1988., Hollowed et al. 1988). The major change involves the incorporation of year-specific growth data.

Since 1976, there has been a continuous decline in the mean length-at-age in both the Canadian and U.S. zones (Figures 6.6 and 6.7). The approximately 10% drop in length-at-age and the fluctuation in weight-at-age noted in particular in 1978 and 1983, indicate that the use of the long-term mean of weight-at-age in assessment models that rely on these relationships to calculate biomass and yield from numbers-at-age, is inappropriate. Consequently matrices of weight-at-age by year have been incorporated into the cohort analysis. The derivation of the matrices is documented in Hollowed et al. (in prep).

Two time series of weight-at-age have been calculated, one from the fishery data and a second from the independent hydroacoustic and trawl surveys. There are discrepancies between these two series (Hollowed et al. in prep) and more work is necessary to determine the appropriate weights-at-age. Until work is completed, yield calculations have been conducted with each of the time series to provide some indication of sensitivity.

As in the previous assessment, an age-structured simulation model, utilizing information on mortality, growth, abundance (from cohort analysis) and recruitment, was used to produce long-term estimates of hake production and projected yields for 1989-90. An instantaneous rate of natural mortality of 0.2 was used for all ages both in cohort analysis and in the forward simulations.

Catch-at-age from 1973-78 and from 1980-85 are from Hollowed and Francis (1986). Estimates for 1979 were updated to reflect corrections for ageing error made to the age composition of the catch. Estimates for 1986 and 1987 in the U.S. were calculated using a procedure developed by Kimura (in press).

Catch-at-age for 1987 in the Canadian zone was calculated by using the ratio of number-at-age to the weight-at-age in the age sample times the total catch. The weight-at-age in the sample was the sum of the weights from individual fish derived from length-weight relationships for males and females sampled in 1987. Canadian and U.S. catch-at-age were summed to provide coastwide estimates (Table 6.11).

Cohort analysis was run using 15 years of catch-at-age data, 1973 to 1987. The cohort analysis was developed by Francis (1983) and uses the analytic formulation of Pope (1972) and Tomlinson (1970). Terminal F values were varied to provide the best least squares fit to the numbers-at-age derived from the NWAFC hydroacoustic/trawl surveys. The estimates of numbers-at-age from the cohort analysis and NWAFC survey and fishing mortality rates by age are presented in Table 6.11.

The age-structured model is a modification of Walters' (1969) generalized model for fish populations. The model has a stochastic as well as a deterministic form. Recruitment is assumed to be a function of temperature at the time of spawning. Bailey (1981) showed hake recruitment to be inversely correlated to wind driven Ekman transport on the spawning ground at the time of spawning. He further reasoned that offshore transport was positively correlated with the level of upwelling which in turn, was negatively correlated with sea surface temperature. Hence, years of 'cold' water temperatures were assumed to be years of low larval survival and, conversely, years of 'warm' water temperatures were assumed to be years of higher larval survival.

The model is run in two modes, equilibrium and look-ahead. The equilibrium model utilizes a theoretical unfished population and is run over 1000 years to establish optimal levels of effort where yield is maximized. The temperatures from 1943 to 1982 were cycled through the model 25 times to make up the 1000-year run. Recruitment was considered to be a function of temperature alone. In warm years (>15 deg) the mean warm year recruitment and in cold years the mean cold year recruitment was used. There is no apparent stock recruit relationship within the range of data available. In light of this, optimum effort was defined as the effort level that produced a spawner biomass above the lowest observed level (0.319 million t) 90% of the time. A summary of parameter values used in the 1000-year runs is presented in Table 6.12. Once the optimum effort level was determined using the deterministic version, additional runs were made using the stochastic version. Stochasticity was incorporated in recruitment as a log-normal random variable with mean equal to the corresponding cold or warm year mean recruitment and variance equal to the observed coefficient of variation in recruitment for the respective temperature conditions.

Runs were conducted under two possible management scenarios, constant effort and variable effort. The variable effort strategy is similar to that described by Shuter and Koonce (1985) as one which greatly reduces the risk of stock collapse when compared with constant catch or constant effort. Effort in a given year was calculated as follows:

$$f_i = \text{effort in year } i$$
$$= f_{opt} \, (SB_i \; / \; SB_{op})$$

Where,

f_{op} = optimal effort
SB_{op} = mean observed spawner biomass level
SB_i = spawner biomass in year i

A summary of equilibrium run results is presented in Table 6.13. Using the mean fishery weight-at-age, the maximum average surplus production of the stock ranges from 243,000 to 266,000 t for the variable and constant effort scenarios respectively, using the deterministic form of the model and from 224,000 and 252,000 thousand t for variable and constant effort respectively using the stochastic form. Using the mean survey weight-at-age, the stock surplus production figures show the same trend as with the fishery weights-at-age but are generally higher. The stochastic version produces slightly lower estimates of average yield from substantially lower values of F_{opt}.

The optimal levels of effort and biomass were then used in look ahead simulations to make projections of future yields. The starting population in 1987 are numbers-at-age from cohort analysis. Recruitment of the 1986, 1987 and 1988 year-classes provides the most uncertainty in the yield projections. Three alternatives are considered, all are average (0.898); all are median, (0.207); and variable recruitment with 1986 = 0.168, The results of 1989-91 catch projections under the various recruitment alternatives are presented in Table 6.15.

The analysis presented is conducted on a coastwide basis. A split stock model is under development which will facilitate exploration of the biological implications of varying harvest strategies on U.S. and Canadian components of the stock. Other areas of the assessment to be addressed by Canadian and U.S scientists include:

1. An evaluation of catch-at-age techniques
2. Estimation of age-specific mortality rates.
3. Evaluation of weight-at-age time series.

6.3.5 Yield options

The yield options for the Canadian fishery are presented below with associated coastwide quotas in brackets. The Canada-U.S. split is based on the proportion of exploitable biomass in the Vancouver INPFC area. The proportion has ranged from 22.2 to 41.1 over the period 1977 to 1986, hence a mean value of 30% was applied to the coastwide quotas to arrive at the Canadian allocation. It is recognized that the Vancouver INPFC area includes a small portion of the U.S. zone, however, movement and exchange of fish in the transboundary area is believed to be considerable and variable from year to year.

Risk reflects uncertainty in the assessment in particular with respect to weight-at-age. At higher yield levels the probability of seriously affecting the spawning biomass and hence stock collapse is greater. The options presented below have been derived using the variable effort scenario, stochastic recruitment, and the variable recruitment estimate. The range results from the two possible weight-at-age scenarios and the sustainable level chosen as the mean of the high and low risk levels.

Low risk sustainable	- 87 (291) thousand t
Sustainable	- 93 (310) thousand t
High risk sustainable	- 98 (326) thousand t

Table 6.1. Pacific hake landings (t), excluding dumped and discarded, for the second quarter and whole year for Minor Areas 14, 17 and 29, and Major Area 4B (Strait of Georgia) during 1977-1987.

	1977		1978		1979		1980		1981		1982	
Region	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr
Minor Area												
14	0	0	-	-	-	-	0	385	448	523	-	-
17	-	-	0	1	484	484	-	-	76	182	1927	2420
29	-	-	0	2	2	2	0	5	810	1434	0	12
Major Area												
4B	0	0	1	2	486	516	1	508	1364	2409	1927	2824

	1983		1984		1985		1986		1987	
Region	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr
Minor Area										
14	53	53	368	368	15	77	849	1209	686	796
17	2208	2240	805	1736	1700	3718	1073	1158	1216	1444
29	0	11	544	951	67	982	618	2296	3832	5852
Major Area										
4B	3078	3122	1717	3056	1827	4976	2540	5031	5811	9127

Table 6.2. Pacific hake landings, CPUE and effort from the Strait of Georgia (Major Area 4B), 1977-1987.

Year	Total catch (t)	CPUE[a] (t/hr)	Effort[b] (hr)
1977	.04	0	0
1978	2	0	0
1979	516	10.207	51
1980	508	4.583	111
1981	2409	8.937	270
1982	2824	4.796	589
1983	3121	4.465	699
1984	4599	6.780	678
1985	4976	4.448	1119
1986	5031	7.450	675
1987	9127	8.019	1138

[a]CPUE @ 25% qualification level.
[b]Effort = Total catch/CPUE.

Table 6.3. Catch in numbers (thousands) of Strait of Georgia Pacific hake at age proportioned from the age composition and used in the Virtual Population Analysis. The catch and age distribution of hake are from the commercial catch and from research surveys.

	Age												
Year	2	3	4	5	6	7	8	9	10	11	12	13	14
79	69	27	123	216	204	207	192	193	51	9	9	10	6
80	78	480	268	369	168	223	134	179	101	0	22	0	0
81	72	456	654	276	468	816	666	738	534	1013	114	96	42
82	42	357	2216	1224	622	786	791	559	677	252	488	50	25
83	3468	974	2296	2577	644	495	347	297	198	248	116	116	17
84	38	488	1352	2780	4169	1578	939	789	676	488	188	75	150
85	937	1478	1334	1082	1046	3317	1731	865	757	541	288	180	0
86	38	1136	1742	1742	1250	1060	2461	2234	947	492	303	341	76
87	168	1432	9095	2695	2105	1137	1305	3748	2442	547	632	758	84

Table 6.4. Annual estimates of numbers at age of Pacific hake in the Strait of Georgia, from Virtual Population Analysis 1979-87 (M=0.23, Terminal F = 0.35).

Age	1979	1980	1981	1982	Year 1983	1984	1985	1986	1987
2	115725	217683	89218	85336	177417	205998	817295	195551	18061
3	32401	91103	171367	70235	67180	138296	162168	643401	153944
4	27801	25507	71719	134906	55291	52367	108871	127664	506506
5	17294	21886	20080	56460	105159	41940	40337	84865	99514
6	9599	13480	17060	15652	43781	81002	30817	31071	65808
7	6714	7443	10508	13141	11828	34128	60736	23502	23507
8	2518	5137	5733	7633	9720	8940	25761	45333	17740
9	5167	1827	3957	3945	5373	7437	6292	18929	33836
10	514	3926	1298	2482	2644	4001	5233	4244	13038
11	398	362	3024	562	1368	1930	2577	3498	2545
12	518	309	285	1500	224	866	1099	1571	2348
13	11	404	225	125	763	77	523	615	979
14	226	0	318	95	56	505	0	257	190

Table 6.5. Annual estimates of fishing mortality rates of Pacific hake in the Strait of Georgia, from Virtual Population Analysis 1979-87 (M=0.23, Terminal F = 0.35).

	Year								
Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
3	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
4	0.01	0.01	0.01	0.02	0.05	0.03	0.02	0.02	0.02
5	0.02	0.02	0.02	0.02	0.03	0.08	0.03	0.02	0.03
6	0.02	0.02	0.03	0.05	0.02	0.06	0.04	0.05	0.04
7	0.04	0.03	0.09	0.07	0.05	0.05	0.06	0.05	0.06
8	0.09	0.03	0.14	0.12	0.04	0.12	0.08	0.06	0.09
9	0.04	0.11	0.24	0.17	0.06	0.12	0.16	0.14	0.13
10	0.12	0.03	0.61	0.37	0.09	0.21	0.17	0.28	0.23
11	0.02	0.01	0.47	0.69	0.23	0.33	0.27	0.17	0.27
12	0.02	0.09	0.59	0.45	0.84	0.27	0.35	0.24	0.36
13	3.88	0.01	0.64	0.58	0.18	7.89	0.48	0.95	1.83
14	0.03	0.07	0.16	0.35	0.41	0.40	0.66	0.40	0.67

Table 6.6. Annual estimates of total mortality rates (Z) of Pacific hake in the Strait of Georgia, from Virtual Population Analysis 1979-87 (M=0.23, Terminal F = 0.35).

	Year								
Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	0.24	0.24	0.24	0.24	0.25	0.24	0.24	0.24	0.24
3	0.24	0.24	0.24	0.24	0.25	0.24	0.24	0.24	0.24
4	0.24	0.24	0.24	0.25	0.28	0.26	0.25	0.25	0.25
5	0.25	0.25	0.25	0.25	0.26	0.31	0.26	0.25	0.26
6	0.25	0.25	0.26	0.28	0.25	0.29	0.27	0.28	0.27
7	0.27	0.26	0.32	0.30	0.28	0.28	0.29	0.28	0.29
8	0.32	0.26	0.37	0.35	0.27	0.35	0.31	0.29	0.32
9	0.27	0.34	0.47	0.40	0.29	0.35	0.39	0.37	0.36
10	0.35	0.26	0.84	0.60	0.32	0.44	0.40	0.51	0.46
11	0.25	0.24	0.70	0.92	0.46	0.56	0.50	0.40	0.50
12	0.25	0.32	0.82	0.68	1.07	0.50	0.58	0.47	0.59
13	4.11	0.24	0.87	0.81	0.41	8.12	0.71	1.18	2.06
14	0.26	0.30	0.39	0.58	0.64	0.63	0.89	0.63	0.90

Table 6.7. Annual exploitation rates (nos. caught/nos. in the stock) by age of Pacific hake in the Strait of Georgia, from Virtual Population Analysis 1979-87 (M=0.23, Terminal F = 0.35).

	Year								
Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01
3	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.01
4	0.00	0.01	0.01	0.02	0.04	0.03	0.01	0.01	0.02
5	0.01	0.02	0.01	0.02	0.02	0.07	0.03	0.02	0.03
6	0.02	0.01	0.03	0.04	0.01	0.05	0.03	0.04	0.03
7	0.03	0.03	0.08	0.06	0.04	0.05	0.05	0.05	0.05
8	0.08	0.03	0.12	0.10	0.04	0.11	0.07	0.05	0.07
9	0.04	0.10	0.19	0.14	0.06	0.11	0.14	0.12	0.11
10	0.10	0.03	0.41	0.27	0.07	0.17	0.14	0.22	0.19
11	0.02	0.00	0.33	0.45	0.18	0.25	0.21	0.14	0.21
12	0.02	0.07	0.40	0.33	0.52	0.22	0.26	0.19	0.27
13	0.93	0.00	0.43	0.40	0.15	0.97	0.34	0.55	0.77
14	0.03	0.00	0.13	0.26	0.30	0.30	0.00	0.30	0.44

Table 6.8. Annual estimates of numbers in stock, numbers landed, exploitation rates, mean F and Z values for ages 2-14, of Pacific hake in the Strait of Georgia, from Virtual Population Analysis (M=.23, Terminal F=0.35).

Year	Nos. in stock	No. landed	Exploitation rate	Mean F Z	Mean
1979	218886	1316	0.01	0.33	0.56
1980	389067	2022	0.01	0.03	0.26
1981	394792	5945	0.02	0.23	0.46
1982	392072	8089	0.02	0.22	0.45
1983	480804	11793	0.02	0.16	0.39
1984	577487	13710	0.02	0.74	0.97
1985	1261709	13556	0.01	0.18	0.41
1986	1180501	13822	0.01	0.19	0.42
1987	938016	26148	0.03	0.29	0.52

Table 6.9. Annual catches of offshore Pacific hake (1000 t) in U.S. and Canadian waters by foreign, joint venture (JV), and domestic fleets. CPUE is calculated for the U.S. fishery only. Total effort is total catch divided by CPUE.

	U.S.				Canada				Combined		
Year	Foreign	JV	Domestic	Total	Foreign	JV	Domestic	Total	Total	CPUE	Effort
1966	137.000	0.000	0.000	137.000	0.700	0.000	0.000	0.700	137.700	19.2	7.171
1967	168.699	0.000	8.963	177.658	36.713	0.000	0.000	36.713	214.371	36.0	5.951
1968	60.660	0.000	0.159	60.819	61.361	0.000	0.000	61.361	122.180	11.8	10.397
1969	86.187	0.000	0.093	86.280	93.851	0.000	0.000	93.851	180.131	18.5	9.726
1970	159.509	0.000	0.066	159.575	75.009	0.000	0.000	75.009	234.584	25.6	9.180
1971	126.485	0.000	1.428	127.913	26.699	0.000	0.000	26.699	154.612	17.5	8.842
1972	74.093	0.000	0.040	74.133	43.413	0.000	0.000	43.413	117.546	15.9	7.381
1973	147.441	0.000	0.072	147.313	15.125	0.000	0.001	15.126	162.439	23.8	6.752
1974	194.108	0.000	0.001	194.109	17.146	0.000	0.004	17.150	211.259	24.3	8.705
1975	205.654	0.000	0.002	205.656	15.704	0.000	0.000	15.704	221.360	19.0	11.646
1976	231.331	0.000	0.218	231.549	5.972	0.000	0.000	5.972	237.521	25.7	9.242
1977	127.013	0.000	0.489	127.502	5.191	0.000	0.000	3.453	130.955	30.9	4.244
1978	96.827	0.856	0.689	98.372	3.453	1.814	0.000	6.464	104.836	35.2	2.980
1979	114.909	8.834	0.937	124.680	7.900	4.233	0.302	12.435	137.115	26.0	5.276
1980	44.023	27.537	0.792	72.352	5.273	12.214	0.097	17.584	89.936	28.5	3.152
1981	70.365	43.556	0.839	114.760	3.919	17.159	3.283	24.361	139.121	28.3	4.915
1982	7.089	67.464	1.024	75.577	12.479	19.676	0.002	32.155	107.732	30.9	3.489
1983	0.000	72.100	1.050	73.150	13.117	27.657	0.000	40.774	113.924	(30.9)	(3.687)[a]
1984	14.722	78.889	2.721	96.382	13.203	28.906	0.000	42.109	138.491	(30.9)	(4.482)[a]
1985	49.853	32.033	4.636	86.522	10.533	13.237	1.192	24.962	111.484	(30.9)	(3.608)[a]
1986	69.861	81.640	3.463	154.964	23.743	30.136	1.774	55.652	210.616	(30.9)	(6.759)[a]
1987	49.656	105.997	4.795	160.448	21.453	48.076	4.170	73.697	234.147	(30.9)	(7.578)[a]
Mean				126.662				32.970	159.637		

[a]Effort for 1983-1987 based on the assumption of constant CPUE equal to that observed in 1982.

Table 6.10. Total landings (t) of offshore hake by foreign and domestic fishery off Canada (Area 3C) during 1978-1986.

		Total landings (t)			
Year	Nations	National	Joint venture	Domestic	Total
1978	Poland	589	1,814		
	USSR	700	0		
	Japan	3,364	0		
	Total	4,653	1,814		6,467
1979	Poland	4,263	3,102		
	USSR	0	1,131		
	Japan	3,637	0		
	Total	7,900	4,233	302	12,435
1980	Poland	4,456	4,560		
	USSR	78	4,300		
	Japan	817	0		
	Greece	0	3,355		
	Total	5,351	12,214	96	17,661
1981	Poland	3,189	4,779		
	USSR	227	7,342		
	Japan	187	0		
	Greece	0	4,9827		
	Total	3,603	17,048	4,440	25,091
1982	Poland	10,357	10,222		
	USSR	0	9,391		
	Japan	2,237	0		
	Total	12,594	19,613	2	32,209
1983	Poland	13,177	13,464		
	USSR	0	14,192		
	Total	13,177	27,656	0	40,833
1984	Poland	13,203	9,214		
	USSR	0	19,692		
	Total	13,203	28,906	0	42,109
1985	Poland	10,533	13,237	1,192	
	Total	10,533	13,237	1,192	24,962
1986	Poland	15,604	13,494		
	USSR	8,138	16,642		
	Total	23,742	30,136	1,774	55,652
1987	Korea	-	26,347		
	Poland	9,716	18,866		
	USSR	11,737	2,863		
	Total	21,453	48,076	4,170	73,699

N.B. Catches reported in this fishery cannot be verified by weight tallies, as domestic catches are.

Table 6.11. Catch at age data for the cohort analysis and observed mean numbers at age from surveys and derived from the cohort analysis, for offshore Pacific hake (from Hollowed et al. in prep.).

Catch at age data (Millions)

Age	1973	1974	1975	1976	1977	1987	1979	1980	1981	1982	1983	1984	1985	1986	1987
3	55.89	0.98	2.69	36.82	3.82	4.15	1.44	15.20	1.78	1.94	103.12	2.20	0.39	9.53	117.66
4	9.68	150.14	3.67	29.26	54.60	8.10	17.70	8.95	107.52	2.07	4.71	155.03	12.87	1.98	5.71
5	21.71	20.52	128.11	29.59	11.32	48.58	10.97	9.11	10.44	71.53	4.58	8.84	116.96	16.49	1.85
6	40.20	35.50	21.86	185.10	20.23	9.40	51.75	10.16	12.18	5.79	64.76	14.40	11.69	217.08	5.06
7	25.15	44.29	23.54	27.62	69.94	19.85	16.51	23.12	6.48	7.55	5.03	41.00	8.17	23.32	223.89
8	23.00	25.73	38.00	13.81	11.58	38.45	31.67	10.65	27.79	6.75	6.30	6.08	17.58	13.44	11.41
9	21.50	11.40	17.15	4.93	6.30	5.85	23.31	8.68	7.53	16.98	5.17	5.84	1.76	25.58	6.10
10	10.32	3.58	7.40	0.99	3.13	2.90	3.70	22.87	6.46	3.43	15.30	4.12	0.71	2.58	24.29
11	4.51	1.63	3.70	0.31	3.13	2.90	1.92	2.37	14.33	3.49	2.54	8.72	1.01	1.56	1.07

Fishing Mortality Coefficients

3	0.027	.003	.014	.055	.032	.024	.009	.011	.016	.016	.035	.010	.015	.110	.037
4	.028	.092	.016	.213	.107	.089	.137	.073	.098	.024	.049	.068	.072	.099	.089
5	.088	.076	.106	.170	.119	.132	.168	.097	.114	.087	.067	.122	.067	.124	.126
6	.175	.202	.109	.220	.168	.137	.202	.231	.182	.085	.106	.306	.235	.171	.051
7	.183	.296	.200	.195	.121	.248	.378	.130	.227	.164	.100	.091	.286	1.018	.268
8	.615	.288	.447	.173	.117	.090	.784	.449	.228	.390	.201	.168	.051	1.065	7.432
9	.655	.720	.316	.094	.111	.080	.072	.512	.669	.212	.589	.289	.067	.097	7.432
10	.780	.211	1.730	.027	.080	.069	.066	.094	.924	.751	.301	1.471	.051	.132	.126
11	.203	.261	.349	.277	.110	.098	.059	.055	.079	3.489	3.687	.280	3.608	.152	.074

Catchability Coefficient

3	0.004	.000	.001	.006	.008	.008	.002	.003	.003	.005	.010	.002	.004	.016	.005
4	.004	.011	.001	.023	.025	.030	.026	.023	.020	.007	.013	.015	.020	.015	.012
5	.013	.009	.009	.018	.028	.044	.032	.031	.023	.025	.018	.027	.019	.018	.017
6	.026	.023	.009	.024	.040	.046	.038	.073	.037	.025	.029	.068	.065	.025	.007
7	.027	.034	.017	.021	.028	.083	.072	.041	.046	.047	.027	.020	.079	.151	.036
8	.091	.033	.038	.019	.028	.030	.149	.142	.046	.112	.054	.037	.014	.158	1.000
9	.097	.083	.027	.010	.026	.027	.014	.162	.136	.061	.160	.065	.019	.014	1.000
10	.116	.024	.149	.003	.019	.023	.013	.030	.188	.215	.082	.328	.014	.020	.017
11	.030	.030	.030	.030	.026	.033	.011	.018	.016	1.000	1.000	.063	1.000	.023	.010

Observed and estimated mean numbers at age in surveys

	1977		1980		1983		1986	
AGE	EST	OBS	EST	OBS	EST	OBS	EST	OBS
1	117	57	1415	1581	2924	2728	86	87
2	508	459	122	128	96	45	20	19
3	95	44	94	90	69	26	133	132
4	120	70	44	74	610	330	1268	1596
5	580	645	177	265	51	31	23	145
6	99	86	24	79	31	32	13	105
7	56	58	17	207	9	29	262	181
8	39	40	243	88	51	45	20	16
9	28	28	43	58	1	17	10	16
Sum of squares	15679		99626		122641		137714	

Table 6.12. Parameter values from cohort analysis used in 1000-year simulation runs of offshore Pacific hake stock (from Hollowed et al., in prep.).

		Old	New
N	number of age-classes	13	
R	number of years that recruitment is delayed after spawning	3	
SBOPT	optimum spawner biomass level (million t) set at mean observed spawner biomass	0.637	0.675
SBMIN	minimum spawning biomass (million mt)	0.319	0.319 and .459
RW	average warm year recruitment (billions)	0.971	1.499
	c.v.	(118%)	(95%)
RC	average cold year recruitment (billions)	0.206	0.168
	c.v.	(77%)	(52%)

	AGE												
PARM	3	4	5	6	7	8	9	10	11	12	13	14	15
M	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
Q	.0044	.0200	.0267	.0565	.0615	.1019	.1075	.1316	.1316	.1316	.1316	.1316	.1316
C	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W1	0.410	0.519	0.611	0.699	0.790	0.895	0.968	1.032	1.116	1.205	1.219	1.233	1.236
W2	0.414	0.519	0.614	0.688	0.748	0.810	0.866	0.895	0.940	0.976	1.011	1.042	1.070
W3	0.406	0.516	0.623	0.714	0.785	0.864	0.946	0.992	1.049	1.105	1.155	1.200	1.239
I	0.520	0.446	0.354	0.282	0.224	0.178	0.141	0.112	0.089	0.071	0.056	0.045	0.036
PCTF	0.496	0.504	0.511	0.519	0.525	0.533	0.542	0.546	0.548	0.556	0.560	0.564	0.567

M = Age specific natural mortality
Q = Age specific catchability coefficient
C = Proportion of mature females
W = Average weight at age (kg) (1=previous value, 2=mean for 1976-87 fishery, 3=mean expected for surveys 1973-1987
I = Initial numbers at age used for management runs (billions)
PCTF = Percentage of weight represented by females

Table 6.13. Summary of the results from the 1000-year runs of the deterministic and stochastic versions of the offshore Pacific hake model. The recruitment scenario assumes no density-dependence. FOPT is calculated so that SB<SBOPT in 10% of years (from Hollowed et al., in prep.).

Management policy		Y(CV) (1000 t)	f(CV) (1000 d)	CPUE (t/d)	B(CV) (1000 t)	Minimum biomass (1000 t)	FOPT (1000 d)
Minimum spawning biomass = 0.319 million t, mean fishery weight-at-age							
Variable Effort	Det	266(51.2)	6.6(36.2)	40.1	1167(38.4)	391	7.4
	Stoch[a]	252(77.1)	4.4(48.9)	57.4	1349(53.2)	367	4.2
Constant Effort	Det	243(39.6)	4.6(0.0)	52.8	1378(42.5)	344	4.6
	Stoch	224(53.9)	3.2(0.0)	69.9	1584(59.2)	291	3.2
Minimum spawning biomass = 0.319 million t, mean survey weight-at-age							
Variable Effort	Det	278(50.6)	7.0(35.9)	39.9	1158(38.0)	393	7.8
	Stoch	268(76.1)	4.8(48.7)	55.4	1321(53.0)	364	4.7
Constant Effort	Det	257(39.8)	4.8(0.0)	53.6	1382(42.4)	345	4.8
	Stoch	242(54.4)	3.5(0.0)	70.1	1581(59.2)	285	3.5

Det = Deterministic run
Stoch = Stochastic run
Y = Yield
f = average effort
CPUE = Catch per unit effort in tons per boat day
B = Total biomass
SB = Spawner biomass
SOPT = Optimum spawner biomass equal to the mean observed spawner biomass

[a]Basis for estimation of 1989-1991 potential yield.

Table 6.14. Parameter values used in 3-year offshore Pacific hake population and yield projections (from Hollowed et al., in prep.)

N	number of age-classes	13
R	number of years that recruitment is delayed after spawning	3
SBOPT	optimum spawner biomass level. (million t) set at mean observed spawner biomass	0.675
FOPT	optimum effort level about which variable effort is calculated	4.20

	AGE												
PARM	3	4	5	6	7	8	9	10	11	12	13	14	15
M	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
Q	.0044	.0200	.0267	.0565	.0615	.1019	.1075	.1316	.1316	.1316	.1316	.1316	.1316
C	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W1	0.364	0.424	0.502	0.553	0.645	0.730	0.826	0.870	0.925	0.982	1.039	1.070	1.107
W2	0.399	0.447	0.520	0.575	0.609	0.674	0.731	0.765	0.818	0.853	0.888	0.922	0.937
I	0.101	0.023	0.155	1.518	0.040	0.022	0.303	0.023	0.012	0.004	0.022	0.010	0.077
PCTF	0.496	0.504	0.511	0.519	0.525	0.533	0.542	0.546	0.548	0.556	0.560	0.564	0.567

M = Age specific natural mortality
Q = Age specific catchability coefficient
C = Proportion of mature females
W = Average weight at age (kg) (1=1986 survey estimate, 2=1987 combined fishery estimate)
I = Initial numbers at age (billions) used for management runs
PCTF = Percentage of weight represented by females

Table 6.15. Summary of the offshore Pacific hake 1989-91 potential yields. Optimum effort of 4.2 obtained from 1000-year simulation (variable effort, stochastic recruitment, 319,000 t minimum spawning biomass, 675,000 optimum spawning biomass). Two weight-at-age and three recruitment scenarios are analyzed (from Hollowed et al., in prep.).

Management policy	Year	Age 3 Recruit	Yield (1000 t)	Effort (1000 d)	Average biomass (1000 t)	Spawner biomass (1000 t)
Use 1986 survey weight-at-age						
Observed	1986	.101	209	2.55	1,173	732
Observed	1987	3.557	230	3.25	2,047	896
Expected	1988	.168	325	4.05	1,704	895
		Average recruitment for 1986-1987 year-classes				
	1989	.878	352	5.70	1,579	915
	1990	.878	313	4.84	1,413	778
	1991	.878	243	4.53	1,363	727
		Median recruitment for 1986-1987 year-classes				
	1989	.207	327	5.32	1,370	855
	1990	.207	250	3.99	1,035	641
	1991	.207	158	3.16	849	508
			Good 1987 recruitment			
	1989	.168	326	5.30	1,358	851
	1990	3.000	350	5.53	1,893	889
	1991	.168	295	5.07	1,541	814
Use 1987 fishery weight-at-age						
Observed	1986	.101	209	2.70	1,160	723
Observed	1987	3.557	230	3.50	2,087	883
Expected	1988	.168	325	4.40	1,691	875
		Average recruitment for 1986-1987 year-classes				
	1989	.878	318	5.58	1,584	897
	1990	.878	309	4.90	1,453	788
	1991	.878	228	4.46	1,372	716
		Median recruitment for 1986-1987 year-classes				
	1989	.207	293	5.17	1,355	831
	1990	.207	243	3.99	1,045	640
	1991	.207	140	3.00	819	482
			Good 1987 recruitment			
	1989	.168	291	5.15	1,342	827
	1990	3.000	351	5.68	1,986	912
	1991	.168	281	5.02	1,554	807

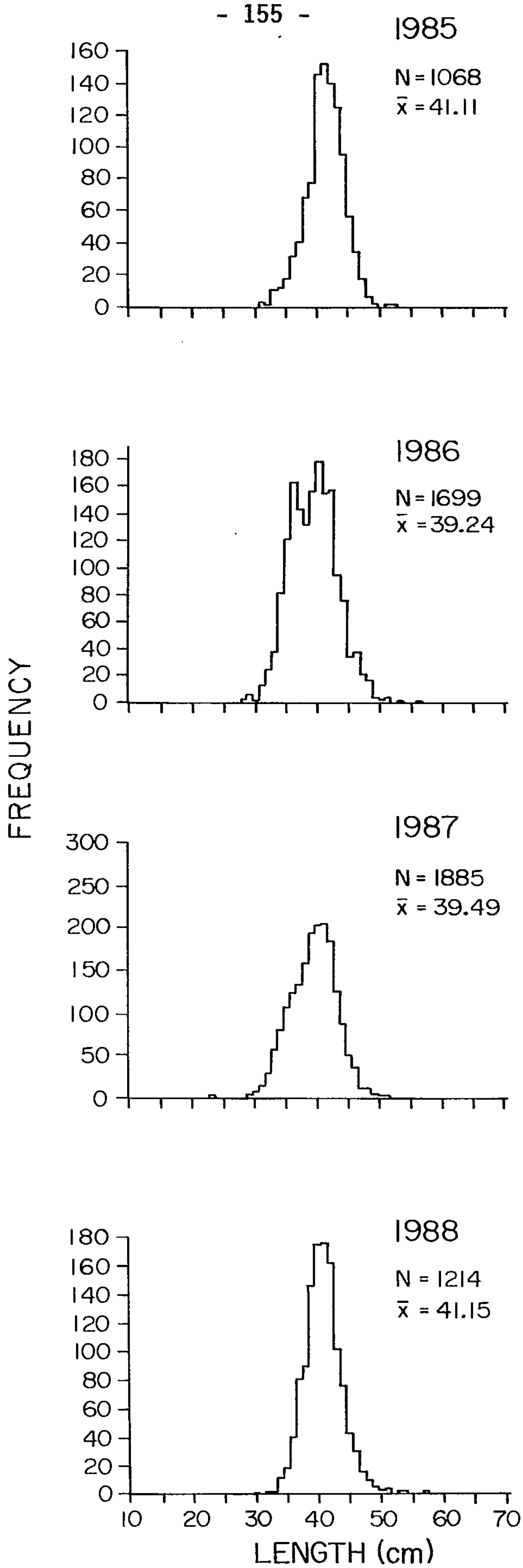


Fig. 6.1 Port sample length frequencies, by year, from 1985 to 1988 for Pacific hake in the Strait of Georgia.

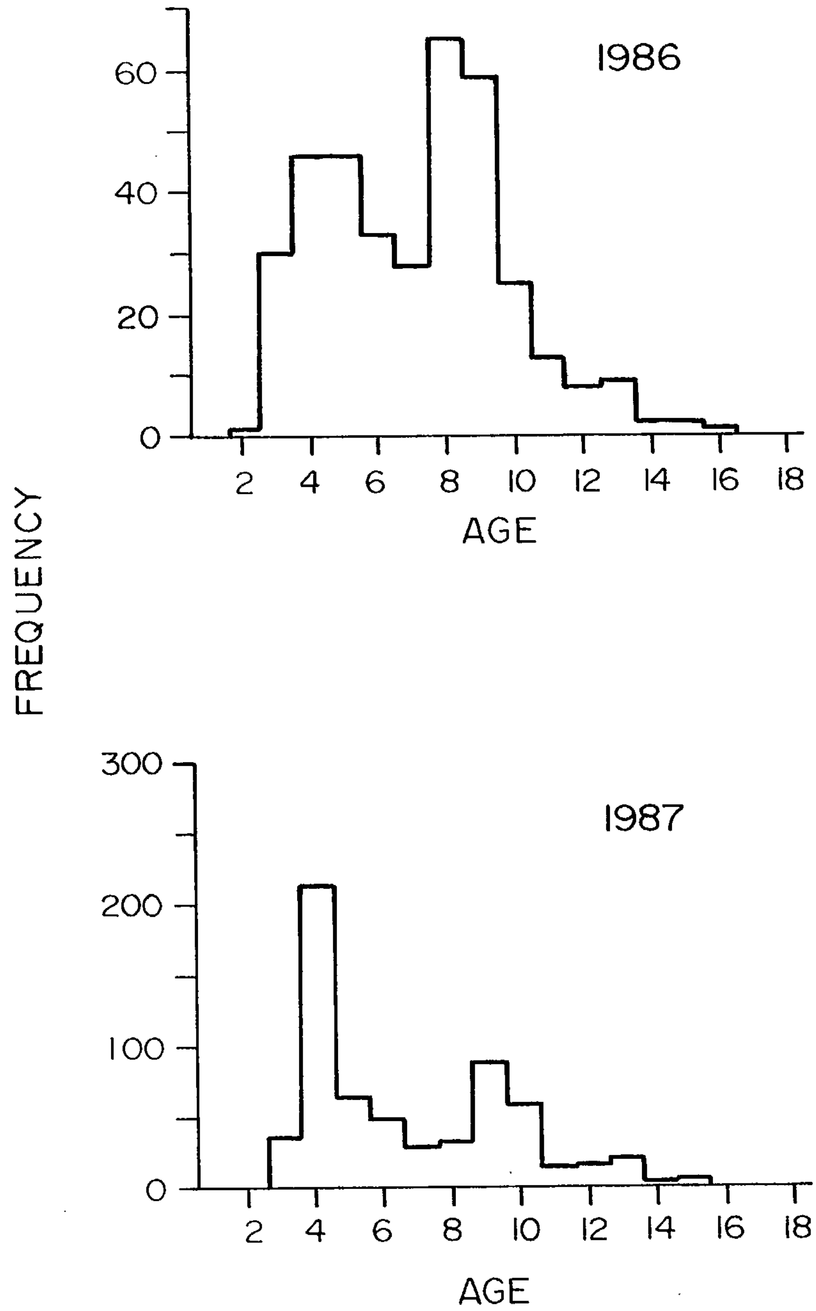


Fig. 6.2. Age frequencies of Pacific hake in the Strait of Georgia for 1986 and 1987.

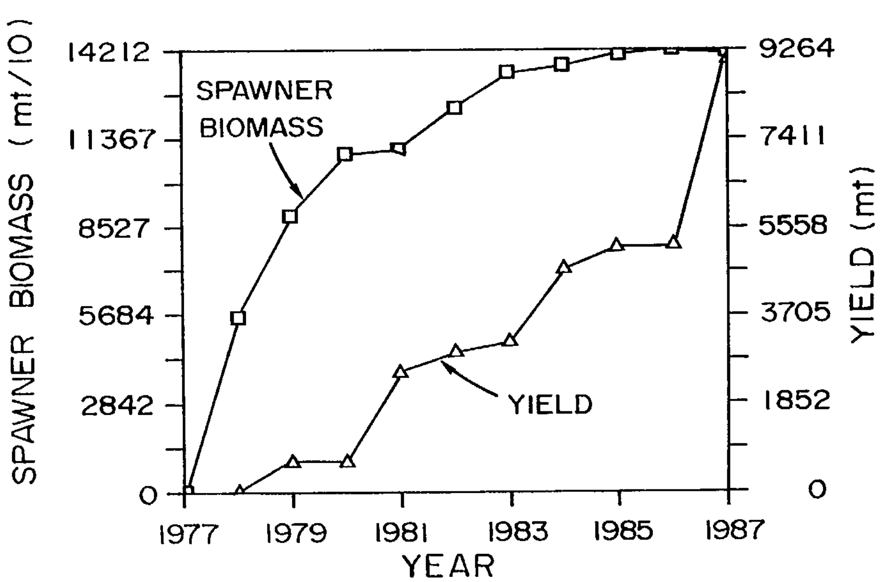


Fig. 6.3. Biomass and yield of Pacific hake in the Strait of Georgia from 1979 to 1987.

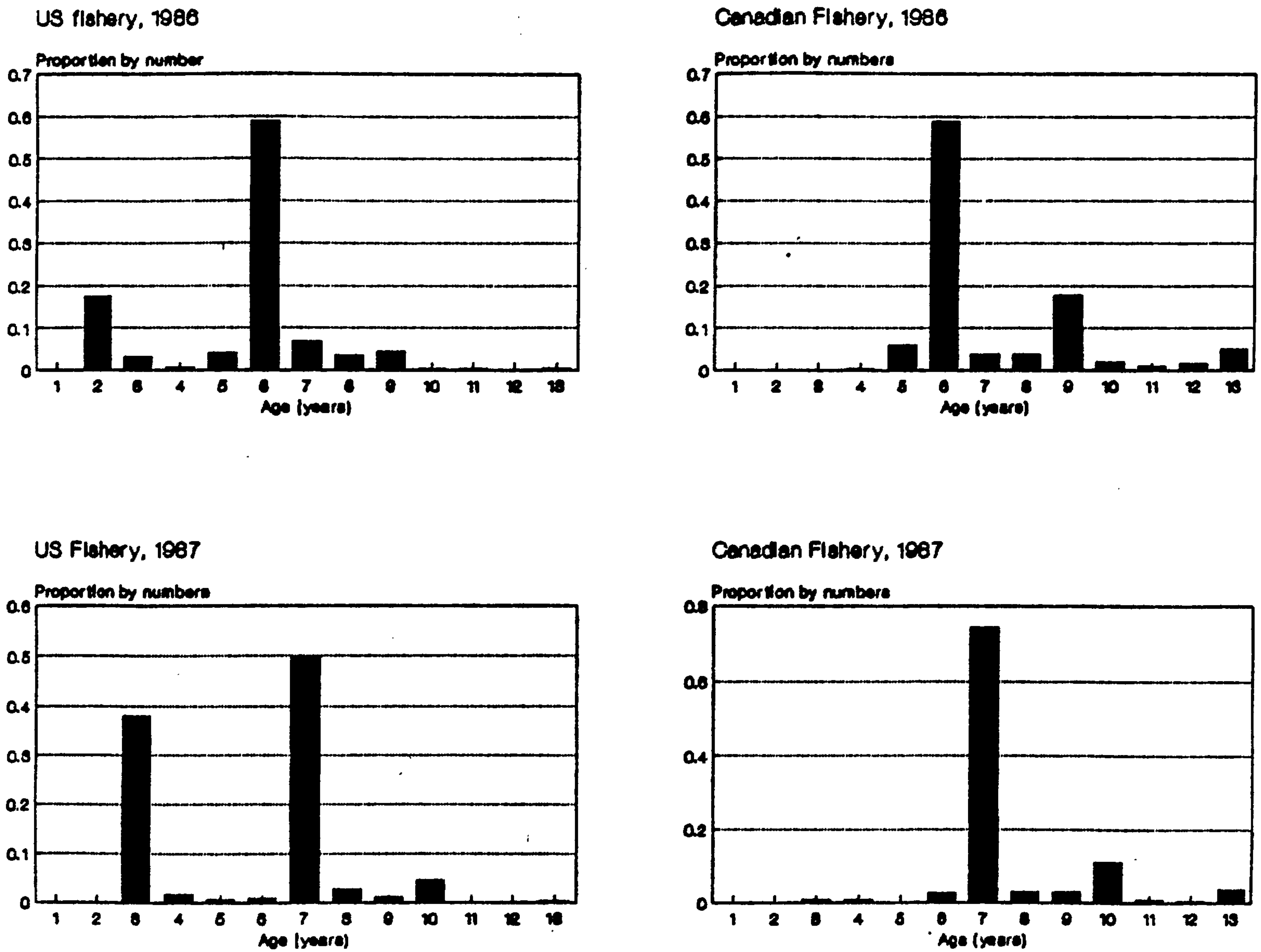
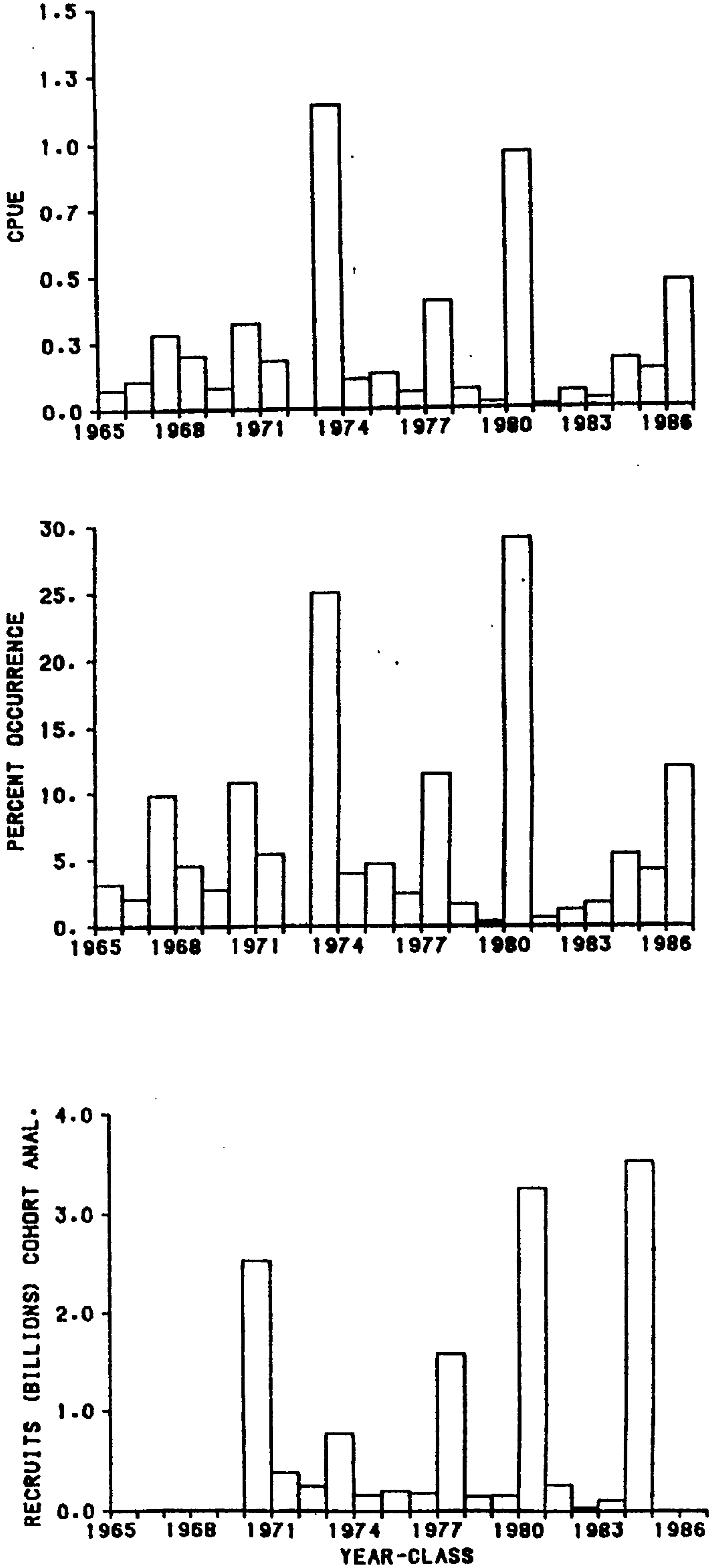


Fig. 6.4. Percent of catch-at-age of offshore Pacific hake in U.S. and Canadian waters, 1986-1987.

Fig. 6.5. Indices of offshore Pacific hake year-class strength from age-0 surveys and the adult fishery (a) CPUE of 0+ hake; (b) percent frequency of occurrence in trawl hauls; (c) numbers at age 3 from cohort analysis (from Hollowed et al. in prep.).


CPUE
1.5
1.3
1.0
0.7
0.5
0.3
0.0
1965
1968
1971
1974
1977
1980
1983
1986
PERCENT OCCURRENCE
30.
25.
20.
15.
10.
5.
0.
RECRUITS (BILLIONS) COHORT ANAL.
4.0
3.0
2.0
1.0
0.0
YEAR-CLASS

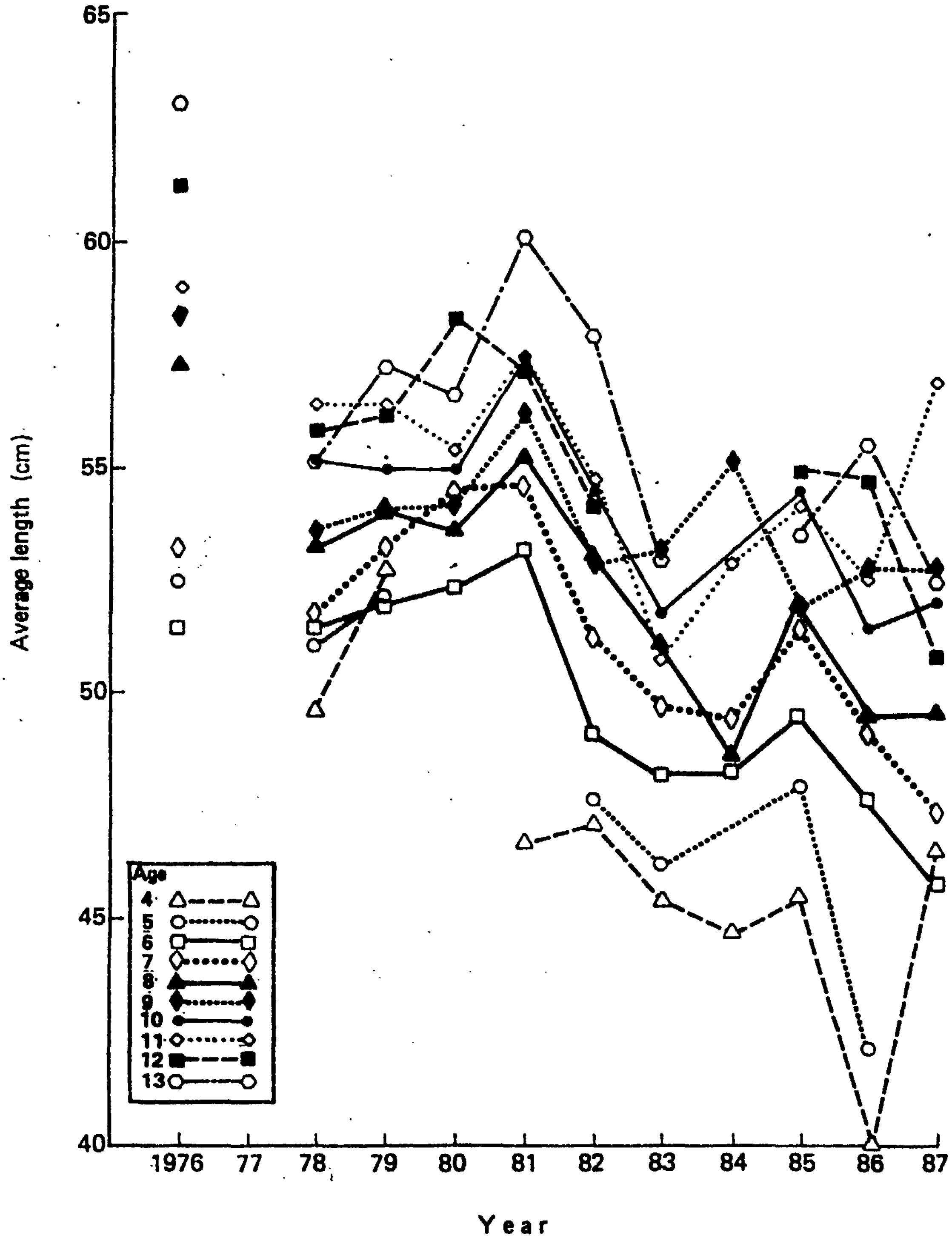
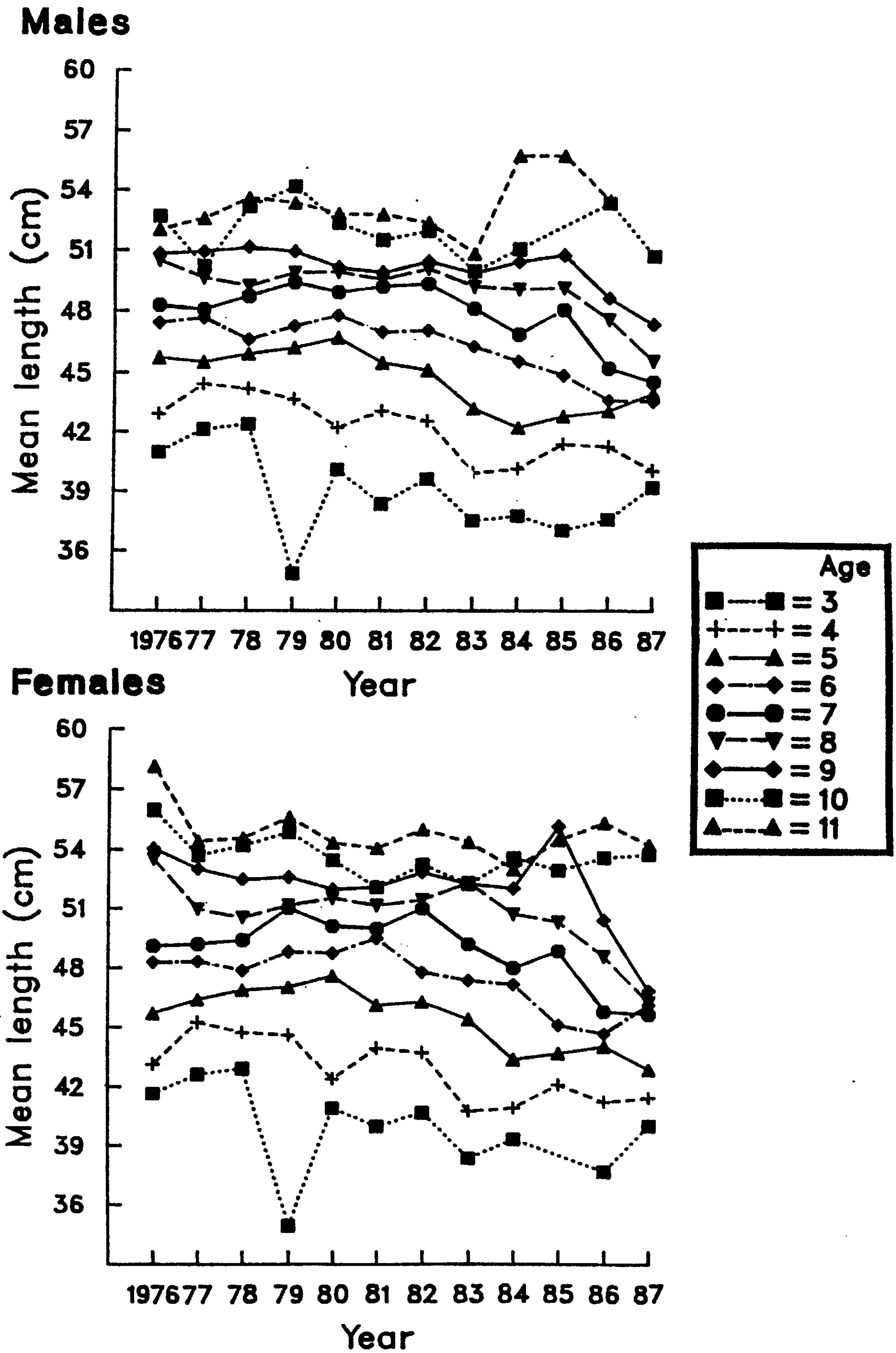


Fig. 6.6. Annual mean length-at-age for sexes combined of offshore Pacific hake 1975-1987, based on samples from the Canadian fishery.

Fig. 6.7. Annual mean length-at-age for male and female offshore Pacific hake 1975-1986, based on samples from U.S. waters only (from Hollowed et al. in prep.)



Males
Mean length (cm)
60
57
54
51
48
45
42
39
36
197677 78 79 80 81 82 83 84 85 86 87
Year
Females
Mean length (cm)
60
57
54
51
48
45
42
39
36
197677 78 79 80 81 82 83 84 85 86 87
Year
Age
= 3
= 4
= 5
= 6
= 7
= 8
= 9
= 10
= 11

7.0 DOGFISH

by M. W. Saunders

7.1. Coastwide (not including Strait of Georgia)

7.1.1. Introduction

The offshore stock referred to in this assessment ranges from Alaska to California and does not include the Strait of Georgia-Puget Sound stock(s).

7.1.2. Landing statistics

The bulk of offshore nominal catch of dogfish in 1987 came from Major Area 3C (71.4%) with the catch evenly split between longline and trawl fisheries (Table 7.1). This represents a substantial, tenfold increase in longline catch in 1987, over 1986. The increase in longline catch reflects an increased number of vessels participating in this fishery. The rising ex-vessel price for dogfish and the low cost involved in rigging a vessel to longline, have resulted in expansion of this fishery.

The trawl and longline fisheries are conducted during the first and second quarters (Table 7.2) when the large, primarily female fish (> 80 cm), that processors demand are available to the fleet. Total catch has increased from 2133 t in 1986 to 2996 t in 1987 (Table 7.1).

Offshore Washington State catch increased from 113 t in 1986 to 984 t in 1987 (Table 7.3). This was due primarily to trawl catches increasing to 893 t in 1987, from 29 t in 1986. Dogfish remain unexploited off Oregon and California.

7.1.3. Condition of stock

The model of Wood et al. (1979) has been updated with catches to 1987 (Tables 7.1 and 7.3). The predicted pulse in abundance set in motion by the 1940s liver fishery is levelling out from the downward trend in abundance (Fig. 7.1 in Saunders 1988). At current harvest levels of less than 2500 t, the marketable biomass of dogfish is predicted to continue increasing over the next two decades. The estimated biomass coastwide at the present time is approximately 280,000 t. Assuming that one-half to two-thirds of the stock resides off the coast of Canada, the biomass of fish in the Canadian zone is between 150,000-200,000 t.

As mentioned earlier, the fishery is concentrated in the first and second quarters of the year. Port samples of longline and trawl caught fish, collected from 1977 to 1987 indicate that the catch during this period is heavily biased toward females. A total of 17 samples were examined, and of 5113 fish sampled, 8.6 % of the fish were males.

The implications of this bias were examined by modifying the model of Wood et al. (1979) to allow changes in sex ratio in the fishery to be modelled. As expected for a fish with low fecundity, the removal of a large proportion of females from the stock, decreases the reproductive potential of the population and in turn results in a lower sustainable yield over the long term.

Previous assessments (Saunders 1985, 1986 and 1987), assuming an even sex ratio in the catch, indicated that yields of up to 15,000 t could be considered low risk sustainable, and yields of 15-25,000 t, high risk sustainable. These yields are sustainable if a fishery is executed during the third and fourth quarters, a period when the sex ratio has been shown to be more even.

Figure 7.1 presents the predicted trends in biomass of the adult (>80 cm) population and the spawning female population at sustainable and non-sustainable levels of catch of nine and fourteen thousand t, respectively. It is important to note the continued increase, over the next twenty years, in the total adult biomass even at the non-sustainable level of females.

7.1.4. Yield options

Possible options include sustained yield, pulse fishing and a variable catch no-nuisance strategy.

A sustained yield fishery will produce oscillations in abundance but they will decrease in amplitude with time. Hence this strategy provides a steady supply while maintaining a stock size lower than present levels. For removals from the offshore stock, including Alaska, British Columbia, Washington, Oregon, and California waters, up to 15,000 t may be considered low risk sustainable and from 15,000 to 25,000 t high risk sustainable assuming an equal sex ratio. If a first and second quarter fishery is to be sustained then yields up to 9,000 t are low risk while 9 to 14,000 t yields are high risk.

The ranges in levels presented are a reflection of the uncertainty surrounding estimates of starting stock size and the degree of compensatory mortality used in forward simulations. At risk is the collapse of the spawning stock.

Industry has expressed concern over the high abundance of dogfish, which is viewed as a nuisance, and has asked if it is possible to maintain the population at below nuisance levels while continuing to support a directed domestic fishery.

One of the control options proposed is periodic or pulse fishing which is the removal of large quantities of fish at a specific time interval. Figure 7.1 (Saunders 1986, p.48) illustrates the effect over time of removing a substantial catch in a single year. The biomass of marketable stock is capable of rebuilding to present levels within 3-4 years of removing 30,000 t and within 10 years of removing an unattainable figure of 210,000 t. The large removal, as discussed in Saunders (1985), accentuates and perpetuates the pulse in abundance introduced by the 1940s liver fishery. The extreme variation in abundance resulting from a pulse fishery is further illustrated by Figure 7.2 (Saunders 1986, p. 49), a forward simulation of marketable biomass with catches of 60,000 t taken every fifth year. While 60,000 t removals keep the population below the present level for 10 years, over the ensuing 25 years the stock fluctuates to well above present levels and to well below a level where commercial fishing is likely to be viable. The point when fishing is assumed to be non-viable is at, or below, the level of the predicted biomass in 1950, at the end of the liver fishery when, as a result of heavy fishing pressure the abundance decreased to a level where fishing success was poor.

An alternative approach, entitled variable catch/no nuisance option, is to fish intensively for several years until the stock is below nuisance levels and then regulate catch to remove more fish in years when recruitment is high from the liver fishery pulse and vice versa when recruitment is decreasing. Figure 7.3 (Saunders 1986, p. 50) shows the effect of such strategy in marketable biomass over time. Initial catches of 30,000 t for the first four years lower the stock rapidly and catches thereafter ranging from 8,000 to 25,000 t per year maintain a relatively stable stock size.

At current catch rates the trawl effort required to catch the maximum tonnages involved is equivalent to the effort expended in a year by the entire groundfish trawl fleet on all species. One possible way to obtain sufficient effort is to establish a joint venture fishery to remove the difference of the yearly catch that domestic markets cannot utilize.

All options refer to coastwide (including U.S.) removals and no provision has been made for adjusting Canadian catches in the event of increased U.S. catch.

Yield option 1: Sustained yield, no 1st and 2nd quarter fishery
- low risk < 15,000 t
- high risk 15-25,000 t

Yield option 2: Sustained yield--first and second quarter fishery, only.
- low risk < 9000 t
- high risk 9-15,000 t

Yield option 3: Pulse fishing

Yield option 4: Variable catch/no nuisance

7.2 Strait of Georgia - Puget Sound

7.2.1 Introduction

This assessment treats the Strait of Georgia and Puget Sound as a single stock. The 1988 assessment remains unchanged from the previous assessment (Saunders 1988).

7.2.2. Landing statistics

Longline catches were up to 788 t in 1987 from 87 t caught in 1986. Trawl catches decreased slightly from 393 t in 1986 to 357 t in 1987 (Table 7.2).

7.2.3. Condition of the stock

The model of Wood et al. (1979) has been updated to include 1987 catches. The bias in sex ratio noted in the catches from the offshore fishery is less pronounced in the Strait of Georgia. A paucity of port sampling data makes it difficult to assess the problem. A synthesis of research and fishery data on sex ratio by area, depth and time should be conducted for future assessments.

The model predicts that the marketable biomass is increasing, and that at current harvest levels (approx. 1000 t) abundance should continue to increase over the next few years. Current biomass levels are in the order of 60,000 t.

The trends in inshore abundance discussed, can be viewed only qualitatively until questions regarding the degree of mixing between Puget Sound, offshore and Strait of Georgia stocks, and the impact of sports and bait fisheries have been answered, and until an estimate of absolute abundance is obtained for accurate calibration of model projections.

7.2.4. Yield options

Dogfish may be harvested on a sustained or periodic fishery basis. The reader is referred to section 7.1.4 for a discussion of the implications of pulse fishing and variable catch/no nuisance strategies.

Over the long-term, removals from the Strait of Georgia-Puget Sound stock that are in the range of 4000 to 6000 t may be considered low risk sustainable, while removals in excess of 6000 t are considered high risk sustainable. Assuming an even split in biomass between the Strait of Georgia and Puget Sound, 2000-3000 t is considered low risk and > 3000 t is considered high risk for the Strait of Georgia.

Again this range is a reflection of the uncertainty surrounding estimates of starting stock size and the degree of compensatory mortality used in forward simulations.

Yield option 1: Sustained yield - low risk - 2000-3000 t
Yield option 2: Sustained yield - high risk - > 3000 t
Yield option 3: Pulse fishing
Yield option 4: Variable catch/no nuisance

Table 7.1. Dogfish longline and trawl catch[a] (t) offshore, by Major Area and by gear for 1979-1987.

	3C				3D			5A			5B		
	LLD[b]	Tr[c]	HL&T[d]	Tot.	LL	Tr	Tot.	LL	Tr	Tot.	LL	Tr	Tot.
1979	4	279	-	283	1	15	16	5	10	15	-	5	5
1980	7	1732	-	1739	26	116	142	5	117	122	-	39	39
1981	10	285	-	295	-	17	17	-	25	25	-	-	0
1982	-	947	-	947	3	23	26	11	14	25	-	45	45
1983	92	450	-	542	-	54	54	16	-	16	-	9	9
1984	-	455	-	455	-	3	3	54	45	99	-	9	9
1985	-	1365	-	1365	60	74	134	360	52	412	38	2	40
1986	73	1770	-	1843	26	65	91	73	105	178	-	-	0
1987	1075	1064	3	2142	141	40	181	298	44	342	8	20	28

	5C				5D			5E			Total			
	LL	Tr	HL&T	Tot	LL	Tr	Tot	LL	Tr	Tot	LL	Tr	HL&T	Tot.
1979	1	11	-	12	26	70	96	-	-	-	37	390	-	427
1980	13	59	-	72	91	242	333	-	1	1	142	2306	-	2448
1981	-	9	-	9	10	32	42	-	-	-	20	368	-	388
1982	3	-	-	3	-	272	272	-	-	-	17	1301	-	1318
1983	-	3	-	3	-	17	17	-	-	-	108	533	-	641
1984	-	15	-	15	-	73	73	-	-	-	54	600	-	654
1985	-	-	-	-	4	4	8	-	-	-	462	1497	-	1959
1986	-	1	-	1	11	9	20	-	-	-	183	1950	-	2133
1987	241	1	.3	242	61	3	64	-	-	-	1823	1173	3.3	2996

[a]Interview and sales slip data from Smith 1980, 1981, Leaman 1982, 1983 and Department of Fisheries and Oceans catch statistics database.

[b]LL = longline.

[c]Tr = trawl.

[d]HL&T = handline and troll.

Table 7.2. Dogfish landings[a] (t) for Major Areas 4B and 3C, by gear and quarter for 1979 to 1987.

Area 4B

	Longline					Trawl					
	Quarter					Quarter					Grand
	I	II	III	IV	Total	I	II	III	IV	Total	total
1979	747	206	419	2081	3453	9	7	106	669	791	4244
1980	806	482	23	229	1540	288	34	-	242	564	2104
1981	5	2	-	486	493	88	-	-	182	270	763
1982	302	67	6	464	839	100	28	120	171	419	1258
1983	273	128	55	336	792	81	111	70	173	435	1227
1984	353	260	347	635	1595	26	80	112	78	296	1891
1985	278	112	5	44	439	166	180	9	77	432	871
1986	70	17	0	0	87	114	116	16	147	393	480
1987	233	49	37	469	788	58	110	79	110	357	1145

Area 3C

	Longline					Trawl					
	Quarter					Quarter					Grand
	I	II	III	IV	Total	I	II	III	IV	Total	total
1979	3	-	-	1	4	2	200	49	28	279	283
1980	2	5	-	-	7	512	1111	109	-	1732	1739
1981	-	-	-	9	9	37	208	17	24	286	295
1982	-	-	-	-	-	209	612	82	44	947	947
1983	-	83	9	-	92	180	147	50	73	450	542
1984	-	-	-	-	-	239	127	67	22	455	455
1985	-	-	-	-	-	450	788	42	85	1365	1365
1986	56	17	-	-	73	729	883	13	146	1771	1844
1987	186	559	78	251	1074	535	483	0.3	46	1064	2138

Table 7.3. Dogfish landings[a] (t) by gear from Washington State.

	Trawl	Longline	Other	Total
1983				
Inshore[b]	856	435	-	1291
Offshore[c]	21	5	-	26
1984				
Inshore	753	504	188	1445
Offshore	239	79	-	318
1985				
Inshore	469	363	139	971
Offshore	172	101	1	274
1986				
Inshore	304	325	117	746
Offshore	83	29	1	113
1987				
Inshore	373	721	335	1429
Offshore	91	893	-	984

[a]From Technical Sub-committee, Washington State Status Reports, unpublished text.

[b]Major Area 4A.

[c]All Major Areas excluding 4A.

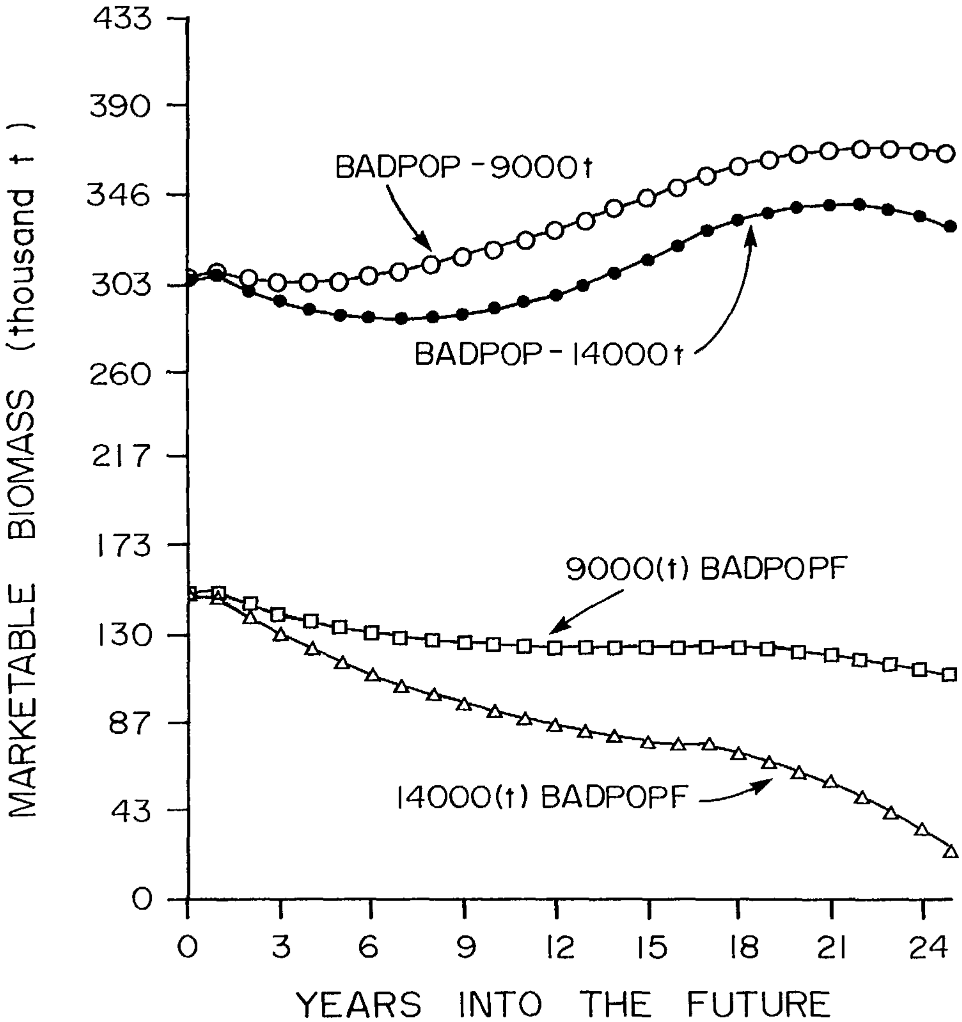


Fig. 7.1. Predicted future biomass of adult (>80 cm) dogfish (BADPOP) and adult female dogfish (BADPOPF) at catch levels of 9 and 14 thousand t, using a sex ratio of males to females of 1/11.

8.0 WALLEYE POLLOCK

8.1. Coastwide

Yield options are not proposed on a coastwide basis.

8.2. Strait of Georgia

8.2.1. Introduction

Walleye pollock are an abundant resident fish cohabiting with Pacific hake in the Strait of Georgia. The fishery has been decreasing over the past years as a result of poor market conditions. All of the pollock catch is processed into frozen fillets which are used as a substitute for Pacific cod fillets.

The 1988 assessment remains unchanged from the previous assessment (Shaw et al. 1985).

8.2.2. Landing statistics

During 1987, a total of 1237 t was landed, an increase of 164% from the 1986 landings (Table 8.3). The landings were predominantly from trawlers using midwater gear. The majority (90%) of the landings were in the first quarter in Minor Area 16. This year's increase is theresult of market demand.

8.2.3. Condition of stock

There have been no new analyses conducted. The 1988 assessment is based on estimates of maximum sustainable yield (MSY) using Gulland's (1970) relationship of MSY = a(M)(B). The following parameter estimates used in the equation were: natural mortality (M) of 0.5-0.7; value of (a) of 0.3-0.5; and a biomass (B) estimate of 15,800-29,400 t (Shaw et al. 1985).

8.2.4. Yield options

The conservative level is based on the lower level of unexploited biomass (15,800 t), a natural mortality of M=0.5, and a constant (a) value of 0.3. The high risk level is based on a midpoint of the biomass estimate (22,600 t), a midpoint in the natural mortality estimate M=0.6 and a constant value of a=0.4, which Gulland (1983) indicated as a realistic value for gadid-like species.

Yield options may be chosen from:

Yield option 1: Conservative sustainable - 2500 t
Yield option 2: Risk sustainable - 5400 t

8.3. West Coast Vancouver Island

8.3.1. Introduction

Walleye pollock remain a small incidental catch in the joint venture Pacific hake fishery off the west coast of Vancouver Island (Major Area 3C). Small quantities of pollock are caught incidentally by the domestic fleet while targetting on other groundfish species in Major Areas 3C and 3D.

8.3.2. Landing statistics

The landings by foreign fleets in 1987 increased from 97 t in 1986 to 1168t (Table 8.2). The majority (93%) of these landings were from the joint venture fishery. The reason for the increase in the landings was due to more accurate reporting of catches as observers were aboard the foreign vessels during the entire 1987 offshore hake fishery.

The domestic fleet reported no catches of pollock from Major Area 3C (Table 8.2).

8.3.3 Condition of stock

The size composition of pollock ranged from 27 to 66 cm with modes at 34, 45 and 49 cm. This is slightly changed from last year as more smaller sized fish (34 cm model length) dominated this year's catch. Approximately 58% of the fish were smaller than 40 cm.

There has been no new analysis for the 1988 assessment.

8.3.4. Yield options

The yield options remain unchanged from the previous assessment (Shaw et al. 1985).

Yield option 1: unrestricted yield.

8.4 Queen Charlotte Sound

Yield options are not proposed for this region.

8.5. Hecate Strait

8.5.1. Introduction

The walleye pollock fishery in northern Hecate Strait and Dixon Entrance (Major Areas 5C and 5D), occurs mainly in the winter months, from November to December, when fish are processed into fillets and act as a substitute for Pacific cod. There is no demand for pollock fillets or roe and the markets have not improved since the late 1970s.

The 1988 assessment remains unchanged from the previous assessment (Shaw et al. 1985).

8.5.2. Landing statistics

Pollock landings in 1987 decreased to 4 t from 95 t reported for 1986 (Table 8.4). There were no landings from Major Area 5C and only 4 t was caught in Major Area 5D.

Condition of stock

No new analysis was conducted this year.

8.5.3. Yield options

The yield options remain unchanged from the previous assessment (Shaw et al. 1985). The catch is currently limited due to weak markets.

Yield option 1: Unrestricted yield.

West Coast of Queen Charlotte Islands

Yield options are not proposed for this region.

Table 8.1. Walleye pollock landings by gear type and by quarter from the Strait of Georgia (Major Area 4B), 1976-1987.

		Major Area 4B		
Year		Quarter 1	Quarter 4	Total
1976				
	MWT[a]	-	-	0
	BT[b]	3	23	26
	Total	3	23	26
1977				
	MWT	-	-	0
	BT	24	26	51
	Total	24	26	51
1978				
	MWT	177	-	177
	BT	142	41	203
	Total	319	41	380
1979				
	MWT	1033	3	1036
	BT	283	20	304
	Total	1316	23	1339
1980				
	MWT	841	-	841
	BT	189	23	215
	Total	1030	23	1056
1981				
	MWT	455	-	465
	BT	99	5	105
	Total	554	5	570
1982				
	MWT	81	-	81
	BT	8	7	19
	Total	89	7	100
1983				
	MWT	19	-	19
	BT	3	2	6
	Total	22	2	25
1984				
	MWT	8	90	155
	BT	-	2	2
	Total	8	92	157
1985				
	MWT	401	319	724
	BT	5	19	24
	Total	406	338	748

Table 8.1 (cont'd)

Year		Major Area 4B		
		Quarter 1	Quarter 4	Total
1986				
	MWT	162	294	457
	BT	10	2	12
	Total	172	296	469
1987				
	MWT	1118	56	1219
	BT	3	15	18
	Total	1121	71	1237

[a]MWT = Midwater trawl.
[b]BT = Bottom trawl.

Table 8.2. Incidental catches of walleye pollock by foreign fleets participating in the offshore hake fishery off west coast Vancouver Island (Major Area 3C), 1980-1987. (Catch statistics from Offshore Division, Vancouver.)

		Landings (t)		
Year	Nations	National[a]	Joint venture	Total
1980	Poland	487	236	
	USSR	63	584	
	Japan	142	0	
	Greece	-	175	
	Total	692	995	1687
1981	Poland	131	205	
	USSR	26	299	
	Japan	9	0	
	Greece	-	285	
	Total	166	789	955
1982	Poland	468	222	
	USSR	0	149	
	Japan	38	-	
	Total	506	371	877
1983	Poland	13	6	
	USSR	-	-	
	Total	13	6	19
1984	Poland	1	66	
	USSR	-	41	
	Total	1	107	108
1985	Poland	2	78	
	Total	2	78	80
1986	Poland	14	19	
	USSR	1	63	
	Total	15	82	97

Table 8.2 (cont'd)

		Landings (t)		
Year	Nations	National[a]	Joint venture	Total
1987	Poland	22	686	
	USSR	64	325	
	Korea	-	71	
	Total	86	1082	1168

[a]"National" landings include landings from the supplementary fishery.

Table 8.3. Total landings (t) of walleye pollock by the domestic fleet by Major Statistical Area, 1954-87.

	Landings (t)									
Year	4B	3B	3C[a]	3D	5A	5B	5C	5D	5E	Total
1954	147	0	3	0	13	1	0	0	0	164
1955	418	0	5	0	1	0	0	3	0	427
1956	380	0	52	0	5	0	0	14	0	451
1957	248	0	4	0	3	0	0	7	0	262
1958	121	0	0	0	.3	0	0	14	0	135
1959	260	0	8	0	.4	0	0	2	0	270
1960	95	0	5	0	1	3	0	10	0	114
1961	115	0	.1	0	1	0	.3	7	0	123
1962	49	0	6	0	0	0	0	12	0	67
1963	13	0	7	0	6	0	0	4	0	30
1964	33	0	2	0	5	0	0	2	0	42
1965	26	0	10	0	0	0	0	9	0	45
1966	37	0	.4	0	1	.1	.4	82	0	121
1967	33	0	0	0	1	0	7	48	0	89
1968	16	0	2	0	7	0	4	13	0	42
1969	30	0	14	0	33	0	0	47	0	124
1970	45	0	0	0	0	0	0	8	0	53
1971	80	0	5	0	0	0	0	0	0	85
1972	71	0	.3	0	172	0	0	1	0	244
1973	9	0	.1	0	62	9	.4	13	0	94
1974	11	0	0	0	6	6	2	47	0	72
1975	1	0	0	0	21	10	1	70	0	103
1976	26	0	5	2	69	400	193	627	.2	1322
1977	50	0	10	0	61	175	16	567	12	891
1978	380	0	6	.4	106	187	11	1700	21	2411
1979	1341	0	31	.3	72	71	238	1566	67	3386
1980	1056	0	3	3	12	23	83	1103	18	2301
1981	570	0	8	1	2	10	79	563	22	1255
1982	100	0	10	0	1	6	3	808	1	929
1983	25	0	3	1	11	10	6	986	28	1070
1984	157	0	5	0	11	7	2	625	< .1	807
1985	748	0	4	0	0	1	0	1176	2	1931
1986	469	0	3	0	0	0	0	95	0	567
1987	1237	0	0	0	29	5	0	4	0	1275

[a]Excludes incidental landings by the foreign fleet participating in the offshore Pacific hake fishery during 1980 to 1985.

Table 8.4. Walleye pollock landings by gear type and by quarter from Major Areas 5C and 5D, 1976-1987.

	Major Area 5C				Major Area 5D			
Year	Quarter1	Quarters2,3	Quarter4	Total	Quarter1	Quarter2,3	Quarter4	Total
1976								
MWT[a]	-	25	102	127	-	208	56	264
BT[b]	<1	19	47	66	5	141	214	360
Total	<1	44	149	193	5	349	270	624
1977								
MWT	-	-	-	0	<1	<1	-	<1
BT	1	14	1	16	34	509	24	567
Total	1	14	1	16	34	509	24	567
1978								
MWT	-	1	-	1	425	299	71	795
BT	1	7	2	10	107	657	141	905
Total	1	8	2	11	532	956	212	1700
1979								
MWT	-	-	-	0	593	52	11	656
BT	1	103	134	238	119	521	270	910
Total	1	103	134	238	712	573	281	1566
1980								
MWT	-	<1	-	<1	201	261	9	471
BT	1	73	9	83	116	482	34	632
Total	1	73	9	83	317	743	43	1103
1981								
MWT	-	-	-	0	61	-	79	140
BT	27	21	31	79	71	248	104	423
Total	27	21	31	79	132	248	183	563
1982								
MWT	-	-	-	0	2	-	607	609
BT	<1	3	<1	3	4	98	97	199
Total	<1	3	<1	3	6	98	704	808
1983								
MWT	-	-	-	0	-	34	784	818
BT	-	6	-	6	43	46	79	168
Total	0	6	0	6	43	80	863	986
1984								
MWT	-	-	-	0	301	-	266	567
BT	-	2	-	2	13	40	5	58
Total	0	2	0	2	314	40	271	625
1985								
MWT	-	-	-	0	369	0	754	1123
BT	-	-	-	0	10	42	1	53
Total	0	0	0	0	379	42	755	1176
1986								
MWT	-	-	-	0	66	0	2	68
BT	-	-	-	0	8	18	1	27
Total	0	0	0	0	74	18	3	95

Table 8.4 (cont'd)

Year	Major Area 5C				Major Area 5D			
	Quarter1	Quarters2,3	Quarter4	Total	Quarter1	Quarter2,3	Quarter4	Total
1987								
MWT	-	-	-	0	1	1	-	2
BT	-	-	-	0	-	2	-	2
Total	0	0	0	0	1	3	0	4

[a]MWT = Midwater trawl.
[b]BT = Bottom trawl.

9.0 SLOPE ROCKFISHES (Sebastes alutus, S. reedi, S. aleutianus, and S. proriger) --- B.M. Leaman.

9.0.1 Introduction

The 1988 calendar year is an interim year for slope rockfish assessments, in which no new analyses were conducted. We adopted a policy of conducting detailed analyses for rockfishes only on alternate years at the advent of the Extended Jurisdiction Program,in 1977. There were several reasons for this policy but the foremost concerned the underlying biology of the species. Population dynamics of rockfishes are very slow: recruitment occurs gradually over an 11-15 y period; growth of individuals is slow; and annual recruitment is generally a small proportion of the standing stock. Therefore, slope rockfish stocks change neither rapidly nor extensively from year to year. It is therefore appropriate to tailor assessment activities to the temporal scale of rockfish population dynamics. Even longer intervals between detailed assessments may be instituted in the future.

Sustainable yield options are presented as a range of values (Table 9.1). This range varies in width depending on our relative level of confidence in the data upon which the assessments are based. The lower value in the range represents a sustainable yield level with a low risk of stock decline, while the upper value represents a relatively high risk of stock decline. In other words, there is not a uniform probability throughout this range; assigning yields at the upper limit definitely carries greater probability of stock decline. In some instances this probability has been quantified (Archibald et al. 1983; Fig. 6). In addition, the conservative and non-sustainable options are presented as limits (e.g., greater than or less than xxxt), rather than as specific values. While we have in the past presented single values for yield options, there is imprecision in both observations and techniques and a range of values more accurately reflects the precision of our understanding. The conceptual basis for these figures remains as outlined in previous documents (Leaman and Stanley 1985, Leaman 1988).

Achievement of management goals for rockfishes in recent years has, in general, been poor. Quota overruns tend to be the rule rather than the exception (Fig. 9.1) and affect individual stocks as well as coastwide quotas. While management imprecision has obviously played a role in this result, management is made more difficult by the complex structure of rockfish stock units, their variable levels of exploitation history, and consequent differences in their current productivity. In addition, the relatively high degree of aggregation among species creates problems for both fishermen and enforcement personnel in the successful management of quotas for some areas. Rapid subscription of small quotas for some species can result in by-catch problems for other species. The net results are threefold:

(i) we do not have adequate resources to enforce the present quota structure, at sea, in spite of both acknowledged and suspected violations;

(ii) the progressively smaller trip-limit system of quarterly quota management produces economic inefficiency; and

(iii) serious problems in the quantity and quality of both statistical and biological data have been created. CPUE becomes less meaningful as trip limits become smaller; the general effect being an inflation of the CPUE index as trip limits are attained before fishing effort produces its normal effect on CPUE. Sampling opportunities also diminish as fish from many different limit-areas are mixed in vessel holds.

It is clear that the present system of management is sub-optimal and a re-assessment of what the Department and the industry are jointly capable of achieving in rockfish stock management appears necessary. It may therefore be appropriate in the future to consider either:

- broader groupings of species/area/time quotas;
- longer-term (3-5 y) quotas;
- individual transferable quotas;
- increased enforcement capability;
- managing for maximum data quality upon which to base assessments (e.g., unrestricted fishing to quotas); or
- combinations of the above.

9.3.1 Southwest Vancouver Island Pacific ocean perch (<u>Sebastes alutus</u>) (including Management Area 125)

9.3.1.1 Introduction

No new Canadian analytic studies have been conducted since the previous assessment. In 1987 the quota for the 3C stock was returned to the recommended sustainable level (100t) after a 4-y overharvesting experiment (Leaman and Stanley 1985). The management measure adopted to achieve this level of catch was a season-long trip limit of 5 t. Industry acted to circumvent this restriction by increasing the frequency of landings, and landing trip limits to smaller ports in Area 3C, so that travel to major ports could be minimized and the number of 'trips' maximized. The result of these practices was a level of landings in 1987 which had not been achieved even during the period of experimental fishing at much higher quotas.

9.3.1.2 Landing Statistics

Nominal statistics of the fishery are variable but have generally declined and showed an inverse relation with effort, since the fishery was re-opened in 1980 (Table 9.2). Statistics of the qualified (25%) fishery show greater declines (Fig. 9.2), with the exception of 1986 when the increase in CPUE was accompanied by a 73% decrease in effort. While statistics of the 1987-1988 fishery are less meaningful due to the restriction to an incidental fishery, there was an increase in qualified effort and CPUE in 1987. All statistics of the fishery have decreased for the first half of 1988, in part due to smaller trip limits.

9.3.1.3 Condition of the Stock

The 3C S. alutus stock remains in poor condition. During the period of experimental fishing, qualified catch rates declined over 50% from those of the 1979 survey (Lapi and Richards 1981). The 1985 U.S. and Canadian biomass surveys showed declines of 63 and 56% in the estimated size of the S. alutus stock, respectively. Those areas receiving the greatest fishing effort since 1979 (Estevan, Clayoquot, Cape Flattery) showed the greatest relative declines in biomass (Leaman et al. 1988).

Biological data from the stock (Leaman et al. 1988, Ito et al. 1987) show few signs of substantial recruitment in recent years. Mean sizes of fish from samples in both 1985 surveys showed slight increases from 1979, to be expected from growth, but only one relatively strong recruiting cohort in the 30-36 cm range, upon which the fishery must depend in future years. Comparison of length frequencies with those generated with known mortality rates, using the method of Stanley (1987), indicates that S. alutus in this area has experienced total mortality rates of ≈0.50. This level is approximately 400% above the equilibrium rate of 0.10. The 1976 cohort appears to be recruiting in relatively greater strength compared with previous cohorts but is still weak in absolute numbers, and does not appear to have been succeeded by cohorts of similar strength.

Optimal long-term stock size is in the range of 25,000-32,000 t, depending on the estimates of virgin stock size and the productivity relationship of the species used. For example, Ito et al. (1987) calculated maximum productivity at ≈0.33 of virgin biomass but cautioned that the productivity-stock size relationship employed was extremely uncertain. Alternatively, Archibald et al. (1983) calculated maximum productivity at ≈0.47 times virgin biomass, on the basis of a detailed biological model. These estimates were based on a recruitment pattern which included occasional, very strong cohorts. This pattern has not been perpetuated in the Vancouver Island S. alutus stock.

9.3.1.4 Yield Options

The S. alutus stock off southwest Vancouver Island remains in poor condition. Equilibrium yield estimates (≈70-200 t) remain as calculated in the 1987 assessment (Table 9.1). The upper end of this range is probably not sustainable in view of the generally poor recruitment expected over the next 5-8 y. Rehabilitation of this stock to its most productive level should not be expected within the next decade, even with very low fishing mortality, although this process would be enhanced if the 1976 cohort were allowed to contribute maximally to stock biomass and reproduction.

9.3.2. Southwest Vancouver Island redstripe rockfish (Sebastes proriger)

9.3.2.1 Landing statistics

Historical landings of S. proriger off southwest Vancouver Is. have been extremely limited (Table 9.3). However, in 1986 the adoption of coastwide slope rockfish quotas, and rapid subscription thereof, forced the domestic fleet to search for other red rockfish to satisfy strong market demands. Although considerably smaller than S. alutus in most areas, S. proriger do attain marketable size (>30 cm) off southwest Vancouver Is. and their landings underwent a dramatic increase in 1986, particularly after the existing slope rockfish quotas were filled. Landings declined in 1987 and are slightly below the similar period for the first half of 1988. Nominal and qualified CPUE in 1987 were marginally (≈5%) higher than those of 1986 but are approximately 10% lower for the first half of 1988 (Fig. 9.3).

9.3.2.2 Condition of the Stock

No quantitative conclusions concerning the condition of this stock are presently possible. There are no biological samples and the fishery results are of limited usefulness.

9.3.2.3 Yield Options

The sustainable yield (Table 9.1) for S. proriger in Area 3C is estimated to range from 200-1000 t (Leaman 1988). In the absence of detailed analysis, but recognizing the biological affiliation of the species and rockfish exploitation histories, it would be prudent to maintain yield at ≤500 t for a period sufficiently long to evaluate its suitability (5 y).

9.4.1 Northwest Vancouver Island Pacific ocean perch (Sebastes alutus)

9.4.1.1 Landing statistics

A major increase (64%) in directed fishing effort for S. alutus off the northwest coast of Vancouver Island occurred in 1986 (Table 9.4). This increase was coincident with the adoption of coastwide quotas and trip limits, and their effects were presented by Leaman (1988). The 1987 and 1988 fishing years have shown a return to the more traditional distribution of fishing effort for S. alutus, and that for Area 3D has dropped substantially. While nominal and qualified (25%) CPUE have increased since 1985 (Fig. 9.4), these increases have occurred during a period of falling effort, rather than being maintained during constant or increasing effort.

9.4.1.2 Condition of the Stock

There is little information upon which to base an assessment for this area. In spite of large landings in 1986 no biological samples were obtained, primarily because much of the total was landed at U.S. ports. In recent years the area has supported landings of ≈250 t/y but the impact of the 1986 fishery is difficult to assess. The increase of qualified CPUE in 1987 is associated with a major reduction in directed effort (-48%) and is cause for some concern. The correlation of CPUE and effort for rockfishes is generally an inverse one, and the CPUE in Area 3D should be closely monitored.

9.4.1.3 Yield Options

The catch history of S. alutus in Area 3D suggests that the historical fishery, although it has been brief, has been able to sustain removals of ≈250 t/y. The intense S. alutus fisheries of the mid-1960s found no significant quantities of fish in Area 3D, hence the virgin biomass must have been considerably less than those of either Queen Charlotte Sound (≈80,000 t) or southwest Vancouver Island (≈68,000 t). If the biomass was in the 10,000-30,000 t range, then long-term sustainable yield might be ≈200-600 t (Table 9.1).

9.5.1 Queen Charlotte Sound/Northwest Vancouver Island redstripe rockfish (*Sebastes proriger*)

9.5.1.1 Landing statistics

Historical landings of *S. proriger* off northwest Vancouver Is. and in Queen Charlotte Sd. have been extremely limited, until 1986 when over 1000 t were landed (Table 9.5). The reasons for this sudden increase, related to the adoption of coastwide quotas and rapid subscription thereof, were detailed in the previous assessment (Leaman 1988). The nominal and qualified CPUE for this fishery are relatively modest for a new fishery, although both increased in 1987. Nominal and qualified CPUE of this fishery are lower (≈-25%) in the first half of 1988. Historical catches by foreign trawlers in this area may have been substantial (Leaman et al. 1978).

9.5.1.2 Condition of the Stock

There is almost no information upon which to base the assessment of this stock, other than fishery statistics. No biological samples have been obtained in the short period of the fishery. There is clearly uncertainty concerning the condition of this stock, however we caution that it is a *Sebastes* sp. and therefore extremely vulnerable to exploitation.

9.5.1.3 Yield Options

The yield options for *S. proriger* in Area 3D/5A are based on published work (Francis 1986) relating initial yields from fisheries to their ultimate long-term yields. Francis estimated that these latter yields seldom exceed 200-300% of initial yields. The average yield from the first six years of the fishery was ≈350 t and this may be used as a lower estimate of sustainable yield (Table 9.1). The upper limit would then be estimated at ≈900 t (i.e. 250% of 350 t). Stability of quotas over the next 3-5 y may assist in the evaluation of their validity.

9.5.2 Queen Charlotte Sound/Northwest Vancouver Island yellowmouth rockfish (*Sebastes reedi*)

9.5.2.1 Landing statistics

The 1986 fishery recorded major landings of *S. reedi* from the southern portion of Area 5A and Area 3D (Table 9.6). Much of this removal was associated with the coastwide quotas described in section 9.4.1.1. Catch rate rose in 1987 but declined during the first half of 1988. The landings from this combined area in 1987 exceeded the suggested yield option by several hundred percent; a result of errors in the designation of quota areas during 1987.

9.5.2.2 Condition of the Stock

No analytic assessments of this stock have been conducted due to a paucity of useful data. It is difficult to determine the effects of fishing, if any, in the absence of these data. The fishery during 1986 and 1987 concentrated on aggregations of spawning females (≈76% female) and would be expected to produce high catch rates. In the previous assessment (Leaman 1988) we indicated that total mortality rate experienced by the stock, as interpreted through size frequency analysis, appears to be in the appropriate range (Z=0.05-0.10). However, we continue to caution that changes in the size frequency of the stock are driven by recruitment and are largely insensitive to short-term fishery effects.

9.5.2.3 Yield Options

The stock of S. reedi in the 3D/5A area has apparently sustained removals of ≈200-250 t/y by the domestic fishery. The previous catch history by foreign vessels is less certain due to species designation problems (Leaman et al. 1978). While the upper limit of sustainable yield is unknown, at this time, it would be prudent to approach the expansion of this fishery in a staged manner. Experience in other rockfish fisheries (Gunderson 1984, Francis 1986) suggests that yields in excess of 200-300% of the initial yields from such fisheries are seldom sustainable. Accordingly, the estimated upper limit for the sustainable yield option from this stock is ≈400-750 t (Table 9.1).

9.5.3 Queen Charlotte Sound (QCSd) Pacific ocean perch (Sebastes alutus)

9.5.3.1 Landing Statistics

The fishery in QCSd has been closed to directed fishing until April 1, since 1985. Fishing effort has generally been substantial after that date (Table 9.7), although standardized (by vessel tonnage class) CPUE continues to decline (Fig. 9.5). In part, the low CPUE for the 1987 fishery can be attributed to the imposition of trip limits (23 t) during the latter part of the year. The 1986 fishery showed CPUE values lower than both the 1983-1984 winter fisheries at the mouth of QCSd and those of the 1975-1983 period. Fishery statistics for Mitchell's Gully are of little value in recent years due to the low amount of fishing effort (<200 h).

9.5.3.2 Condition of the Stock

The QCSd S. alutus stocks have been analyzed more intensively than any groundfish stock on the Pacific coast. No new analytic assessments have been undertaken since those conducted and reviewed in the previous assessment (Leaman 1988). All of these studies have reached the same conclusion, namely that the QCSd S. alutus stocks are severely reduced from their unfished abundance. This conclusion is invariant, derived with a number of independent analytical methods, and supported by the biological characteristics of the stocks. All of the analytic studies have also noted that increased yield from these stocks could be realized if they were rehabilitated to a higher biomass level. While some of these analyses are complex, it is clear that there simply are not as many fish in QCSd as there either once was or should be, if higher yields are desired. Management of the quotas for these stocks has been imprecise and quota overruns have been the rule rather than the exception since 1983 (Fig. 9.6). It is highly probable that the stocks have continued to decline since the advent of the management program in 1977.

9.5.3.3 Yield Options

As with all rockfish stocks, the dynamics of the Goose Is. Gully stock of S. alutus are relatively slow and rehabilitative management actions of even large measure have little impact over the short term. Previous work (Archibald et al. 1983, Leaman and Stanley 1985) has shown that, with the exception of complete closure, there are relatively small differences in the periods of rehabilitation between F=0.0-0.05. However, increased yields in the future could be realized if fishing mortality on the stocks was decreased (i.e., F<0.06). The timetable of reconstruction at various levels of fishing mortality has been outlined previously (Archibald et al. 1983).

While there may be some uncertainty about the exact level of stock biomass in 1988, the values of F associated with long term maximum yield are relatively well determined (F≈0.06). Present stock biomass is estimated to be in the range of 8000-13000 t, suggested by the simulations using the 1985 and 1977 age compositions, respectively. Yields from these biomasses are dependent on the choice of management policy and have been outlined in previous assessments (Table 9.1, Archibald et al. 1983, Leaman & Stanley 1985). For example only, yields at F=0.06 would range, including the contribution of the Mitchell's Gully component of the stock, from ≈700-1000 t. Yields at this level of F are not predicted to produce rehabilitation of the stocks. If management considers maximum available yield and a balanced sex ratio to be desirable management goals then a winter fishery, with its female bias, would reduce available yield relative to an unbiased summer fishery.

9.6.1 Moresby Gully Pacific ocean perch (Sebastes alutus)

9.6.1.1 Landing Statistics

Catch rates for this stock (Table 9.8) do not display a healthy pattern, in relation to previous experience with rockfish stock histories. There were low catches and catch rates until 1980 when the stock first began to be exploited by the commercial fishery (this stock was discovered by the Department in 1973). After an initial learning period, the fleet began to target the stock heavily and catch rates first rose, then declined. The 1986 catch rate was probably abnormally low, due to effort diversion elsewhere during coastwide quota management. Between 1983-1987 the qualified (25%) catch rate declined by 40% (Fig. 9.7). While there was a minor increase in CPUE during 1987, the index has continued to decline in 1988. Catch statistics suggest therefore negative effects of fishing effort. Quantifying this effect is difficult without a time series encompassing the residency of several cohorts in the fishable stock; such data are unlikely to be available before the 1990s.

9.6.1.2 Condition of the Stock

Assessment of the Moresby Gully stock of S. alutus on the basis of cohorts continues to be hampered by the lack of a detailed history of its age composition and the relatively short history of its fishery. It is therefore difficult to detect fishery effects, even when they are present, due to the late age at full recruitment (partial vulnerability is >0.5 only at ages ≥11 y) and the 'fishing up' effect common to fisheries on this type of species (Francis 1986, Leaman 1987). Present stock assessment relies upon catch statistics and length frequency composition.

The estimation of mortality rates experienced by the stock, as interpreted through length frequency analysis (Stanley 1987), is compromised by the paucity of samples from the fishery in the latter part of most years. Samples from the spring of the year are composed primarily of smaller fish (mainly males) because mature adults have not yet returned from offshore spawning areas. Mortality rates calculated from such samples will tend to overestimate mortality experienced by the entire stock. The previous assessment (Leaman 1988) noted that mortality rates estimated for the stock using 1981-1985 data were inconclusive because of a larger number of smaller fish than would be expected for a constant low mortality rate (Z=0.10). Since that time, the simulation model used to estimate present mortalities has been improved to allow a variable history of fishing mortality (Rasmusson and Stanley 1988), which is more realistic than assuming that existing mortality rates had been experienced for the entire history of the cohorts present in the fishery.

Samples from the latter portion of 1987 show a bimodal frequency distribution (Figure 9.8), rather than the unimodal frequency noted in earlier years. This bimodality was also noted in the 1985 samples, although the possible contaminating effects of seasonal movements on the 1985 samples were noted in the last assessment (Leaman 1988). In addition, there has been a shift toward smaller fish since 1981, such that the larger fish are less abundant. If this pattern is interpreted in terms of the weight distribution of the catch and the decreasing catch rates, it can be seen that the larger fish mode has decreased substantially in abundance.

Catch rates for the S. alutus stock in Moresby Gully are cause for concern. There is no indication that the stock is increasing (although the 1976 cohort appears stronger than recent cohorts) and the decline in CPUE, taken in the context of experience with other rockfish stock histories, suggests stock decline. Tempering this suggestion is the fact that the fleet did not fish this stock during the optimum period of availability (summer) in the 1984-1986 period. However, CPUE from the 1988 summer fishery is below the 1985 value (1986 was considered to be abnormally low) by 37% and continues the decline since 1983.

Management of this stock will continue to be hampered by data limitations and the effects of changing management policies will therefore be difficult to detect and evaluate. The sensitivity of rockfish stocks to high fishing effort argues that any changes in yield should be as relatively small increments applied over time intervals sufficiently long for evaluation of their effects. In the interim, the negative trend in catch rates should be cause for concern.

9.6.1.3 Yield Options

In 1987, an internal Groundfish Section review of the Moresby Gully S. alutus assessment stated that considerably greater yield (3500 t) than was previously identified (2000 t) could be taken from the stock. The present assessment indicates that concerns previously expressed about the condition of the stock, on the basis of catch statistics and general life history, should be heeded. While there has been no change in the primary assessment for 1988, the high-risk yield (3000 t) is based on the alternative 1987 review. The low-risk sustainable yield is estimated as 1900 t (Table 9.1). Management is cautioned that the long delay to full recruitment of a cohort renders most measures of stock status insensitive during the early stages (5-10 y) of rockfish fisheries. When declines such as those noted for this stock are observed, their import should be even greater.

9.6.2 Moresby Gully redstripe rockfish (Sebastes proriger)

9.6.2.1 Landing Statistics

In concert with other fisheries for S. proriger, that in Moresby Gully is of relatively recent origin (Table 9.9). Landings have not yet exceeded 350 t. Qualified (25%) CPUE has been variable since the first significant landings in 1985, although the 1988 CPUE values are considerably below those of previous years at similar levels of effort.

9.6.2.2 Condition of the Stock

There is very little information upon which to assess the S. proriger stock in Moresby Gully. The size composition of the stock in 1988 is similar to that of 1986-1987 and no adverse effects of the historical fishery are evident. We noted in the 1987 assessment that the mortality rate expressed in the length frequency of the stock was at an appropriate level. However, we again caution that length frequency changes are driven by recruitment and short-term fishery effects are thus difficult to detect.

9.6.2.3 Yield Options

Yield from the Moresby Gully stock of S. proriger cannot be determined analytically. In the absence of any adverse indications from the limited available data, we assume that the minimum historical landings can be sustained. Indeed, the large stock of S. alutus in this area may infer a relatively large stock of S. proriger, based on analysis of historical patterns of association between these species (Leaman and Nagtegaal 1987). The catch proportion ratio from that analysis (0.217) implies a yield range of ≈350-570 t for S. proriger in Moresby Gully (Table 9.1).

9.6.3 Moresby Gully yellowmouth rockfish (Sebastes reedi)

9.6.3.1 Landing Statistics

The fishery for S. reedi in Moresby Gully has been erratic (Table 9.10). Landings underwent a major increase in 1982 but declined, along with fishing effort, until 1987. Both qualified (25%) and unqualified CPUE have been highly variable since 1982. Fleet activity is generally directed at S. alutus in this area because CPUE for it is considerably (80-150%) higher.

9.6.3.2 Condition of the Stock

There is little information with which to assess the Moresby Gully S. reedi stock. We will assume the mean level of harvest is sustainable and represents the minimum level of long-term yield. The association with S. alutus in landings is not as strong as that in Area 5E (Leaman and Nagtegaal 1987), hence catch proportion ratios are inappropriate.

9.6.3.3 Yield Options

The long-term average harvest from this stock (≈160 t) is assumed to be a lower limit of sustainable yield (Table 9.1). There is little to guide the determination of an upper estimate; we will use the same criterion as in section 9.5.1.3, i.e., 200-300% of initial harvests represents a non-sustainable level (Francis 1986, Gunderson 1984). The upper limit is therefore estimated to be ≈500 t.

9.7.2 West Queen Charlotte Islands (south of 54°) Pacific ocean perch (Sebastes alutus)

9.7.2.1 Landing Statistics

Landings of S. alutus from Area 5E(S) peaked in 1978 (2413 t) but have since been restricted to much lower levels (Table 9.11). This species has also been managed on the basis of a slope rockfish assemblage, with seasonal openings, since 1983. In 1987-1988 the seasonal openings, which were designed to optimize individual species yields within the assemblage, were abandoned in favour of quarterly quotas. The effect of this policy was to remove the advantage of seasonal openings in the achievement of an optimal mix of species in the assemblage quota.

Present CPUE (qualified and nominal) for the fishery is well below peak levels and qualified CPUE has declined to the lowest level on record (Fig. 9.9). Qualified CPUE (0.716 t/h) is only 22% of the highest value on record. Achievement of management targets has generally been poor (Leaman and Nagtegaal 1987), although the 1986-1987 period has shown improved adherence to targets.

9.7.2.2 Condition of the Stock

The stock continues to be dominated by the older cohorts (1940, 1952), in terms of weight. On a positive note, there are indications that the 1976 cohort may be relatively stronger than recent year recruitments (Fig. 9.10), and it should be fully recruited to the fishery by 1991-1992. This cohort accounted for approximately 27% of the total number of fish in the fishable stock in 1985 and is expected to continue to increase in proportion over the next 5-10 y.

The size frequency of the stock reflected in 1988 samples, when compared to simulated frequencies calculated with known mortality rates (Stanley 1987) supports the inference drawn in 1987, that the mortality rate for the stock has been consistently above the target value of 0.1 and is closer to 0.2.

9.7.2.3 Yield Options

The continued decline of catch statistics in 1987-1988 and the mortality rate estimated with size frequency analysis endorse the concerns previously expressed. A reduction of the estimated yield from this stock is therefore presented for 1989; sustainable yield is estimated to range from 300-500 t (Table 9.1).

9.7.3 West Queen Charlotte Islands (south of 54°) yellowmouth rockfish (Sebastes reedi)

9.7.3.1 Landing Statistics

Landings of S. reedi in Area 5E(S) peaked in 1977, declined in 1978 and have been regulated by quota since 1979 (Table 9.12). Nominal CPUE has declined relatively steadily since 1977 and is now <35% of peak levels. Qualified (25%) CPUE has been variable, although it is also well below levels of the late 1970s. After a major resurgence of qualified CPUE in 1986, it has returned to the level of <1.0 t/h recorded in recent years (Fig. 9.11). Achievement of management yield targets has generally been poor, largely resulting from the adoption of quarterly quotas (with a higher percentage of S. alutus in the first two quarters) and consequent truncation of the third and fourth openings, and the opportunity to realize greater proportions (and catch rates) of S. reedi. Interpretation of catch rates trends is hampered by this seasonal pattern of the fishery.

9.7.3.2 Condition of the Stock

No analytic assessments of this stock have been conducted and biological samples are extremely limited. Catch statistics are somewhat more stable than those for S. alutus in recent years, however landings have also been below target levels. Comparison of length frequency composition from 1987 commercial samples with that from simulated mortality rates suggests that total mortality rate experienced by this stock has been approximately ≤0.20.

9.7.3.3 Yield Options

Yield options for the S. reedi stock in Area 5E(S) remain approximately the same as in 1987, although the range of values in Table 9.1 reflects the uncertainty associated with this assessment. Sustainable yield is estimated to range from 400-700 t.

9.7.4 West Queen Charlotte Islands (south of 54°) rougheye rockfish (Sebastes aleutianus)

9.7.4.1 Landing Statistics

Landings and fishing effort for S. aleutianus in Area 5E(S) have been erratic since the inception of the fishery in 1977 (Table 9.13). In part, this has occurred due to the grouping of S. aleutianus with the other slope rockfishes for management. Rapid subscription of the S. alutus and S. reedi components of that quota has often truncated fishing for S. aleutianus. S. aleutianus was removed from the slope rockfish quota for Area 5E(S) in 1988 and catch rates have increased over those of the 1984-1987 period. However, they are still less than one-half of the levels recorded in the early years of the fishery.

9.7.4.2 Condition of the Stock

A lack of any data except fishery statistics hampers assessment of this stock. We have no biological samples more recent than 1979, at which time the age range was extensive (18-72) and the estimated rate of natural mortality low (0.02-0.04) (Archibald et al. 1981). Vital statistics of this level imply relatively low yield potential.

9.7.4.3 Yield Options

The estimated yield options for the S. aleutianus stock in Area 5E(S) reflect the uncertainty of our assessment (Table 9.1), although the generally low level of available yield from the area is recognized. Sustainable yield is estimated to range from 200-300 t.

9.7.5. West Coast Queen Charlotte Islands (south of 54°) redstripe rockfish (Sebastes proriger)

9.7.5.1 Landing Statistics

Landings of S. proriger from Area 5E(S) have complemented those of the other slope rockfishes, over the 1980-1988 period (Table 9.14). Directed effort and landings remained low until 1985, when other slope quotas began to be fully subscribed early in the calendar year. For the 1985-1987 period, directed effort (25% qualification) has exceeded 300 h/y and approached that for S. alutus, although qualified CPUE has decreased continuously. A major decline in both qualified and nominal CPUE has been recorded for the first half of 1988 (Fig. 9.12).

9.7.5.2 Condition of the Stock

Assessment information for this stock is limited. Size composition data (Leaman 1988) suggest that the mortality rate experienced by females (≈0.15-0.18) is within the appropriate range (0.16-0.20), although that for males (≈0.05) is lower than expected. The latter is difficult to account for on the basis of fishery results, unless the fishery is assumed to be sex-specific and/or significant grading of the catch by size is practiced.

Examination of research samples suggests that male S. proriger are indeed more strongly represented in catches than in landings (Nagtegaal and Farlinger 1980, Nagtegaal et al. 1980, Shaw and Archibald 1981).

9.7.2.3 Yield Options

In the previous assessment we suggested that the present level of landings (600 t/y) was unlikely to be sustainable. Cluster analysis of landings from this area (Leaman and Nagtegaal 1987) suggested that the normal catch ratio of S. proriger to S. alutus was ≈0.217. Based on the yield options identified for S. alutus (Table 9.1), the estimated level of sustainable yield for S. proriger is in the 60-100 t range. These figures may be conservative if the landing patterns, upon which the catch ratio is based, do not accurately reflect the catch of S. proriger. There has been no evidence of such market limitations in recent years, although they may have been operative in the late 1970s.

9.8.1 West Queen Charlotte Islands (north of 54°) rockfish (all Sebastes)

9.8.1.1 Introduction

The Langara Spit area (Area 5E(N)) has been the object of an experimental open-fishing program since the fall of 1983. The genesis of this experiment and its purposes were outlined in the previous assessment (Leaman 1988). We present here a brief update on the condition of the stocks which are the subjects of this experiment.

9.8.1.2 Landing Statistics

Annual landings increased steadily following the inception of the experiment (Tables 9.15-9.18), before undergoing a substantial decline in 1987. With the exception of S. proriger (Table 9.18), the CPUE (nominal and qualified) for all species has dropped throughout the course of the experiment. However, even for S. proriger the CPUE has declined following the major increment in landings (1986). For all species, present levels of qualified (25%) CPUE are less than 50% of peak levels (e.g., Fig. 9.13).

The species composition of the catch has changed over the course of the experiment (Fig. 9.14, Table 9.19) as the fleet has moved to alternative species (with lower catch rates) to supplement fishing on the major target, S. alutus, although that species has always comprised the majority of the catch.

9.8.1.3 Condition of the Stocks

The Langara Spit rockfish stocks continue to be in poor condition. Catch rates have decreased continuously since the initiation of the experimental fishery and the biological characteristics of the major target, S. alutus, indicate further depletion of the stock. Age composition samples illustrated that the fishery was based primarily upon fish <10 y old at the outset. These ages are not fully recruited and have only been sexually mature for 1-2 y. The long-term implications of a fishery based on immature and recently mature fish are obvious and serious. The most recent age samples from the commercial fishery (1987) indicate that the fishery is based almost entirely upon a single cohort. The 1976 cohort now represents over 50% of the total numbers of fish in the stock (Fig. 9.15). In comparison, this cohort represents only 25% of the numbers (and a far lower proportion of the biomass) of the 5E(S) S. alutus stock. The increasing dominance of this cohort, in conjunction with declining catch rates, should be cause for grave concern about the future yield potential from this stock.

In the previous assessment we noted that this stock appears to have experienced total mortality rates (Z) in excess of 0.50, and close to 0.70. Clearly, such mortality is well above sustainable levels ($Z \approx 0.10$).

In summary, biological characteristics and fishery statistics of the major rockfish stocks in the Langara Spit area indicate continued high mortality rates and poor stock condition. Higher yields from this area could be realized through rehabilitative actions, although a return to maximum long-term yield could take 30-40 y, even with rigorous conservation.

9.8.1.4 Yield Options

Yields of S. alutus in the order of 2000 t/y appear to have generated total mortality rates in the 0.6-0.7 range. If these figures are correct, then sustainable yields ($Z \approx 0.10$) should be in the range of 140-170 t. The upper limits of sustainability are unlikely to be more than twice this figure, and may be less if stock biomass has been reduced below levels giving rise to observed mortality rates. Similar calculations were applied to the average yield of 300 t/y for S. aleutianus. Yield options for S. reedi and S. proriger are simply guideline figures based on Francis' (1986) observations concerning the relationship between initial and long-term yields (see Section 9.5.1.3). Hence, sustainable yields are estimated to be ≈350-500 t and 500-700 t, respectively (Table 9.1). A cautionary note concerning the potential yield from these two species should be added. Both species were recorded by observers in catches by Japanese trawlers during 1977 (Leaman et al. 1978). The exact exploitation history for these species is therefore uncertain and yields identified here as those of initial fisheries may overestimate long-term yield, when used in this fashion. Characteristics of these two species in this area will bear careful scrutiny in the future.

The open-fishery component of this experiment was originally proposed to terminate at the end of 1987 and be followed by a second phase, where the process of stock rebuilding at low or no fishing mortality could be initiated. The results of the second phase will be used to provide guidance on management policies for this and other rockfish stocks. Management chose to continue the open-fishery portion of the experiment in 1988, to provide further evidence of the negative effects of unrestricted fishing. The decline in stock biomass and the deterioration of all stock status indices as a result of the open fishery have been well demonstrated (Leaman 1988). Incremental scientific benefits from continued open fishing are expected to be very small.

Table 9.1. Yield options for slope rockfishes off the British Columbia coast for 1989.

Species	Area	Yield Options (t) Conservative	Sustainable (Low risk - High risk)	Non-sustainable
S. alutus	3C	<100	100 - 200	>200
S. proriger	"	<200	200 - 1000	>1000
S. alutus	3D	<200	200 - 600	>600
S. reedi	3D/5A	<250	250 - 750	>750
S. proriger	"	<350	350 - 900	>900
S. alutus	5A/B	<700	700 - 1000	>1000
S. alutus	Moresby	<1900	1900 - 3000	>3000
S. reedi	"	<160	160 - 500	>500
S. proriger	"	<350	350 - 570	>570
S. alutus	5E(S)	<300	300 - 500	>500
S. reedi	"	<400	400 - 700	>700
S. aleutianus	"	<200	200 - 300	>300
S. proriger	"	<50	50 - 100	>100
Slope rockfish[a]				
Jan.-June	"	<300	300 - 500	>500
Sep.-Dec.	"	<600	600 - 1000	>1000
S. alutus	5E(N)	<150	150 - 170	>250
S. reedi	"	<350	350 - 500	>500
S. aleutianus	"	<50	50 - 100	>100
S. proriger	"	<500	500 - 700	>700
Slope rockfish[b]	"	<200	200 - 270	>270

[a] *S. alutus*, *S. reedi*, and *S. aleutianus*
[b] *S. alutus* and *S. aleutianus*

Table 9.2. Canadian landing statistics for Pacific ocean perch off southwest Vancouver Island (including Mgmt Area 125).

YEAR	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
	4.47	4.47	6.50	.688	4.28	4.50	.951
1968	.12	.12	6.30	.019	-	-	-
	-	-	-	-	-	-	-
1970	298.84	297.77	444.80	.669	273.11	293.20	.931
	206.99	201.14	552.00	.364	190.50	333.70	.571
1972	72.24	13.25	21.30	.622	12.67	14.30	.886
	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-
	5.46	5.46	166.50	.033	1.46	7.00	.209
1976	1.29	1.29	5.00	.258	.87	1.00	.870
	15.04	13.81	447.50	.031	8.67	42.30	.205
1978	48.88	48.57	57.80	.840	47.51	32.00	1.485
	80.62	79.91	147.10	.543	77.14	44.90	1.718
1980	285.59	284.77	448.20	.635	277.93	234.90	1.183
	381.54	364.99	750.80	.486	341.61	430.50	.794
1982	395.23	372.29	740.30	.503	342.56	430.70	.795
	373.97	179.30	348.30	.515	167.71	143.30	1.170
1984	406.17	317.39	481.90	.659	316.86	478.80	.662
	243.11	222.85	1079.60	.206	195.86	692.70	.283
1986	242.15	178.52	547.70	.326	140.49	185.10	.759
	542.27	414.95	655.60	.633	340.10	366.90	.927
(a)	172.50	97.93	760.20	.129	53.66	191.60	.280

% qualification = % <u>alutus</u> in catch needed for inclusion of data

L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.3. Canadian landing statistics for redstripe rockfish in Area 3C.

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1980	.29	.29	1.00	.290	-	-	-
	12.76	12.76	10.50	1.215	9.32	4.30	2.167
1982	2.53	2.53	50.30	.050	2.42	1.80	1.344
	30.07	24.63	292.10	.084	11.66	31.30	.373
1984	34.57	11.01	331.10	.033	3.71	3.20	1.159
	61.01	44.16	406.50	.109	19.37	44.50	.435
1986	514.72	368.19	1724.10	.214	241.19	286.50	.842
	377.13	325.11	1299.00	.250	199.50	224.30	.889
(a)	208.93	131.41	742.40	.177	113.41	145.30	.781

% qualification = % *proriger* in catch needed for inclusion of data

L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.4. Canadian landing statistics for Pacific ocean perch off northwest Vancouver Island (Area 3D).

Year	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
	2.55	2.55	10.00	.255	2.55	10.00	.255
1968	.41	.04	66.50	.001	-	-	-
	2.49	2.49	40.50	.061	1.26	12.50	.101
1970	5.38	5.38	150.60	.036	-	-	-
	11.39	11.39	82.00	.139	10.32	67.00	.154
1972	45.02	-	-	-	-	-	-
	-	-	-	-	-	-	-
1974	2.92	2.92	59.00	.049			-
	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-
	1.13	1.13	7.30	.155	.14	4.00	.035
1978	7.05	4.48	18.90	.237	3.45	6.90	.500
	44.24	44.24	53.90	.821	43.89	40.80	1.076
1980	144.26	143.50	300.90	.477	126.80	190.10	.667
	165.97	165.97	353.40	.470	163.40	283.40	.577
1982	112.86	112.13	200.80	.558	109.92	124.30	.884
	463.33	214.39	574.30	.373	182.58	281.60	.648
1984	337.40	236.03	441.80	.534	231.60	353.30	.656
	312.69	262.51	506.40	.518	217.59	356.40	.611
1986	1045.95	658.23	815.00	.808	611.16	585.80	1.043
	450.49	414.95	655.60	.633	363.23	304.70	1.192
(a)	360.99	206.89	253.80	.815	174.83	131.50	1.330

% qualification = % <u>alutus</u> in catch needed for inclusion of data

L = Landings (t)

E = Effort (h)

CPUE = Nominal catch per unit effort (t/h)

(a) to 25/7/88

Table 9.5. Canadian landing statistics for redstripe rockfish in Queen Charlotte Sound-northwest Vancouver Island.

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1980	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1982	2.58	2.58	121.00	.021	-	-	-
	40.76	38.25	139.40	.274	36.63	1.30	28.177
1984	49.37	15.66	281.90	.056	2.01	5.50	.365
	124.60	84.55	935.40	.090	45.27	197.00	.230
1986	1062.44	974.59	1932.80	.504	797.72	679.80	1.173
	1344.80	1230.43	2118.70	.581	996.35	830.80	1.199
1988	331.51	283.00	696.80	.406	218.05	269.90	.808

% qualification = % proriger in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.6. Canadian landing statistics for yellowmouth rockfish in Queen Charlotte Sound--northwest Vancouver Island.

Year	Total landings	0% Qualification			25% Qualification		
		L	E	CPUE	L	E	CPUE
	5.35	5.35	31.50	.170	-	-	-
1972	-	-	-	-	-	-	-
	176.65	176.65	37.00	4.774	176.21	32.50	5.422
1974	78.91	78.91	23.00	3.431	78.91	23.00	3.431
	1.08	1.08	34.50	.031	-	-	-
1976	12.29	12.29	10.00	1.229	12.29	10.00	1.229
	335.89	335.89	466.00	.721	331.29	226.30	1.464
1978	16.54	16.54	110.00	.150	10.86	16.00	.679
	10.25	10.25	102.00	.100	6.49	9.70	.669
1980	27.92	27.92	97.50	.286	24.77	32.70	.757
	4.74	4.74	25.60	.185	.07	2.00	.035
1982	227.89	176.94	167.50	1.056	163.42	39.80	4.106
	628.09	460.12	501.50	.917	367.12	151.40	2.425
1984	458.27	201.59	405.10	.498	182.28	214.60	.849
	716.91	337.90	854.90	.395	292.01	204.50	1.428
1986	1208.37	944.84	1247.40	.757	817.10	546.10	1.496
	1170.14	1075.16	1307.50	.822	907.37	417.10	2.175
(a)	465.13	404.43	580.20	.697	343.18	200.70	1.710

% qualification = necessary % reedi in catch for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.7. Total landings (foreign and domestic) of Pacific ocean perch, standardized CPUE and calculated total effort on principal fishing grounds of Queen Charlotte Sound. (Fishery changed to a winter fishery on spawning females 1983-1985.)

	Goose Island Gully			Mitchell's Gully		
Year	Total landings	Standard CPUE	Calculated effort	Total landings	Standard CPUE	Calculated effort
	1890	.836	2261	-	-	-
1960	1679	.698	2405	-	-	-
	1199	.797	1504	-	-	-
	1838	1.161	1583	-	-	-
	3712	1.457	2548	-	-	-
	3450	1.134	3042	57	-	-
1965	7478	1.491	5015	488	.780	626
	20752	1.441	14401	1369	.815	1680
	12119	1.068	11347	5319	1.157	4597
	10213	1.045	9773	2556	1.137	2248
	6872	.763	9007	2945	.995	2960
1970	6489	.672	9657	1296	1.010	1283
	3455	.526	6568	813	.954	852
	5645	.829	6809	995	.854	1165
	3755	.773	4858	2264	1.351	1676
	7269	.773	9404	1917	.974	1968
1975	4209	.507	8302	1151	.989	1164
	2442	.733	3332	576	.673	856
	1693	.660	2565	256	.551	465
	865	.821	1054	375	.817	459
	951	.799	1190	480	.670	716
1980	1226	.932	1316	305	.862	354
	801	.760	1054	680	4.474	152
	570	.514	1110	286	2.648	108
	1215	1.257	967	31	.929	33
	841	2.017	417	19	.594	32
1985	743	.475	1565	80	.149	537
	623	.534	1167	-	-	-
	1548	.518	2989	98	.506	193
(a)	612	.504	1215	167	1.145	146

(a) to 25/7/88

Table 9.8. Canadian landing statistics for Pacific ocean perch in Moresby Gully.

Year	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
1968	1.13	1.13	3.50	.323	1.13	3.50	.323
1969	.78	.78	23.80	.033	-	-	-
1970	27.35	25.58	594.30	.043	3.75	10.50	.357
1971	9.78	9.78	346.30	.028	1.62	8.50	.191
1972	13.18	13.18	567.10	.023	-	-	-
1973	37.93	34.21	672.90	.051	20.33	15.80	1.287
1974	36.30	34.97	595.50	.059	21.52	16.30	1.320
1975	116.53	107.25	1023.00	.105	93.64	91.30	1.026
1976	85.64	70.51	2185.00	.032	40.18	107.00	.376
1977	73.72	34.75	1788.00	.019	11.97	48.50	.247
1978	175.90	175.90	996.40	.177	126.63	82.60	1.533
1979	369.67	354.70	2046.00	.173	276.02	457.00	.604
1980	2544.95	2247.51	2259.20	.995	2232.59	1607.50	1.389
1981	2216.64	1523.91	1782.10	.855	1487.78	1009.20	1.474
1982	3625.58	2733.06	1846.00	1.481	2694.44	1282.80	2.100
1983	2219.99	1507.05	853.80	1.765	1503.57	668.70	2.248
1984	2055.02	1286.64	1578.70	.815	1269.42	693.10	1.832
1985	1967.25	1330.05	1593.70	.835	1275.72	740.60	1.723
1986	628.66	623.39	1239.70	.503	562.83	492.10	1.144
1987	1910.85	1809.87	1676.30	1.080	1775.03	1313.20	1.352
(a)	1355.14	1261.84	1407.80	.896	1229.59	1131.30	1.087

% qualification = necessary % alutus in catch for inclusion of data

L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.9. Canadian landing statistics for redstripe rockfish in Moresby Gully.

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1980	19.32	19.32	193.00	.100	1.26	6.50	.194
	5.32	3.94	116.70	.034	-	-	-
1982	22.83	17.67	286.40	.062	2.12	5.50	.385
	19.94	15.72	107.80	.146	6.20	25.10	.247
1984	70.52	33.08	409.40	.081	18.52	41.20	.450
	180.83	152.72	544.40	.281	96.82	141.80	.683
1986	109.61	106.97	507.50	.211	51.29	125.00	.410
	306.72	289.49	800.80	.362	176.35	245.90	.717
(a)	154.25	116.03	682.30	.170	56.98	176.30	.323

% qualification = % proriger in catch needed for inclusion of data

L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.10. Canadian landing statistics for yellowmouth rockfish in Moresby Gully.

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1978	91.94	91.94	54.30	1.693	84.65	45.20	1.873
	20.48	20.48	37.60	.545	-	-	-
1980	20.13	20.13	28.70	.701	1.50	5.50	.273
	109.67	40.95	116.60	.351	-	-	-
1982	417.32	325.15	711.60	.457	228.75	202.10	1.132
	202.04	78.24	239.70	.326	15.22	39.80	.382
1984	338.09	106.12	308.10	.344	34.73	50.20	.692
	232.01	177.51	342.90	.518	114.20	85.80	1.331
1986	100.28	100.28	226.80	.442	64.46	72.50	.889
	116.40	74.80	459.00	.163	34.43	56.30	.612
(a)	141.41	98.20	453.80	.216	49.59	46.80	1.060

% qualification = % reedi in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.11. Canadian landing statistics for Pacific ocean perch in Area 5E (S).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	CPUE	L	E	CPUE
1976	78.78	78.78	59.00	1.335	78.78	59.00	1.335
	1549.42	1475.24	1041.50	1.416	1321.29	651.40	2.028
1978	2413.70	2346.93	1043.90	2.248	2255.89	724.40	3.114
	839.28	839.28	557.40	1.506	823.09	376.10	2.188
1980	876.96	472.90	496.20	.953	449.31	332.50	1.351
	599.21	432.73	235.70	1.836	412.99	172.50	2.394
1982	614.11	606.73	443.10	1.369	550.38	308.80	1.782
	835.17	762.67	629.80	1.211	721.46	403.80	1.787
1984	840.88	457.92	344.80	1.328	434.90	215.90	2.014
	828.61	603.93	691.50	.873	562.91	453.80	1.240
1986	641.91	473.78	733.50	.646	341.09	275.40	1.239
	660.94	553.32	834.60	.663	485.83	453.30	1.072
(a)	332.76	323.58	738.60	.438	281.14	392.40	.716

% qualification = necessary % alutus in catch for inclusion of data

L = Landings (t)

E = Effort (h)

CPUE = Nominal catch per unit effort (t/h)

(a) to 25/7/88

Table 9.12. Canadian landing statistics for yellowmouth rockfish in Area 5E (S).

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1976	-	-	-	-	-	-	-
	1256.74	1256.74	583.00	2.156	1226.64	438.20	2.799
1978	1104.64	1104.64	600.40	1.840	858.89	296.30	2.899
	388.54	388.54	356.50	1.090	328.72	204.70	1.606
1980	499.91	477.23	321.50	1.484	477.23	321.50	1.484
	922.41	380.12	192.20	1.978	350.89	129.90	2.701
1982	414.39	351.87	335.90	1.048	307.98	191.90	1.605
	588.21	556.22	575.50	.966	501.10	356.70	1.405
1984	441.08	212.33	336.20	.632	169.75	178.90	.949
	495.77	344.95	609.80	.566	220.00	257.80	.853
1986	564.49	538.46	489.30	1.100	466.77	240.10	1.944
	450.59	395.39	714.30	.554	318.68	267.60	1.191
(a)	106.01	101.13	531.90	.190	48.28	55.10	.876

% qualification = necessary % reedi in catch for inclusion of data

L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.13. Canadian landing statistics for rougheye rockfish in Area 5E (S).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	CPUE	L	E	CPUE
1976	-	-	-	-	-	-	-
	76.28	76.28	134.50	.567	74.69	66.00	1.132
1978	139.49	139.49	396.90	.351	105.17	118.30	.889
	192.09	192.09	347.70	.552	159.51	137.10	1.163
1980	51.42	51.42	60.00	.857	50.31	23.00	2.187
	9.93	9.93	46.20	.215	5.13	7.20	.713
1982	274.38	274.38	269.30	1.019	262.55	156.20	1.681
	74.16	61.37	324.10	.189	26.70	22.00	1.214
1984	100.85	73.37	215.30	.341	21.49	24.20	.888
	157.86	115.67	411.90	.281	77.52	178.30	.435
1986	268.77	165.56	371.60	.446	89.55	158.30	.566
	296.11	260.53	702.20	.371	226.54	414.20	.547
(a)	371.15	301.27	703.30	.428	284.68	443.90	.641

% qualification = % aleutianus in catch needed for inclusion of data

L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.14. Canadian landing statistics for redstripe rockfish in Area 5E (S).

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1980	110.96	110.96	310.10	.358	64.70	77.90	.831
	132.63	81.01	148.60	.545	44.51	35.50	1.254
1982	33.55	31.10	210.70	.148	5.45	9.00	.606
	142.79	132.13	316.10	.418	76.31	96.60	.790
1984	148.45	85.11	212.30	.401	45.26	22.20	2.039
	918.73	763.12	708.10	1.078	713.17	439.80	1.622
1986	728.23	588.80	637.80	.923	459.01	318.00	1.443
	628.94	607.25	638.70	.951	554.61	358.00	1.549
(a)	225.87	201.23	568.70	.354	160.22	229.80	.697

% qualification = % proriger in catch needed for inclusion of data

L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.15. Canadian landing statistics for Pacific ocean perch in Area 5E (N).

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1976	-	-	-	-	-	-	-
	1.42	1.42	19.70	.072	.70	2.30	.304
1978	22.22	22.22	151.10	.147	6.65	16.80	.396
	227.49	227.49	177.50	1.282	223.83	108.50	2.063
1980	84.56	84.56	119.30	.709	64.80	39.50	1.641
	109.22	63.58	32.40	1.962	53.15	24.10	2.205
1982	342.23	218.48	144.10	1.516	194.18	109.30	1.777
	291.98	226.43	401.80	.564	208.28	193.50	1.076
1984	2173.86	1819.93	1213.50	1.500	1779.38	980.00	1.816
	1921.21	1821.61	1908.70	.954	1712.09	1514.50	1.130
1986	2725.37	2658.69	2957.40	.899	2558.46	2319.30	1.103
	1129.70	1048.62	1294.00	.810	1015.88	1119.60	.907
(a)	889.28	886.78	1208.10	.734	869.35	1101.70	.789

% qualification = necessary % alutus in catch for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.16. Canadian landing statistics for yellowmouth rockfish in Area 5E (N).

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1976	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
	16.86	16.86	69.90	.241	4.08	4.10	.995
1980	-	-	-	-	-	-	-
	2.34	2.34	4.90	.478	2.34	4.90	.478
1982	67.88	54.58	70.30	.776	52.36	36.50	1.435
	52.23	18.36	44.50	.413	3.48	9.00	.387
1984	72.84	63.05	468.30	.135	15.79	14.90	1.060
	179.88	173.60	1008.30	.172	55.12	40.50	1.361
1986	614.97	608.05	2151.90	.283	403.15	511.30	.788
	108.91	105.46	652.40	.162	66.19	89.70	.738
(a)	74.44	74.44	626.00	.119	33.59	47.80	.703

% qualification = necessary % reedi in catch for inclusion of data

L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.17. Canadian landing statistics for rougheye rockfish in Area 5E (N).

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1976	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
	13.99	13.99	139.50	.100	9.73	64.10	.152
1980	2.58	2.58	42.50	.061	-	-	-
	98.08	98.08	26.00	3.772	94.20	23.00	4.096
1982	69.09	69.09	74.40	.929	65.66	34.80	1.887
	127.46	84.01	271.50	.309	43.39	44.30	.979
1984	226.21	207.86	824.70	.252	93.50	134.30	.696
	453.67	453.25	1344.40	.337	310.64	397.20	.782
1986	460.81	430.00	1627.30	.264	264.83	338.90	.781
	179.86	176.26	946.70	.186	89.79	154.20	.582
(a)	273.15	273.09	1064.30	.257	182.79	452.40	.404

% qualification = % aleutianus in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.18. Canadian landing statistics for redstripe rockfish in Area 5E (N).

Year	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1980	-	-	-	-	-	-	-
	.33	.33	4.90	.067	-	-	-
1982	13.27	6.43	35.30	.182	-	-	-
	18.44	3.14	17.50	.179	-	-	-
1984	110.85	108.31	552.10	.196	27.45	18.50	1.484
	258.99	258.99	1153.50	.225	93.53	98.30	.951
1986	716.62	711.98	2366.90	.301	474.57	314.00	1.511
	224.29	214.13	929.80	.230	103.78	186.10	.558
(a)	79.13	79.13	815.70	.097	34.02	57.70	.590

% qualification = % proriger in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
(a) to 25/7/88

Table 9.19. Catches and percentages of rockfish for the major species in the fishery for Minor Area 35, 1976-1988.

Year	Total rockfish	aleutianus	alutus	brevispinis	proriger	reedi
1976	-	-	-	-	-	-
	5.51	-	1.42/ 25.77	-	-	-
1978	48.22	-	22.22/ 46.08	15.70/ 32.56	-	-
	287.27	13.99/ 4.87	227.49/ 79.19	7.77/ 2.70	4.76/ 1.66	16.86/ 5.8
1980	105.05	2.58/ 2.46	84.56/ 80.50	15.45/ 14.71	-/	-/ .00
	376.13	98.08/ 26.08	109.22/ 29.04	2.26/ .60	.33/ .09	2.34/ .62
1982	691.53	69.09/ 9.99	342.23/ 49.49	37.57/ 5.43	13.27/ 1.92	67.88/ 9.8
	568.18	127.46/ 22.43	291.98/ 51.39	16.32/ 2.87	18.44/ 3.25	52.23/ 9.1
1984	2995.78	226.97/ 7.58	2186.33/ 72.98	248.34/ 8.29	110.85/ 3.70	72.80/ 2.4
	3230.61	465.37/ 14.41	1938.46/ 60.00	244.68/ 7.57	259.00/ 8.02	180.31/ 5.5
1986	4968.30	431.30/ 8.68	2727.20/ 54.89	165.80/ 3.34	707.30/ 14.24	620.40/ 12.
	1880.18	179.86/ 9.57	1129.70/ 60.08	84.87/ 4.51	224.29/ 11.93	108.91/ 5.7
(a)	1651.20	313.52/ 18.99	964.13/ 58.39	109.81/ 6.65	87.30/ 5.29	83.51/ 5.0

(a) to 25/7/88

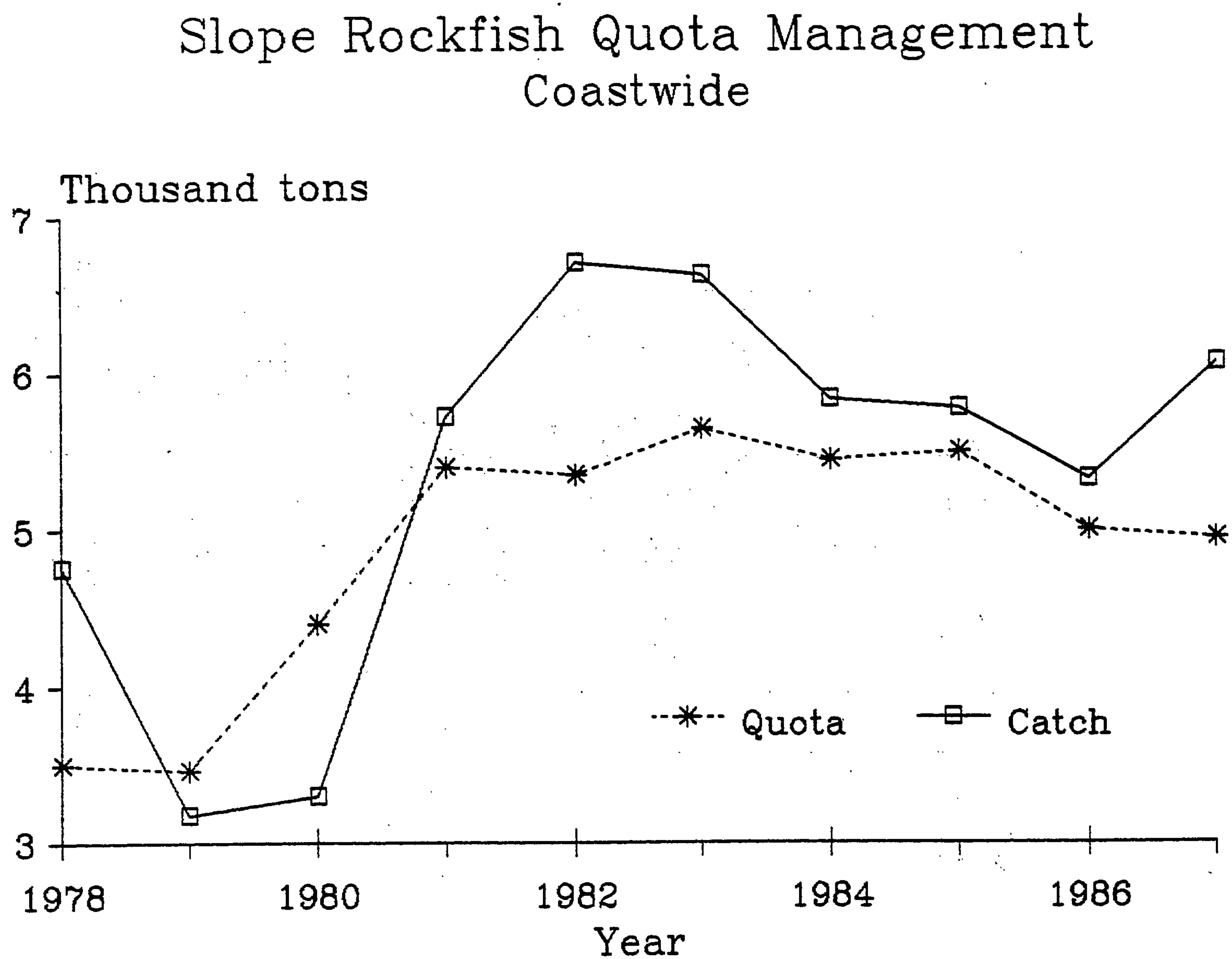


Fig. 9.1. History of slope rockfish quotas and catches (summed coastwide), 1978-1987.

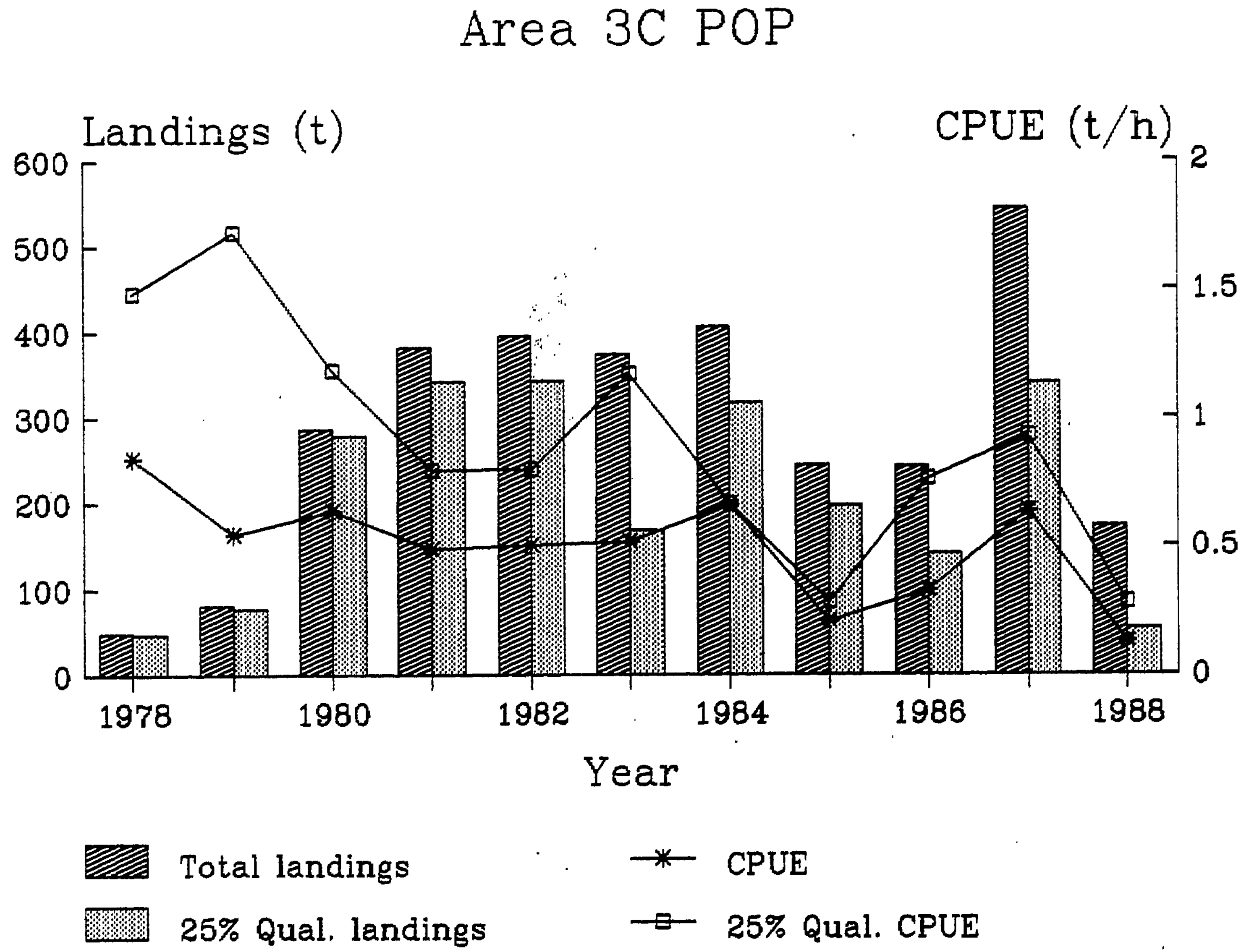


Fig. 9.2. Catch and catch per unit effort (CPUE) for Pacific ocean perch (Sebastes alutus, POP) off southwest Vancouver Island (Area 3C), 1978-1988. Qualified statistics include data where ≥25% of catch was POP.

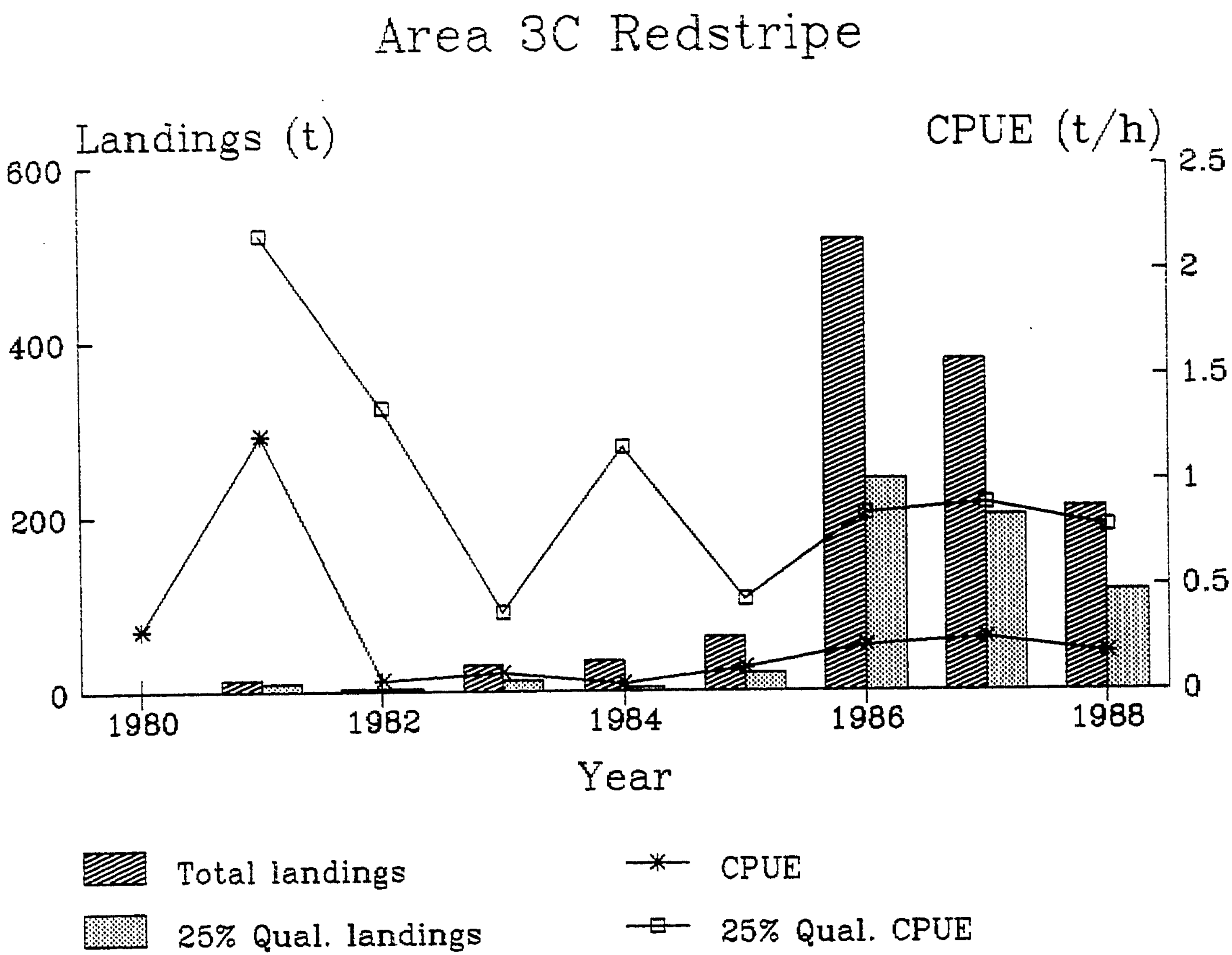


Fig. 9.3. Catch and catch per unit effort (CPUE) for redstripe rockfish (S. proriger) off southwest Vancouver Island (Area 3C), 1980-1988. Qualified statistics include data where ≥25% of catch was redstripe rockfish.

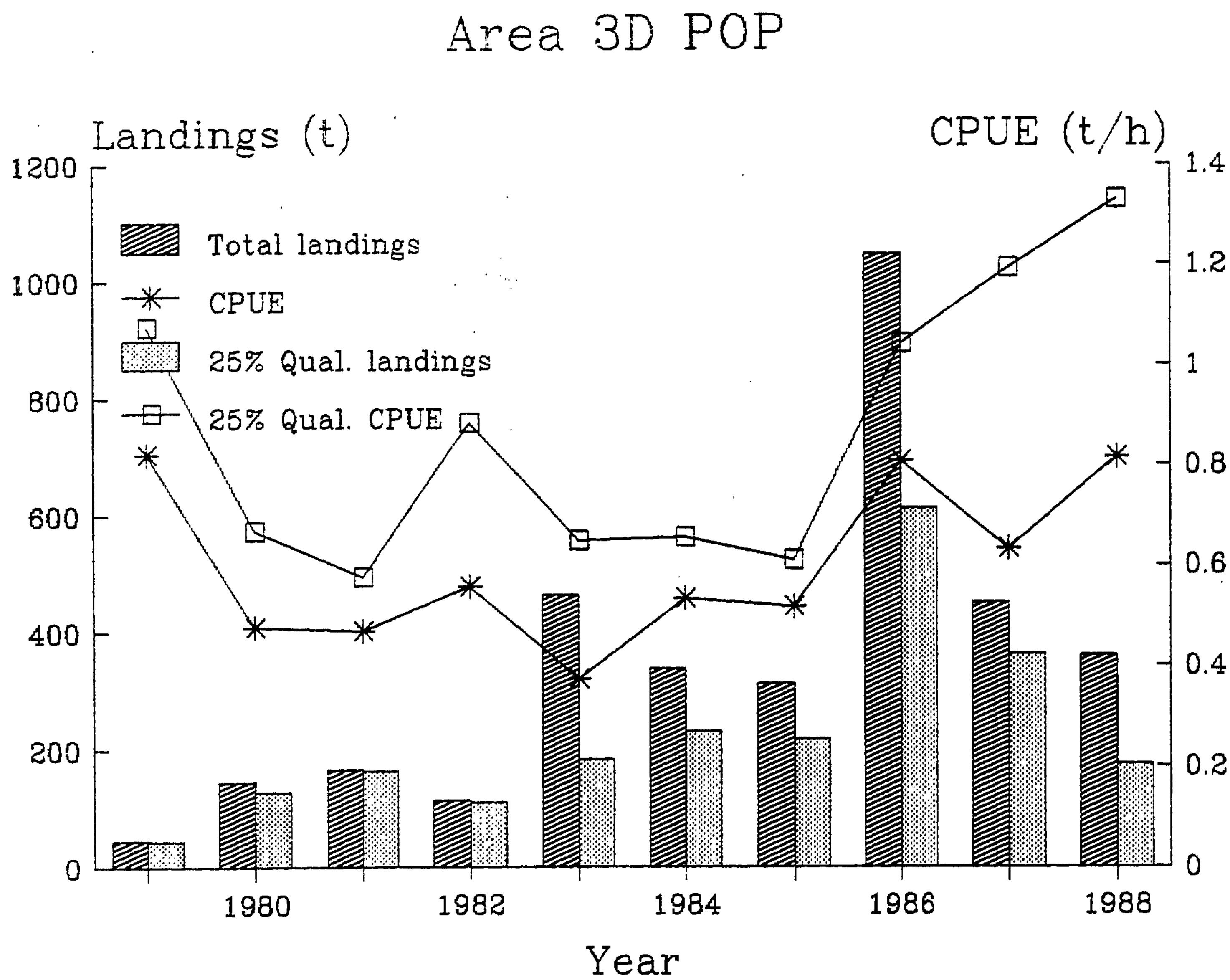


Fig. 9.4. Catch and catch per unit effort (CPUE) for Pacific ocean perch (*S. alutus*, POP) off northwest Vancouver Island (Area 3D), 1979-1988. Qualified statistics include data where ≥25% of catch was POP.

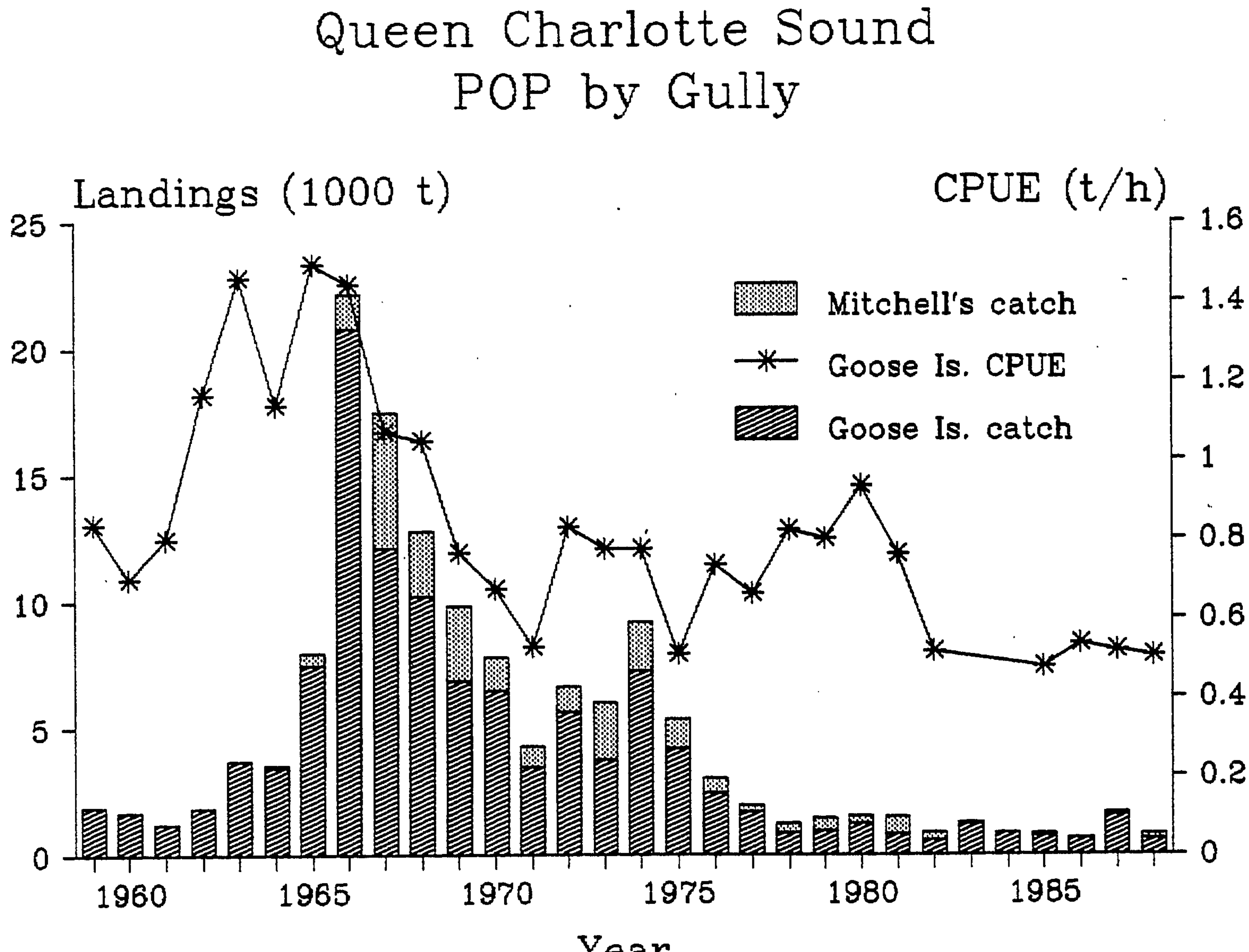


Fig. 9.5. Catch and catch per unit effort (CPUE) for Pacific ocean perch (S. alutus, POP) in Queen Charlotte Sound, 1959-1988, by gully. 1983-1984 winter fishery on spawning females excluded.

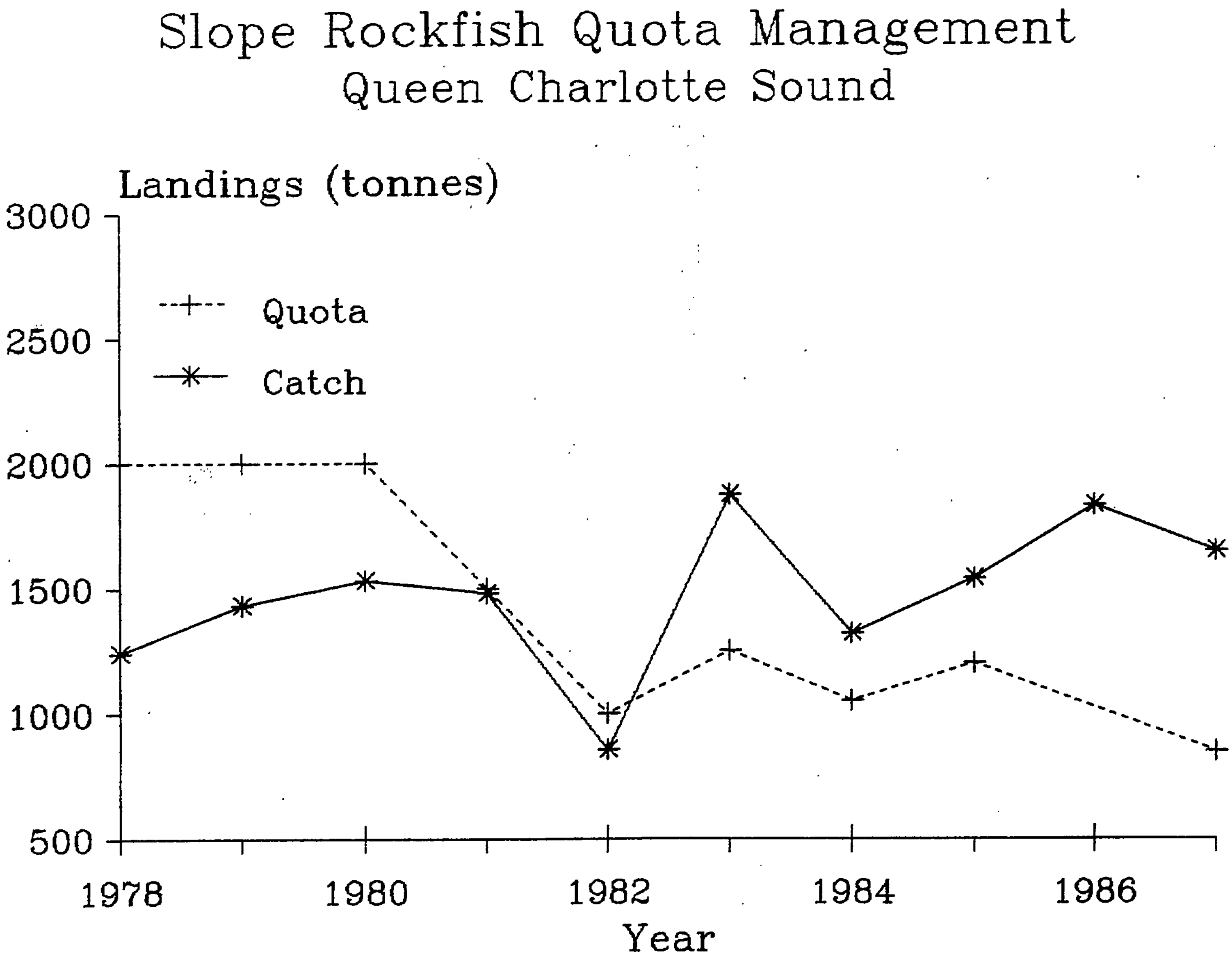


Fig. 9.6. History of slope rockfish quotas and catches in Queen Charlotte Sound, 1978-1987.

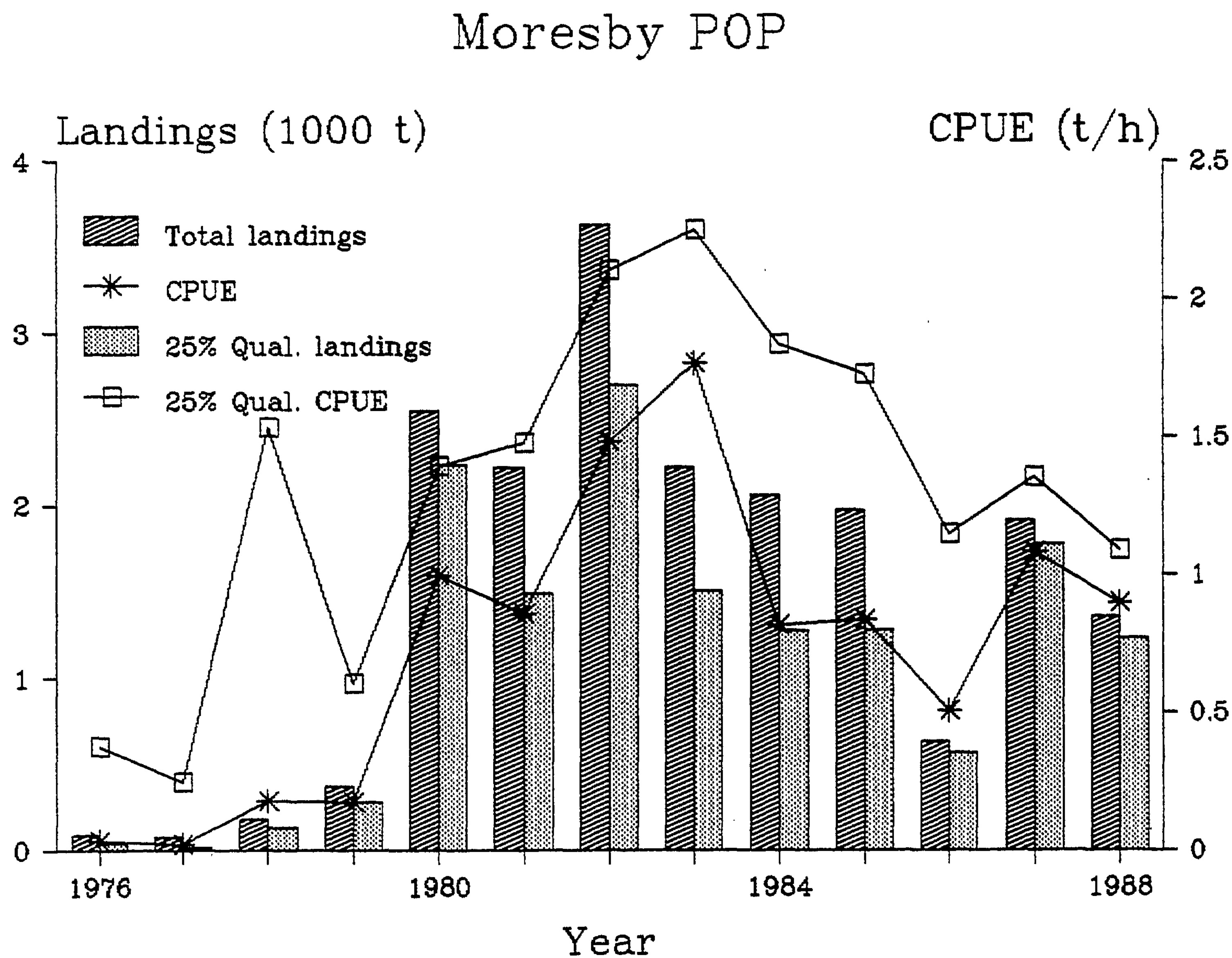


Fig. 9.7. Catch and catch per unit effort (CPUE) for Pacific ocean perch (*S. alutus*, POP) in Moresby Gully, 1976-1988. Qualified statistics include data where ≥ 25% of catch was POP.

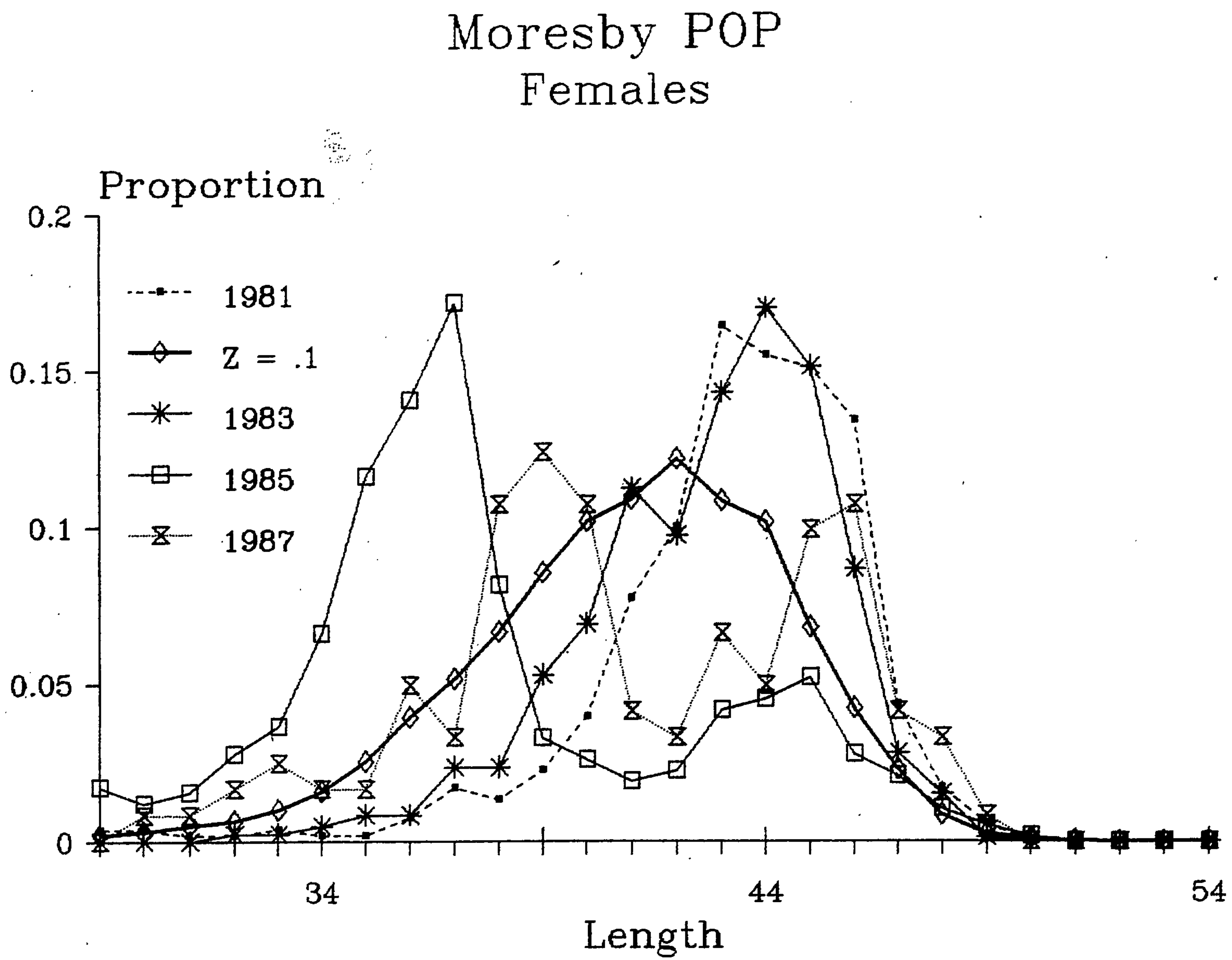


Fig. 9.8. Length frequencies of female Pacific ocean perch (S. alutus, POP) from Moresby Gully in 1981, 1983, 1985, and 1987, compared with the frequency generated using a known mortality rate (Z=0.1).

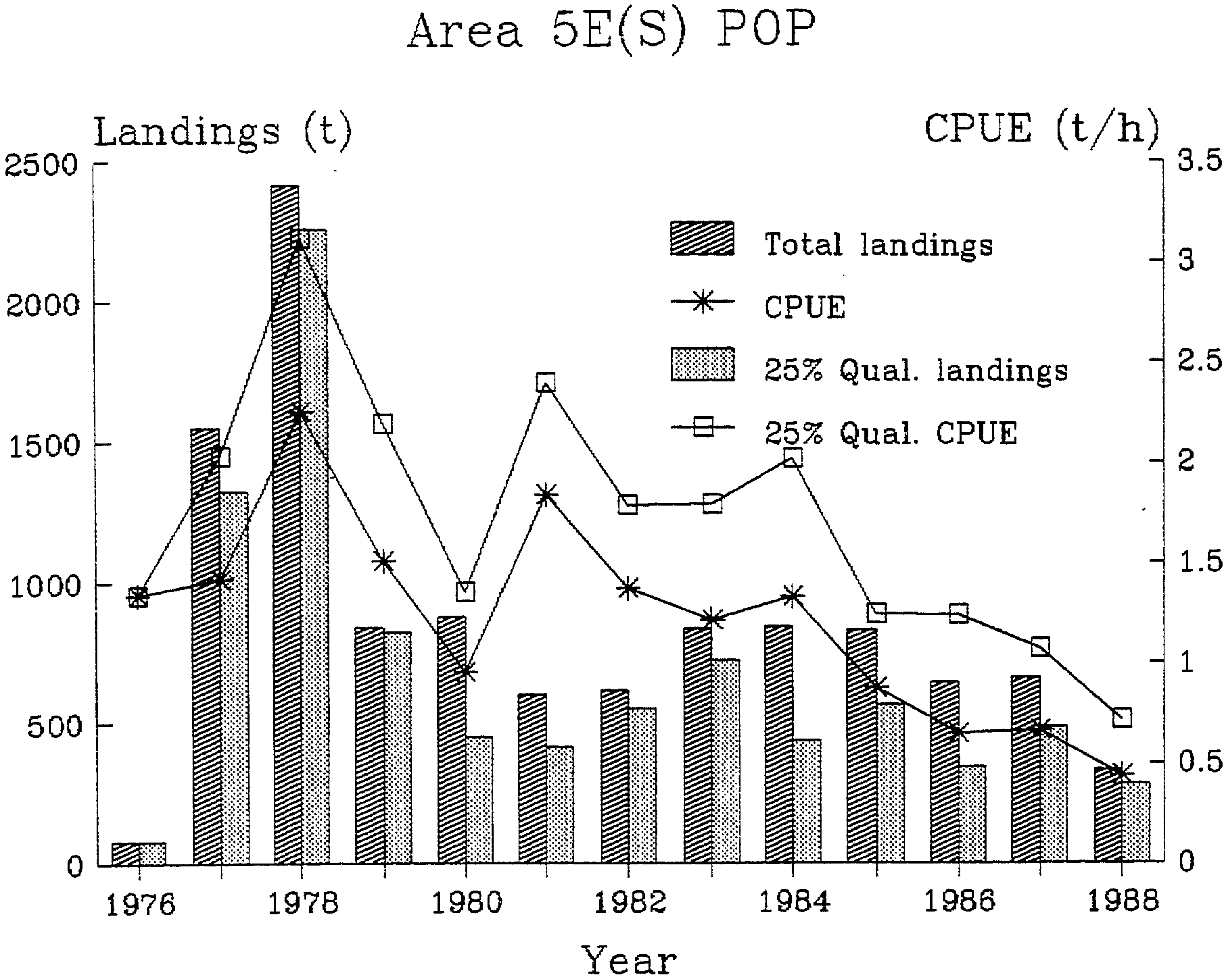


Fig. 9.9. Catch and catch per unit effort (CPUE) for Pacific ocean perch (S. alutus, POP) off the west coast of the Queen Charlotte Islands (Area 5E(S)), 1976-1988. Qualified statistics include data where ≥25% of catch was POP.

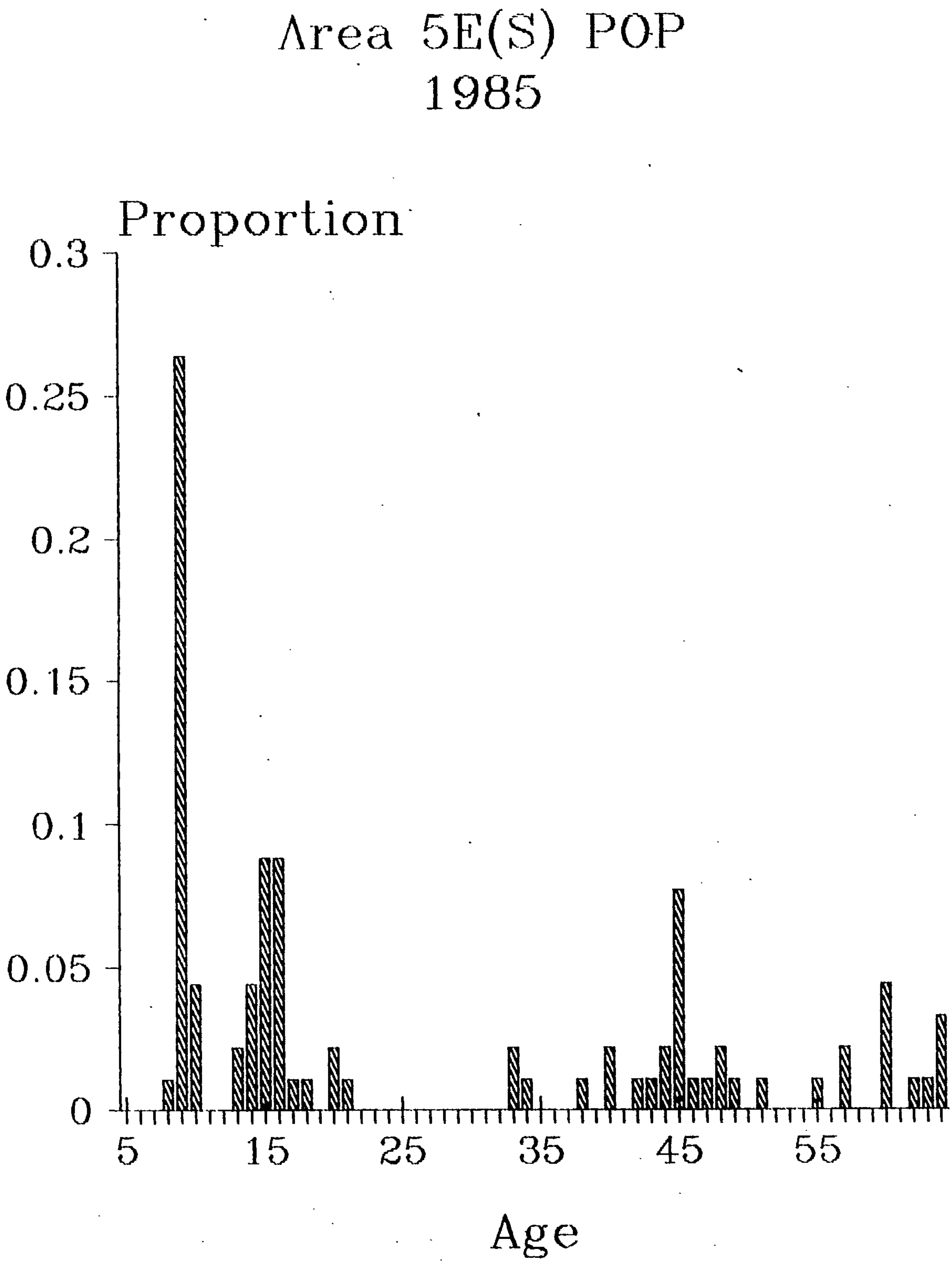


Fig. 9.10. Age frequency of Pacific ocean perch (S. alutus, POP) off the west coast of the Queen Charlotte Islands (Area 5E(S)), 1985.

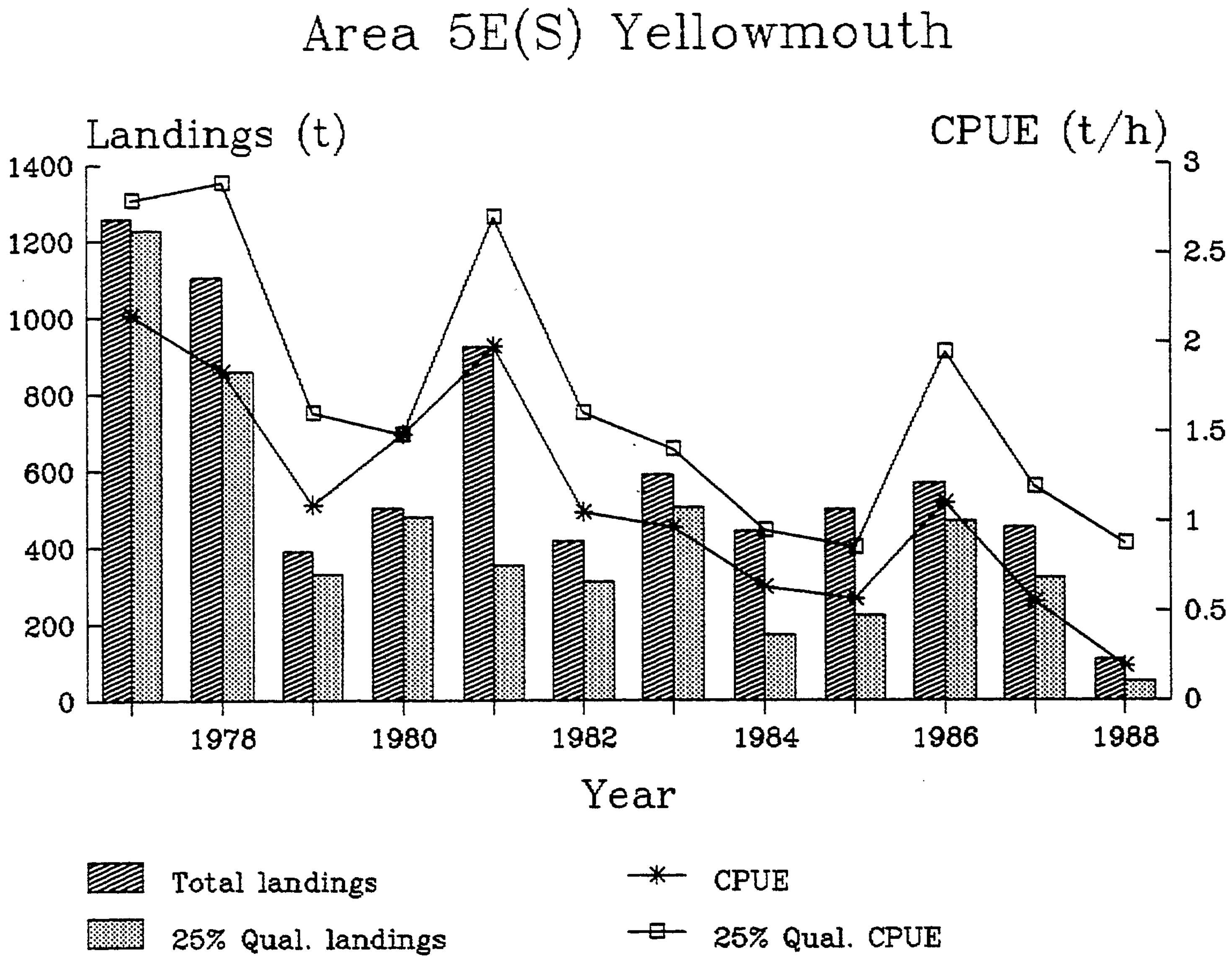


Fig. 9.11. Catch and catch per unit effort (CPUE) for yellowmouth rockfish (S. reedi) off the southwest coast of the Queen Charlotte Islands (Area 5E(S)), 1977-1988. Qualified statistics include data where ≥25% of catch was yellowmouth rockfish.

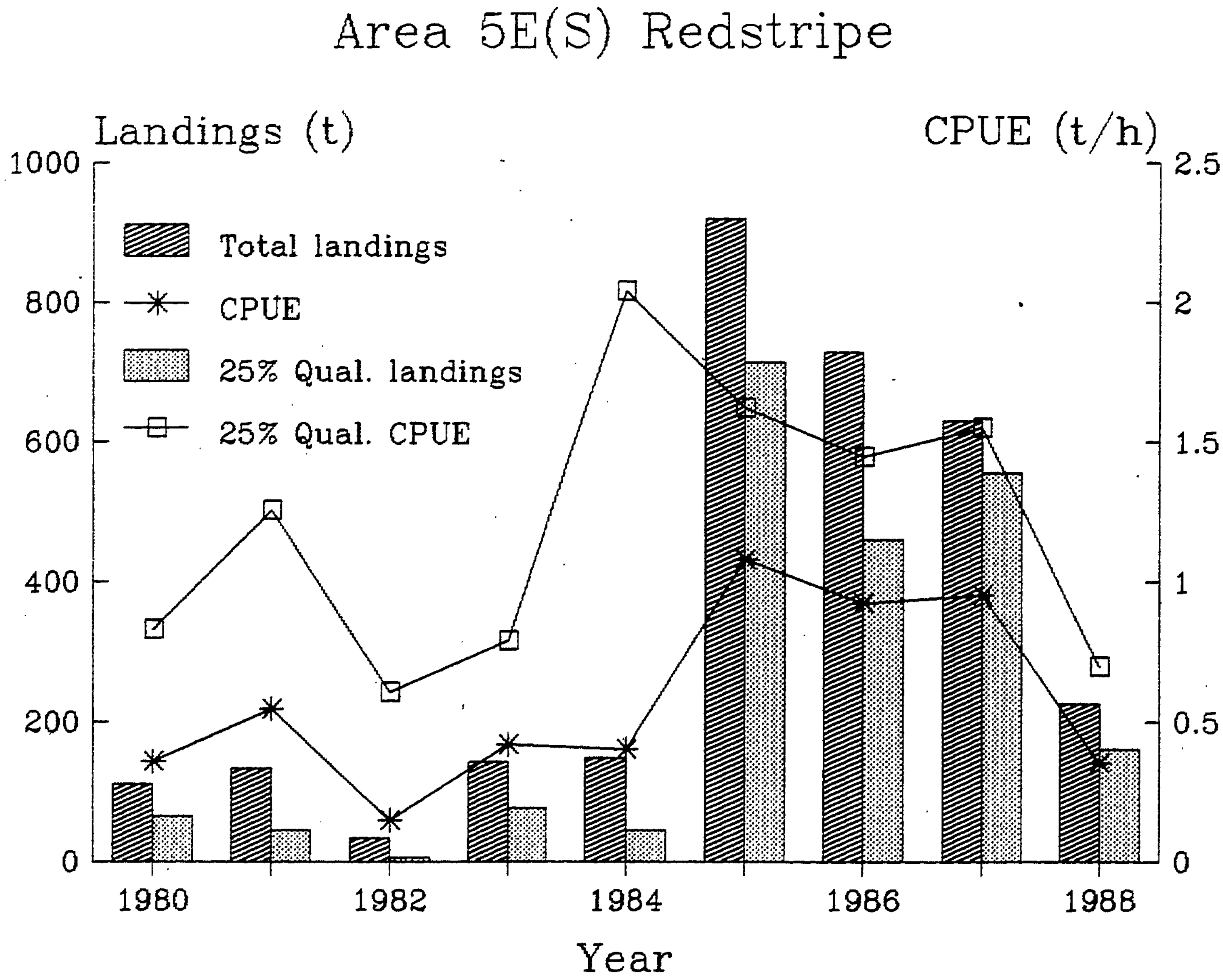


Fig. 9.12. Catch and catch per unit effort (CPUE) for redstripe rockfish (S. proriger) off the southwest coast of the Queen Charlotte Islands (Area 5E(S)), 1980-1988. Qualified statistics include data where ≥25% of catch was redstripe rockfish.

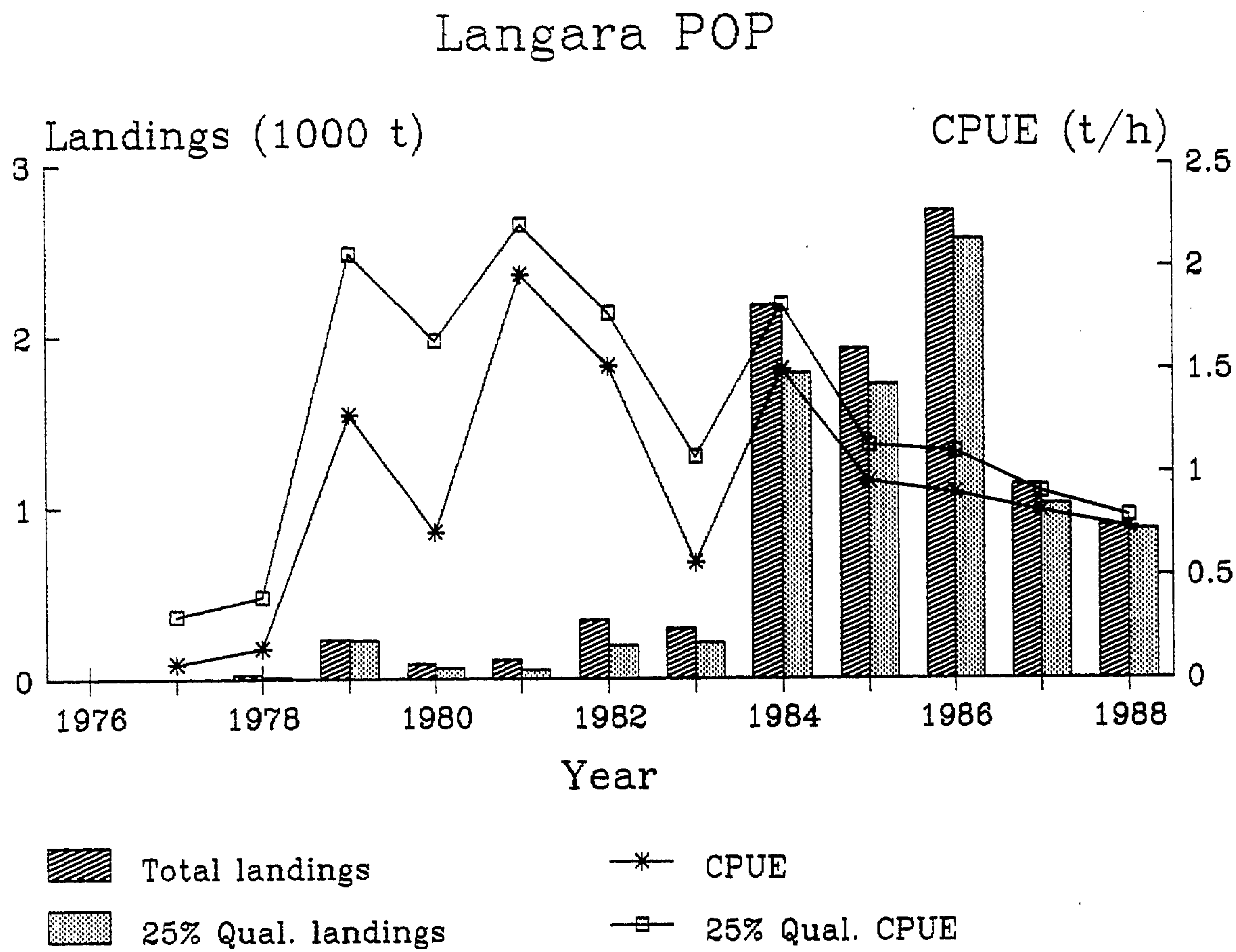


Fig. 9.13. Catch and catch per unit effort (CPUE) for Pacific ocean perch (S. alutus, POP) in Area 5E(N) (Langara Spit), 1976-1988. Qualified statistics include data where ≥25% of catch was POP.

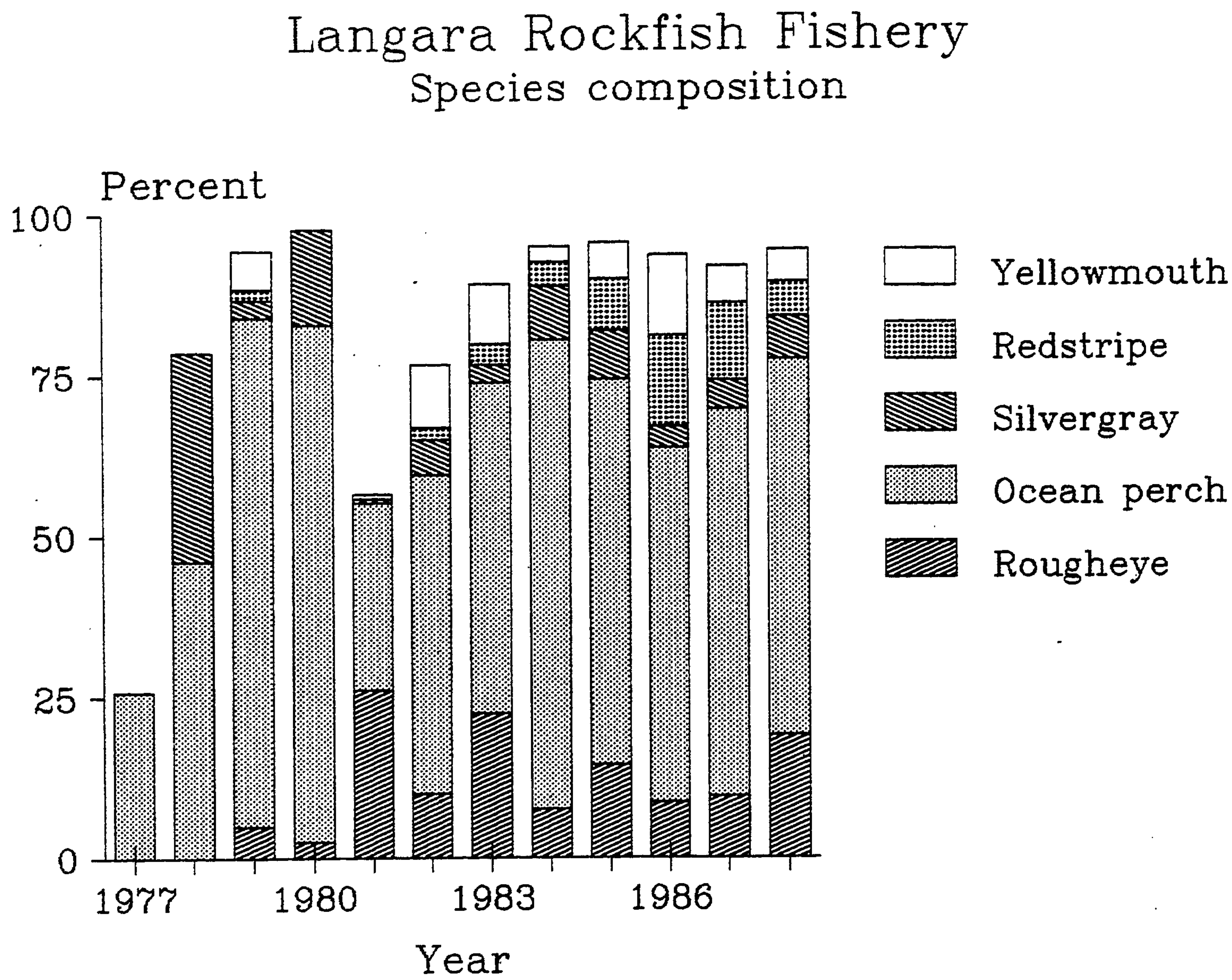


Fig. 9.14. Composition of rockfish catches in the Area 5E(N) (Langara Spit) fishery, by major species, 1977-1988.

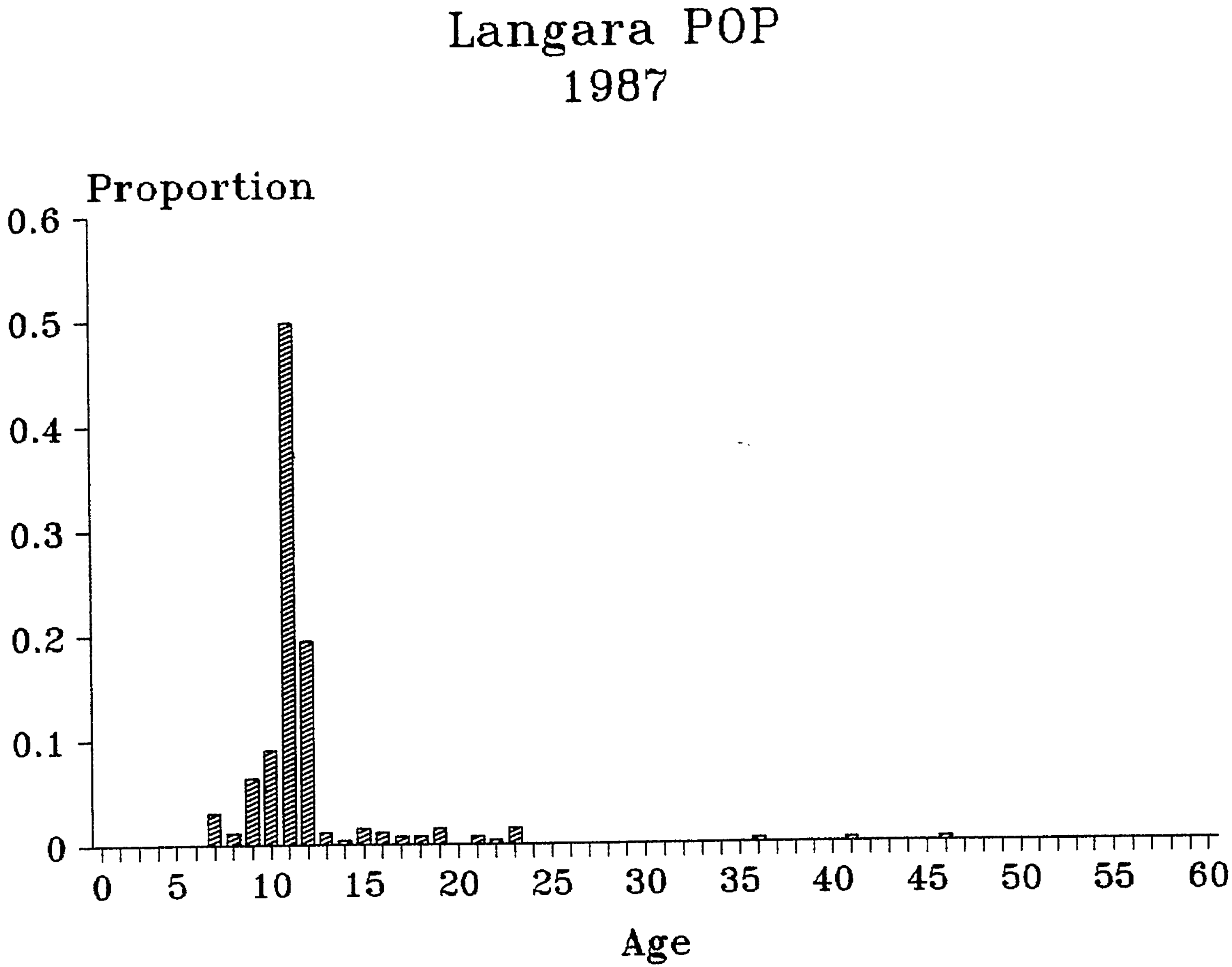


Fig. 9.15. Age frequency of Pacific ocean perch (S. alutus) in the Area 5E(N) (Langara Spit) fishery, in 1987.

10.0. SHELF ROCKFISH (silvergray, yellowtail and canary rockfish) by R. D. Stanley

10.0.1. General Introduction

The assessment approach is unchanged from the previous review of shelf rockfish stocks (Stanley 1988). Recent biological information gathered from the stocks is examined for evidence that the average level of past harvests has had a significant impact on age or size composition. Where possible, we examine for trends over time, however the time series of biological data are short or incomplete for most of these stocks. Readers are referred to the introductions to the slope and shelf rockfish sections in previous documents (Leaman and Stanley 1985, Stanley 1987a, Stanley 1988) for more detailed explanations of the approach.

We present a recommended yield range for each stock, summarized in Table 10.1. The lower limit is a conservative estimate of the sustainable yield. Yields equal to or above the upper limit are unlikely to be sustainable over the long term.

Total landings for shelf rockfish are summarized for 1967-87 in Figure 10.1. The sum of the recommended yield options for shelf rockfish since 1984 for fisheries on the "traditional" grounds is summarized in Figure 10.2. The graph represents either the midpoint of the recommended range or the "sustainable" option depending on the format of the recommendations for the given year. The sum of the quota recommendations has increased over 50% since 1984.

10.0.2. Shelf rockfish stocks

This assessment differs from the previous document by treating the silvergray and canary rockfish fisheries off the west coast of Vancouver Island (3C+3D) as single stocks rather than separating them into north (3D) and south units (3C). While assessment and management by individual stock remains the Department's goal, this has led to a large number of individual quotas and trip limits. These in turn have increased enforcement costs and provided added incentive to fishermen to falsify the fishery information upon which the assessments are based. We have therefore moved away from the ideal biological objective of assessing on as high a spatial resolution as possible, in case they may be separate stocks, to the more practical approach of combining areas unless the data indicate otherwise.

The silvergray and canary rockfish fisheries off the west coast of Vancouver Island were suitable candidates to combine because:

a) the limited amount of biological information that is available from these fisheries does not reasonably support assessment on such a high spatial resolution;
2) the two Areas share the same general history of exploitation;
3) approximately half of the landings of both species come from Area 25 in the centre of the overall region, close to the common border of the two Areas;

4) there is no obvious geographical barrier to movement associated with the boundary;
5) while no tagging studies have been conducted on the adults of these species, results from some tagging in Oregon indicate juvenile canary rockfish can travel extensively (William Barss, pers. comm.).

10.0.3. Catch rate indices

Trends in catch rates were not emphasized in previous shelf rockfish assessments because it was assumed that the number of deliveries from these fisheries was too small and catch rates too variable to generate a precise estimate. We also assumed that catch rate is probably an inaccurate and non-linear correlate of abundance for schooling rockfish.

While we still assume that there are non-linearities in the catch rate-abundance relationship, we examined the variance with bootstrap techniques (Efron 1982) and found that yearly estimates derived from the data have a higher precision than previously perceived. Some examples of the bootstrap-derived 80% confidence limits of the annual estimates are shown in Figures 10.3 and 10.4. The asymmetrical limits were derived from the bias-corrected percentile method proposed by Efron (1982) for small samples. They were calculated using a program published by Buckland (1985).

Estimates of annual catch rates are presented for all major stocks. In each case, the annual estimates were derived from the set of the nominal catch records where catch of the shelf rockfish species during one fishing visit represented at least 25% of the nominal catch (25% qualification). The qualified landings were chosen to select a subset of the database which represented targeted fishing.

This set of qualified observations was then examined with a log linear model which predicts log catch as a linear function of log effort such that:

$$\log(\text{Catch}) = u + \log(\text{Effort}) + H_i + Y_j + \epsilon$$

where u is an overall mean and Hi and Yj are class variables. H_i (i=1,4) represents one of four horsepower classes (0-250 hp, 251-500 hp,501-750 hp, 750+ hp). Y_j (j=1,n) is the derived vector of "n" year effects, which, after transformation, represent the relative impact of YEAR on fishing success and is therefore the annual index of catch rate corrected for variation in horsepower (Gavaris 1980, Kimura 1981). ϵ is the normally distributed error with a mean of zero and constant variance.

The log transformation also permits an exponential relationship between catch and effort on the non-transformed scale. For some fisheries, catch was a non-linear function of effort such that the slope of the regression of log catch on log effort was significantly less than 1.0, ranging between 0.75 and 0.95. The coefficient of less than 1.0 indicates a "diminishing returns" effect with increasing effort during one visit to the grounds.

All other effects being constant, catch rate can be expected to increase from one year to the next if trip limits become progressively smaller. Each trawler would spend less time during one visit to a locale since the lower trip limits would be reached more quickly. The structure of the model permits the removal of this bias.

Horsepower was a statistically significant class variable for every bottom trawl fishery (as was year) although accounting for a small amount of the variance. Horsepower is assumed to be a representative correlate of the composite of factors which determine "fishing power", such as net size and towing speed.

The bootstrap estimates shown earlier were derived prior to standardizing for vessel horsepower so they differ from the figures of stock CPUE shown for the two assessments. Because they were calculated from observations unstandardized for horsepower or the non-linearity of catch and effort, they slightly overestimate the variance.

10.1. Coastwide

10.1.1. Silvergray and canary rockfish

We have not presented coastwide yield options for silvergray or canary rockfish.

10.1.2. Yellowtail rockfish

10.1.2.1. Introduction

This fishery has gained prominence in the last three years as annual landings have increased from less than 1000 t from 1980-1984 to approximately 5000 t in 1986 and 1987 (Table 10.2 and Figure 10.5). While the traditional grounds in Queen Charlotte Sound continue to provide a substantial proportion of the catches, industry has begun exploiting this species off the central coast of Vancouver Island with both midwater and bottom trawl gear. Yellowtail rockfish quotas, which were not attained in the early 1980s, are becoming a major source of contention with industry.

The increased catches off Vancouver Island have also drawn the attention of the U.S. fishing industry. Washington Department of Fisheries (WDF) biologists have traditionally treated yellowtail rockfish from northern Washington and southern B.C. (INPFC Vancouver Area) as one stock. As catches from Canadian waters were traditionally less than 20% of the total landings from this area, U.S. managers did not need to consider the Canadian removals in the context of their management plan. However in 1986 and 1987, the Canadian landings from this area alone were approximately equivalent to the U.S. estimate of sustainable yield for the Vancouver Area stock.

While it is not yet known whether the recent fishery off the central coast of Vancouver Island is exploiting the same biomass as the traditional U.S. fishery to the south off Cape Flattery, U.S. biologists perceive that the combined U.S. and Canadian landings represent excessive exploitation of a unit stock.

In response to the increasing concern over this stock the Canada/U.S. Groundfish Committee instructed its Technical Sub-committee to form a Yellowtail Rockfish Working Group. The group's mandate is to:

1) Review the status of the yellowtail rockfish stocks;
2) Study management strategies for yellowtail rockfish;
3) Review the implications of the various management strategies on the yellowtail stock;
4) Report to the TSC and Parent Committee on their progress.

The first meeting was held in early July. DFO and WDF biologists are working jointly to create one standardized biological data base. It will be complete by May 1, 1989. This database will be used to identify stock boundaries and then used for new stock assessments which will be complete by late summer, 1989.

Included in these developments, WDF has aged 3000 specimens collected from Canadian landings between 1980-1986. It has provided, for the first time, a catch-at-age time series for Canadian landings.

While some biological information is already available, the impact of varying gear type, locality, season and depth, on size and age composition must be resolved with the completed database, before examining for time-dependent changes. The present document is, therefore, an interim assessment pending completion of the new databases.

In the interim, we continue to treat yellowtail rockfish as one stock for the southern and central waters. The northern section of the coast is discussed in Sections 10.5.2. This decision was prompted by the apparently widespread movement of tagged yellowtail rockfish (Stanley 1988).

10.1.2.2. Landing statistics

Canadian trawlers landed 4,183 t of yellowtail rockfish in 1987. If incidental catch rates in the offshore hake fishery were similar to those reported by DFO observers in 1983, this fishery would have accounted for an additional 1114 t. Landings in 1986 and 1987 were the highest on record except for a midwater fishery by Polish vessels in 1975. Mean landings for 1967-1986 were 2365 t.

Standardized bottom trawl catch rates for Queen Charlotte Sound demonstrate a stable pattern while the annual landings have varied widely (Figure 10.6, Table 10.3). The variation in landings was not related to quotas and not believed to have been caused by market conditions and might therefore have been the result of varying availability. The CPUE index does not reflect this variation, implying that catch rate analysis for this species may not be very informative.

Bottom trawl catch rate off the west coast of Vancouver Island appears to be increasing since 1985. Midwater catch rates for this area do not show a trend over the three years of this fishery (Figure 10.7).

10.1.2.3. General biological information

While some new information is available on the size and age composition in yellowtail rockfish landings, trend analysis of these indicators of stock status must await completion of the full database.

10.1.2.4. Condition of the Stock

The increase in landings during the last three years in two regions of the coast supports the contention that the 20-year mean of 2363 t is a minimum estimate of the long-term sustainable yield. The issue then becomes how much additional harvest is sustainable or, what level of harvest should be considered excessive in the long term. Without the databases with which to resolve this threshold analytically, we can only introduce for consideration various points of reference.

Industry has suggested that the current quota of 3500 t can be at least doubled. Their support for an annual yield of 7000 t is to be based on the ease with which they fill their trip limits, the widespread distribution of catches, and the significant discarding of yellowtail rockfish that low trip limits cause. They also suggest that the abundance of this species is highly cyclical in nature and must be fished when possible.

An annual harvest of 7000 t is high relative to historical levels at three times the 20-year mean and therefore an untested exploitation level from either a growth or recruitment overfishing perspective. Annual landings have equalled this level once in the past when the Polish midwater fleet removed over 7000 t in 1975. They returned in 1976 with the same amount of effort but realized only half the catch. Similarly, as noted by a 1987 PSARC reviewer, after undergoing removals of 3951 t annually from 1975-1979, landings from this fishery declined to average less than 800 t for the next 5 years, 1980-1984. The decline was not caused by quota restrictions nor, as far as we know, by market conditions.

A sustainable yield of 7000 t would imply a biomass of 140,000 tons under the assumption that the exploitation rate (5%) should be approximately equal to the natural mortality rate. This suggests a biomass equal to the virgin stock of Pacific ocean perch in Goose Island Gully, prior to the foreign fisheries from 1965-1976. There is no evidence, quantitative or anecdotal, to suggest that yellowtail rockfish stocks are of this magnitude.

Relative to the productivity of other rockfish species, a quota of 7000 t would be equal to the currently recommended sustainable yield for all Pacific ocean perch stocks summed together. Industry has never suggested that yellowtail stocks approach perch stocks in biomass even at the currently reduced levels of the latter species.

Annual catch rates for yellowtail rockfish are low relative to those observed in other targeted rockfish fisheries. Catch rates for Pacific ocean perch or yellowmouth rockfish frequently exceed 2.0 t/hr (Leaman 1988), especially during the "fishing up" phase. Bottom trawl catch rates for yellowtail rockfish in Queen Charlotte Sound have varied between 0.3 and 0.6 t/hr. Bottom and midwater trawl catch rates off the west coast of Vancouver Island have ranged from 0.8 to 2.01 t/hr.

The U.S. fishery for widow rockfish, also a midwater species of rockfish, provides some perspective. This fishery underwent a boom and bust fishery over the last decade (Gunderson 1984). U.S. biologists now recommend a coastwide (California-Oregon-Washington) quota of 12000 t for this species. Yellowtail rockfish may occupy a similar ecological niche, with the widow rockfish distribution centered in Oregon and yellowtail rockfish becoming more dominant in cooler climes to the north, with its centre off the Washington and B.C. coast. If yellowtail rockfish were as productive as widow rockfish, and 50% of the harvest could be assumed to come from B.C. waters, this would yield about 6000 t annually. There is nothing, however, to suggest that yellowtail biomass approaches the productivity of the widow rockfish stock which produced approximately 28,000 t at its peak in 1981, then collapsed.

Based on catch-at age analysis, WDF biologists suggest an Acceptable Biological Catch (ABC) for the INPFC Vancouver Area (including southern B.C. waters) is 1196-3028 t. The range of the ABC for the INPFC-Columbia Area is estimated to be 2000-4000 t. The recommended ABC for the two areas combined is 4000 t. This presumes a catch of 1000 t by Canadian trawlers off the west coast of Vancouver Island.

U.S. biologists suggest that stock biomass has been declining such that the current biomasses of both stocks are between 20 and 35% of the original levels. However, they also estimate that MSY will be achieved at approximately the same proportion of the initial biomass.

These estimates represent a small increase from earlier assessments which had been influenced by the declining biomass estimates of the triennial surveys. The present assessment is based on catch-at-age data derived from the recently completed re-ageing of 25,000 otoliths.

While the U.S. assessments are consistent with the data presented, it must be noted that the effect of these lower levels of biomass on recruitment is unknown, and will remain unknown until cohorts spawned during the current period of reduced biomass begin to be major contributors to the fishery in the 1990s.

The available information indicates that. while a harvest of at least 2363 t is sustainable, there is nothing to support the contention that the B.C. coast could sustain the landings of 7000 t as proposed by industry. There is considerable evidence to suggest that Pacific rockfish stocks cannot sustain the annual harvests that can easily be reached by trawl fleets in the absence of restrictions (Francis 1986). Furthermore, while yellowtail stocks are highly variable in availability, that does not necessarily mean that they are highly variable in abundance. Unlike Pacific cod, they are a typical long-lived and slow-growing rockfish (Figure 10.8). What is caught now has a definite impact on what is caught for the next 20 years, during which time availability can vary widely.

10.1.2.5. Yield options

Managers may wish to regard the 1989 quota as an interim catch limitation pending the full assessment due in August, 1989.

Without consistent trends of declining size or catch rates, there is no sign of growth overfishing. The mean landings for the preceding 20 years, 2365 t, represents a minimum estimate of the sustainable yield. We suggest that the U.S. recommendation of a combined yield of 4000 t for the Oregon, Washington, and southern B.C. coasts serve temporarily as a high-risk estimate for the traditional south and central grounds of B.C. waters. We remind managers that the offshore hake fishery produces a significant incidental catch of yellowtail rockfish.

10.2. Strait of Georgia (Area 4B)

Catches of shelf rockfish are insignificant in the Strait of Georgia.

10.3. West Coast Vancouver Island (Areas 3C+3D)

10.3.1. Silvergray rockfish

10.3.1.1. Landing statistics

Silvergray rockfish landings equalled 604 t in 1987 (Figure 10.9 and Table 10.4). The 20-year mean (1967-1986) is 523 t. Standardized catch rates appear stable since 1984. The catch rate for the first half of 1988 is slightly lower than the estimate for 1987 (Figure 10.9.).

10.3.1.2. General biological information

Samples collected during the 1985-1986 charters (Figures 10.10-10.12) indicate a much younger age of full recruitment than reported earlier (Stanley 1987a). The more recent data indicate that most of the exploited population is between the ages of 10 and 20 in contrast with a range of 20-30 in the 1977-1979 samples. The absence of 10- to 20-year-old fish in the earlier samples tended to increase the estimated age of full recruitment. It also suggests two pulses of recruitment, the most recent being based around 1970 and the earlier centered about 1953.

Regression of $\log_e$ frequency against age indicates instantaneous total mortality rates (Z) for males of 0.136 (ages: 14-33) and 0.155 for females (ages 16-35) (Figure 10.10). The previous assessment, based on length frequency analysis, reported higher estimates (males: 0.15-0.20; females: 0.20-0.30) because it used partial recruitment factors derived from the 1977-1979 ageing information which indicated a much older age for the onset of full recruitment.

The lower estimates of Z derived from the ageing information are still somewhat high relative to our estimates of the instantaneous natural mortality rate of 0.03-0.07 (Archibald et al. 1981). The catch curves also appear to show a steeper aspect (higher Z) over the first 9 years after full recruitment. The estimates of Z for males aged 14-22 in the 1985-86 samples equal 0.172 and for females aged 16-24 equal 0.236. This might indicate that the significantly higher landings since approximately 1976 are deflecting the catch curve downward for the younger cohorts that have been exposed only to the recently increased level of exploitation. It could also be explained by a surge of recruitment.

10.3.1.3. Yield options

While the catch rate increased in 1987, it is lower over the first half of 1988 and still low at 0.69 t/hr as an absolute value for a targeted rockfish. The fishery seems to be focussing on a new pulse of recruitment with no indication yet of whether there are strong year-classes to follow.

The 20-year mean harvest of 523 t remains our minimum estimate of sustainable yield, however if catch rates should fall or if the age distribution becomes more truncated and indicates a higher Z, then we will recommend lower harvests for coming years. Owing to the lower estimates of Z in this assessment, we are less concerned about the stock but still see no evidence to suggest that the stock can support a sustained harvest significantly in excess of historical removals. We therefore recommend a yield range of 400-600 t for Area 3C+3D.

10.3.2. Canary rockfish

10.3.2.1. Landing statistics

Landings were 695 t in 1987 (Figure 10.13, Table 10.5), close to the 20-yr average (1967-1986) of 714 t. Annual catch rates continue to decline since the advent of a significant Canadian domestic fishery (1982-1988).

10.3.2.2. General biological information

No new sample information has been collected or analyzed since the last review. At the suggestion of a trawl skipper, we examined whether canary rockfish landings were inversely related with herring abundance in Area 3C and 3D. He suggested that when herring abundance is low the canary rockfish schools move away from their hard-bottom habitat to more trawlable grounds. We did not observe a negative correlation between DFO estimates of herring abundance in these Areas (Haist et al. 1987) and the landings of canary rockfish. It is noted however, that the recent decline in catch rates of canary rockfish does correspond to a rebuilding in the herring stocks.

10.3.2.3. Yield options

The continued decline in catch rates is of concern and suggests that a harvest in excess of the long-term average of 714 t cannot be sustained. The changes continue to be viewed as "natural" variation in abundance or availability rather than as evidence for over-exploitation, but if the declines continue, managers might be advised to consider more conservative yields. A yield of less than two-thirds of the historical yield would be viewed as conservative. Owing to the continued decline in catch rates, the recommended yield range is 500-700 t, down from the sum of the Area specific ranges recommended for 1988 of 700-1000 t.

10.3.3. Combined yield option for silvergray and canary rockfish for Areas 3C+3D

Managers may wish to combine quotas for the two species in Areas 3C+3D. The annual catch ratio of silvergray to canary rockfish has been 0.87, 1.51 and 1.02 over the last three full years. The ratio of the midpoints of the yield ranges is approximately 0.83. Consequently, a combined quota will be a choice between a minor underage of canary rockfish or a minor overage of silvergray rockfish landings.

10.4. Queen Charlotte Sound (Area 5A+5B)

10.4.1. Silvergray rockfish

10.4.1.1. Landing statistics

The landings of 1228 t in 1987 were the highest ever for the Canadian domestic fishery and second highest overall (Figure 10.14, Table 10.6). Including a total catch of 738 t by Japanese trawlers in the 1970s, the mean annual harvest for 1967-1986 was 679 t.

Catch rate increased in 1987 and was the highest since the Canadian domestic fishery became significant (1978-1987) (Figure 10.14). The standardized catch rate has gradually increased since 1980.

10.4.1.2. General biological information

No new biological information has been made available since the last assessment. Samples were collected in late 1988 and will be aged for use in the next assessment.

10.4.1.3. Yield options

The increasing catch rate indicates that the average of annual landings over the last 20 years can be considered a minimum estimate of sustainable yield. Managers may wish to maintain a harvest in excess of the average value of 679 t. We recommend a harvest range of 700-1000 t. Choice of the upper range would allow managers to experimentally increase harvest by almost 50% in comparison with the previous 20 years. However, managers are advised that there is no evidence to suggest that this stock can sustain this level of harvest.

10.4.2. Canary rockfish

10.4.2.1 Landing statistics

Landings increased to 550 t in 1987 (Figure 10.15, Table 10.7). Annual landings have averaged 357 t between 1967 and 1986. Catch rates are highly variable with no clear trend.

10.4.2.2. General biological information

No new biological information has been collected since the previous assessment.

10.4.2.3. Yield options

The increased catch rate in 1987 is a positive sign, but viewed for the present as a short-term increase in availability. The chronically low nominal catch rates (0.25-0.44 t/hr) from grounds that have been extensively fished for a variety of species for over 30 years suggests that there is a relatively small biomass, probably not capable of supporting significantly more yield than the historical average of 357 t.

This level continues to be a minimum estimate of sustainable yield. Managers may wish to choose a yield option a modest amount higher. We recommend a yield range of 350-500 t.

10.4.3.1. Combined yield option for silvergray and canary rockfish

The catch ratios of silvergray to canary rockfish over the last three years, 2.23, 2.67 and 2.45, have been close to 2.00, the ratio of the midpoints of the recommended yield ranges. A combined quota will probably result in a slightly higher proportion of silvergray rockfish in the catches than might be desired.

10.5. Hecate Strait (Area 5C+5D)

10.5.1. Silvergray rockfish

10.5.1.1. Landing statistics

Landings from this stock, which is presumed to reside in Moresby Gully, became significant in 1977 with the advent of a Pacific ocean perch fishery in the southern part of the gully (Figure 10.16, Table 10.8). Mean landings for 1977-1986 equalled 518 t. Landings in 1987 equalled 763 t.

The annual catch rate (Figure 10.16) does not show a consistent trend since 1979. Catch rates declined in 1987 and again over the first half of 1988.

10.5.1.2. General biological information

Length frequencies from a 1988 sample are shown in Figures 10.17 and 10.18 with expected length frequencies from two theoretical exploitation scenarios (Rasmussen and Stanley 1988). The landings history for this stock can be divided into a period of limited landings from 1977-1983 when they averaged 344 t and the more recent period from 1984-1987, when landings averaged 884 t. For the first scenario, we assumed that the harvest had resulted from relatively high instantaneous fishing mortality rates of 0.15 and 0.30, for the first and second periods of exploitation respectively. The second scenario assumes that the harvests have been small and associated with F values of 0.025 and 0.05. Fishing mortality was assumed to be 0.0 prior to 1977. The natural mortality rates, partial recruitment factors, and growth parameters used in the model are shown in Table 10.9.

The size distributions for both sexes are indicative of older fish and therefore low exploitation rates. The size composition tends to be even larger than that predicted from minimal F values. This may have resulted from an underestimation of "L infinity" of the von Bertalanffy parameterization or underestimating the age of full recruitment. Estimates of these parameters will be updated in subsequent assessments.

10.5.1.3. Yield options

The sustainable yield option was raised from 300 to 600 t in 1983, prior to any effective quota restrictions, under the suspicion that a significant biomass might be present. We suggested that the option be maintained at that level for 3-5 years while monitoring for signs of the fishery's impact.

The one sample of older fish tends to contradict the recent decline in catch rate therefore it cannot be demonstrated that the mean harvest of 518 t since 1977 has had a significant impact. We assume therefore that 518 t is a minimum estimate of the sustainable yield. Managers may continue to permit yields significantly in excess of this level, however, the short-term decline in CPUE is a source of concern and, because of this, the recommended yield range of 400-1000, suggested in the last assessment, is changed to 500-800 t. We suggest that a harvest of 800 t annually be considered as a high risk yield.

10.5.2. Yellowtail rockfish

The yellowtail rockfish fishery in Hecate Strait continues to be insignificant, only 104 t were landed in 1987. Managers may wish to choose a ceiling yield option as they have in the past.

10.5.3. Canary rockfish

The canary rockfish fishery in Hecate Strait continues to be insignificant, only 107 t were landed in 1987. Managers may wish to choose a ceiling yield option as they have in the past.

10.6. West Coast of Queen Charlotte Islands (Area 5E)

10.6.1. Silvergray rockfish

10.6.1.1. Landing statistics

The silvergray rockfish fisheries off the west coast of the Queen Charlotte Islands continue to be minor and incidental to the fisheries for Pacific ocean perch (Table 10.10). Less than 15% of the reported catches meet a 25% qualification criteria. Landings declined to 78 t and 105 t in the southern and northern areas respectively.

No restrictions have been placed on catches of shelf rockfish north of 54° since the beginning of the experimental open fishing in this area in late 1983. Over this period, landings and catch rates (0% qualification) have declined steadily to where the catch rate for the first half of 1988 is only 30% of the rate observed in 1984. It appears that there was only a modest biomass present at the beginning of the experiment and that it could not sustain an average harvest of 232 t for even 3 years.

10.6.1.2. Yield options

In spite of the declining catch rates, managers may choose not to impose any landing restrictions. The fishery is largely incidental to slope rockfish fishing, so trip limits will not reduce catches, only increase the amount of discarding. If the trend in catch rates is indicative of a decline in stock biomass, it provides managers with some insight as to the productivity of this species.

10.6.2. Yellowtail and canary rockfish

These fisheries remain insignificant. Only 46 t of yellowtail rockfish and 13 t of canary rockfish were reported to have come from this area in 1987. Managers may wish to continue with guideline quotas as in past years.

Table 10.1. Mean harvest (1967-1986), 1987 landings, status indicators, and suggested yield ranges for shelf rockfish.

Area	Species	Mean harvest (t)	1987 landings (t)	Status indicators: Small size/ low ages	Status indicators: Declining size/age	Status indicators: Catch rate	Suggested yield range (t)
3C+3D+5A+5B	yellowtail	2365	4183[a]	unkn.	unkn.	stable or increasing	2000-4000
3C+3D	silvergray	532	604	yes	yes	stable	400-600
3C+3D	canary	695	714	unkn.	unkn.	declining	500-700
5A+5B	silvergray	679	1224	unkn.	unkn.	increasing	700-1000
5A+5B	canary	357	560	unkn.	unkn.	stable	350-500
5C+5D	silvergray	518	763	no	no	declining	500-800
	yellowtail	minor	104	(-----------	u	---------------)	(500)
	canary	minor	107	(-----------	u	---------------)	(500)
5E-N	silvergray	minor	85	unkn.	unkn.	declining	b
5E-S	silvergray	minor	113	unkn.	unkn.	unkn.	b
	yellowtail	minor	46	unkn.	unkn.	unkn.	(500)
5E	canary	minor	13	unkn.	unkn.	unkn.	(500)

[a]Does not include catch in offshore hake fishery.
[b]Recommended no trip limits.

Table 10.2. Yellowtail rockfish landings (t) from B.C. waters, 1967-1988. ("bt" = bottom trawl and "mw" = midwater trawl.)

	West coast Vancouver Island[a]					Q.C. Sound[b]			Hecate Strait, Dixon Entrance, W. coast Q.C. Island		
Year	Can. (bt)	Can. (mw)	U.S. (bt)	Poland (mw)	Offshore hake	Can. (bt)	Can. (mw)	U.S. (bt)	Can. (bt)	Can. (mw)	Total
1967	4	0	103			19	0	996	1	0	1,123
1968	0	0	23			23	0	278	0	0	324
1969	45	0	243			86	0	2,174	15	0	2,563
1970	29	0	154			160	14	2,629	17	0	3,003
1971	18	0	128			225	0	1,955	51	0	2,377
1972	14	0	76			692	3	2,735	29	0	3,549
1973	26	0	23			516	5	2,735	1	0	3,324
1974	20	0	117			150	14	809	47	1	1,158
1975	13	0	89	6,700		317	97	303	57	0	7,576
1976	86	0	72	2,339		590	38	363	164	31	3,683
1977	77	177	300			762	251	1,242	301	2	3,112
1978	83	13	169		120	1,445	201	397	273	111	2,812
1979	67	66	132		187	1,312	23	192	469	122	2,570
1980	60	8	45		142	471	0	81	124	42	973
1981	44	0	10		120	281	0		86	12	553
1982	134	1			320	280	13		87	12	847
1983	44	9			347	308	15		58	14	795
1984	42	0			350	177	18		86	30	703
1985	353	38			264	341	0		80	129	1,205
1986	1,178	2,354			594	822	0		92	12	5,052
1987	1,039	1,451			1,114	1,441	101		150	1	5,297
1988[c]	966	633				1,052	577		99	0	3,327

[a]Includes landings from Strait of Juan de Fuca.
[b]Excludes landings from Moresby Gully.
[c]To June 30, 1988.

Table 10.3. CPUE indices (t/hr) and total effort (h) for the principal fisheries of yellowtail rockfish in B.C. waters[a].

	W.C. Vancouver Island						Q.C. Sound		
	Bottom trawl			Midwater trawl			Bottom trawl		
	Effort[b]	Nominal CPUE[b]	Standardized CPUE[c]	Effort[b]	Nominal CPUE[b]	Standardized CPUE[d]	Effort[b]	Nominal CPUE[b]	Standardized CPUE[c]
1972	-	-	-	-	-	-	1102	0.53	0.53
1973	-	-	-	-	-	-	936	0.53	0.44
1974	-	-	-	-	-	-	270	0.35	0.30
1975	-	-	-	-	-	-	829	0.32	0.36
1976	-	-	-	-	-	-	1347	0.29	0.38
1977	-	-	-	-	-	-	2449	0.25	0.28
1978	-	-	-	-	-	-	2493	0.51	0.45
1979	-	-	-	-	-	-	1759	0.68	0.44
1980	-	-	-	-	-	-	993	0.38	0.37
1981	-	-	-	-	-	-	570	0.33	0.41
1982	-	-	-	-	-	-	639	0.28	0.30
1983	-	-	-	-	-	-	428	0.44	0.42
1984	-	-	-	-	-	-	441	0.24	0.31
1985	322	0.80	0.80	-	-	-	557	0.45	0.36
1986	1013	0.63	0.92	1036	2.01	2.01	1341	0.46	0.50
1987	765	0.73	1.09	1201	1.06	1.00	1958	0.38	0.35
1988[e]	491	0.97	1.40	613	1.09	1.37	1418	0.50	0.53

[a]Time series of catch rate indices initiated once landings became significant (>250 t).
[b]25% qualification for interviewed landings.
[c]Standardized for horsepower class and a non-linear relationship of catch and effort.
[d]Standardized for horsepower class.
[e]To June 30, 1988.

Table 10.4. Area 3C and 3D landings (t), effort (h), and nominal CPUE (t/h) of silvergray rockfish 1967-1988.

Year	Nat.	Total landings[a]	Interviewed Landings[b]	Interviewed Effort[c]	Interviewed CPUE	Interviewed (25% qual.) Landings	Interviewed (25% qual.) Effort	Interviewed (25% qual.) CPUE
1967	USA	196	195	4471	.04	-	-	-
1968	USA	205	200	2928	.07	-	-	-
1969	USA	334	334	3647	.09	-	-	-
1970	Can	2	2	119	.02	1	1	1.00
	USA	371	358	4785	.07	-	-	-
1971	Can	5	5	48	.10	2	2	1.00
	USA	161	161	3009	.05	-	-	-
1972	USA	442	442	2969	.15	-	-	-
1973	USA	227	227	2619	.09	-	-	-
1974	Can	1	1	12	.08	-	-	-
	USA	236	235	2666	.09	-	-	-
1975	Can	4	4	44	.09	0	0	-
	USA	113	113	2938	.04	-	-	-
1976	Can	5	5	9	.55	0	0	-
	USA	326	326	3945	.08	-	-	-
1977	Can	28	28	516	.05	17	28	.61
	USA	1035	1035	5427	.19	-	-	-
1978	Can	22	22	284	.08	1	8	.13
	USA	972	972	6244	.16	-	-	-
1979	Can	22	22	131	.17	13		
	USA	1248	1248	4812	.26	-	-	-
1980	Can	23	23	214	.11	9	15	.60
	USA	764	764	3848	.20	-	-	-
1981	Can	15	15	77	.19	9	24	.38
	USA	284	284	5424	.05	-	-	-
1982	Can	129	129	388	.33	124	126	.99
	USA	60	60	11,819	.01	-	-	-
1983	Can	646	646	1455	.44	390	837	.47
1984	Can	570	335	1644	.20	237	658	.36
1985	Can	921	349	1242	.28	273	521	.52
1986	Can	1093	690	3135	.22	474	906	.52
1987	Can	604	516	2199	.24	323	458	.72
1988[d]	Can	380	267	1357	.20	204	286	.71

[a]U.S. total landings equals Washington and Oregon combined.
[b]U.S. interviewed landings from Washington only (Tagart and Kimura 1982).
[c]U.S. interviewed effort represents total rockfish effort from Washington o (Tagart and Kimura 1982).
[d]To June 30, 1988.

Table 10.5. Area 3C and 3D landings (t), effort (h), and nominal CPUE (t/h) of canary rockfish.

Year	Nat.	Total landings[a]	Interviewed			Interviewed (25% qual.)		
			Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	USA	578	575	4471	.13	-	-	-
	Can	4	4	41	.10	1	8	.12
1968	USA	938	902	2838	.32	0	0	-
	Can	19	19	157	.12	10	12	.83
1969	USA	779	746	3647	.20	-	-	-
	Can	46	46	266	.17	42	127	.33
1970	USA	990	938	4785	.20	-	-	-
	Can	18	18	96	.19	17	89	.19
1971	USA	1011	962	3009	.32	-	-	-
	Can	66	66	533	.12	52	235	.22
1972	USA	294	292	2969	.10	-	-	-
1973	USA	493	490	2619	.19	-	-	-
1974	Can	26	26	461	.06	15	26	.58
	USA	607	605	2666	.23	-	-	-
1975	Can	14	14	186	.08	9	10	.90
	USA	658	658	2938	.22	-	-	-
1976	Can	193	193	822	.23	157	207	.76
	USA	395	395	3945	.10	-	-	-
1977	Can	196	196	1808	.12	109	147	.74
	USA	358	358	5427	.07	-	-	-
1978	Can	68	68	434	.16	40	56	.71
	USA	1063	1063	6244	.17	-	-	-
1979	Can	122	114	680	.17	94	175	.54
	USA	315	315	4812	.07	-	-	-
1980	Can	126	126	1058	.12	109	204	.53
	USA	477	477	3848	.12	-	-	-
1981	Can	66	66	929	.07	42	84	.50
	USA	249	249	5424	.05	-	-	-
1982	Can	316	316	1415	.22	286	309	.93
	USA	133	133	11,819	.01	-	-	-
1983	Can	853	647	1723	.38	593	1049	.57
1984	Can	1189	947	1079	.46	916	1170	.78
1985	Can	903	611	1897	.32	557	779	.72
1986	Can	722	529	2841	.19	344	651	.53
1987	Can	695	600	2535	.24	462	670	.69
1988[d]	Can	255	170	1389	.12	98	274	.36

[a] U.S. total landings equals Washington and Oregon combined.
[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).
[c] U.S. interviewed effort represents total rockfish effort from Washington only (Tagart and Kimura 1982).
[d] To June 30, 1988.

Table 10.6. Area 5A and 5B landings (t), effort (h), and CPUE (t/h) of silvergray rockfish, 1967-88.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	CAN	87	89	539	.17	63	200	.32
	USA	397	396	9,431	.04	-	-	-
1968	CAN	78	78	644	.12	37	109	.34
	USA	933	822	8,488	.10	-	-	-
1969	CAN	78	78	1188	.07	28	152	.18
	USA	1,291	1276	13,557	.09	-	-	-
1970	CAN	14	14	287	.05	6	29	.21
	USA	189	189	9,264	.02	-	-	-
1971	CAN	16	16	331	.05	6	66	.09
	USA	521	512	7,137	.07	-	-	-
1972	CAN	54	54	654	.08	21	108	.19
	USA	251	251	9,224	.03	-	-	-
1973	CAN	40	40	328	.12	33	70	.47
	USA	189	189	9,625	.02	-	-	-
1974	CAN	45	45	412	.11	9	12	.75
	USA	377	377	8,797	.04	-	-	-
1975	CAN	31	31	479	.06	19	61	.31
	USA	306	306	5,179	.06	-	-	-
1976	CAN	172	172	1,914	.09	82	224	.37
	USA	443	443	4,620	.10	-	-	-
1977	CAN	198	198	2,462	.08	123	320	.38
	USA	440	440	5,165	.09	-	-	-
1978	CAN	723	723	4,049	.18	468	1,069	.44
	USA	57	57	909	.06	-	-	-
1979	CAN	629	629	3,885	.16	429	1,225	.35
	USA	298	298	1,696	.18	-	-	-
1980	CAN	629	625	3,681	.17	495	1,538	.32
	USA	147	147	1,146	.13	-	-	-
1981	CAN	415	415	2,120	.20	340	808	.42
1982	CAN	618	597	4,099	.15	430	1,208	.36
1983	CAN	524	477	3,348	.14	323	1,073	.30
1984	CAN	982	718	3,481	.21	642	1,948	.33
1985	CAN	997	724	3,555	.20	611	1,860	.33
1986	CAN	700	564	3,812	.15	388	1,314	.30
1987	CAN	1224	1083	6,509	.17	641	1,596	.40
1988[d]	CAN	410	350	2,581	.14	226	528	.43

[a]U.S. total landings equals Washington and Oregon combined.
[b]U.S. interviewed landings from Washington only (Tagart and Kimura 1982).
[c]U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).
[d]To June 30, 1988.

Table 10.7. Area 5A and 5B landings (t), effort (h), and CPUE (t/h) of canary rockfish, 1967-88.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	CAN	41	41	535	.08	13	32	.41
	USA	216	215	9,431	.02	-	-	-
1968	CAN	49	49	576	.09	31	78	.40
	USA	1,034	937	8,488	.11	-	-	-
1969	CAN	67	67	733	.09	37	110	.34
	USA	464	418	13,557	.03	-	-	-
1970	CAN	6	6	80	.08	4	12	.33
	USA	220	220	9,264	.02	-	-	-
1971	CAN	18	18	329	.05	6	8	.75
	USA	207	183	7,137	.03	-	-	-
1972	USA	61	61	9,224	.01	-	-	-
1973	CAN	29	29	119	.24	23	80	.29
	USA	298	298	9,625	.03	-	-	-
1974	CAN	3	3	81	.04	1	7	.14
	USA	257	257	8,797	.03	-	-	-
1975	CAN	23	23	403	.06	15	17	.88
	USA	189	189	5,179	.04	-	-	-
1976	CAN	92	92	1,558	.06	16	49	.33
	USA	447	447	4,620	.10	-	-	-
1977	CAN	121	121	2,356	.05	53	192	.28
	USA	288	288	5,165	.06	-	-	-
1978	CAN	263	263	2,692	.10	101	242	.42
	USA	8	8	909	.01	-	-	-
1979	CAN	308	308	3,070	.10	211	582	.36
	USA	62	62	1,696	.04	-	-	-
1980	CAN	276	276	2,157	.13	198	451	.44
	USA	88	88	1,146	.08	-	-	-
1981	CAN	144	144	1,636	.09	69	201	.35
1982	CAN	358	330	3,203	.10	210	706	.30
1983	CAN	343	299	2,851	.11	152	454	.33
1984	CAN	507	321	2,506	.13	228	686	.33
1985	CAN	391	281	2,823	.10	162	553	.29
1986	CAN	262	211	2,931	.07	64	253	.25
1987	CAN	560	510	4,248	.12	245	572	.43
1988[d]	CAN	234	211	2,398	.09	94	322	.29

[a]U.S. total landings equals Washington and Oregon combined.
[b]U.S. interviewed landings from Washington only (Tagart and Kimura 1982).
[c]U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).
[d]To June 30, 1988.

Table 10.8. Area 5C and 5D landings[b] (t), effort (h), and CPUE (t/h) of silvergray rockfish, 1971-88.

Year	Total landings	Interviewed			Interviewed (25% qual.)		
		Landings	Effort	CPUE	Landings	Effort	CPUE
1971	34	34	229	.15	24	121	.20
1972	61	61	232	.26	44	54	.81
1973	10	10	147	.07	-	-	-
1974	13	13	64	.20	11	34	.33
1975	11	11	190	.06	4	5	.79
1976	118	118	1,440	.08	55	414	.13
1977	232	232	2,019	.12	142	468	.30
1978	235	235	1,413	.17	177	301	.59
1979	429	429	3,029	.14	285	701	.41
1980	346	344	1,938	.18	186	396	.47
1981	456	415	1,762	.24	343	311	1.10
1982	259	238	1,799	.13	149	212	.70
1983	451	348	1,108	.31	289	337	.86
1984	647	383	2,081	.18	315	710	.44
1985	1,043	729	2,133	.34	578	458	1.26
1986	1,082	1,056	1,796	.59	1,024	927	1.10
1987	763	632	1,928	.33	531	592	0.90
1988[a]	548	548	1,667	.33	427	648	.66

[a]To July 10, 1988.
[b]No significant history of U.S. fishing on this stock.

Table 10.9. Growth and partial recruitment factors used for predicting the length distributions of silvergray rockfish under different exploitation scenarios.

Growth Parameters	Males	Females
L	54.90	60.10
k	0.101	0.069
t_o	-4.13	-8.46
α^1 - standard deviation of mean length about predicted mean length	0.26	0.26
α^2 - standard deviation of individual length about mean length	2.67	3.00
Partial Recruitment Factors		
Age		
8	0.12	0.03
9	0.29	0.07
10	0.48	0.16
11	0.76	0.28
12	0.93	0.40
13	0.98	0.54
14	1.00	0.69
15	1.00	0.94
16	1.00	1.00
17+	1.00	1.00

Table 10.10. Area 5E-N and 5E-S landings (t), effort (h), and CPUE (t/h) of silvergray rockfish, 1977-88.

Year		Total landings	Interviewed			Interviewed (25% qual.)		
			Landings	Effort	CPUE	Landings	Effort	CPUE
1977	S	20	20	136	.15	0	0	-
	N	0	0	0	-	0	0	-
1978	S	124	124	572	.22	56	105	.53
	N	16	16	91	.18	16	21	.76
1979	S	44	44	189	.23	30	19	1.58
	N	8	8	95	.08	0	0	-
1980	S	104	104	246	.42	81	97	0.84
	N	15	15	17	.91	15	17	.91
1981	S	57	22	74	.30	12	12	1.00
	N	2	2	10	.20	0	0	-
1982	S	27	22	152	.14	7	4	1.75
	N	38	30	56	.54	27	9	3.00
1983	S	130	130	414	.31	44	58	.76
	N	16	11	108	.10	1	1	1.00
1984	S	78	71	246	.29	47	104	.45
	N	248	233	731	.32	61	33	1.88
1985	S	212	175	466	.38	85	142	.60
	N	245	245	1258	.20	158	219	.72
1986	S	295	245	601	.41	112	154	.73
	N	172	170	1772	.10	35	39	.89
1987	S	113	102	586	.17	30	53	.58
	N	85	83	1004	.08	6	21	.30
1988[a]	S	78	77	642	.12	19	21	.92
	N	105	87	1080	.08	21	42	.52

[a]To June 30, 1988.

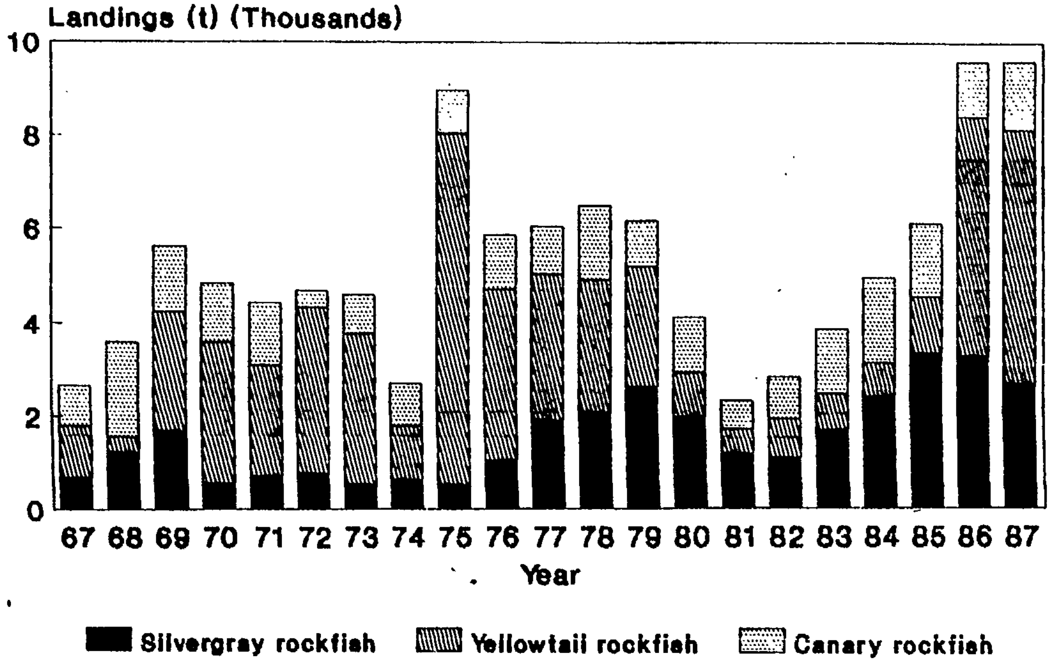


Fig. 10.1. Shelf rockfish landings from B.C. waters.

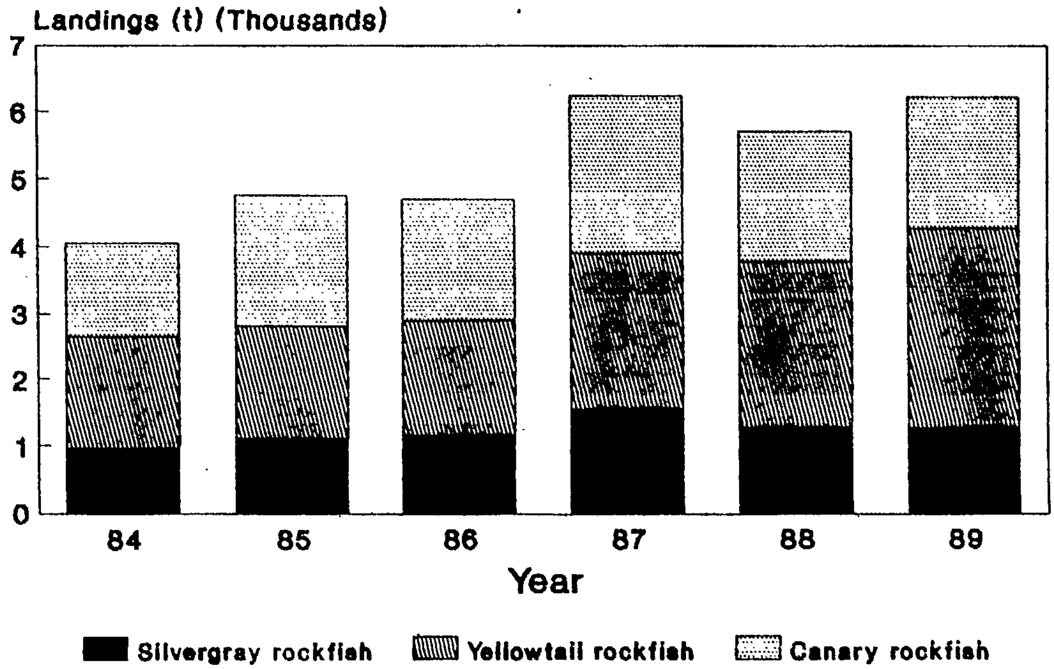


Fig. 10.2. Sum of yield recommendations for shelf rockfish. Sum of range midpoints or sustainable yield options for traditional fisheries.

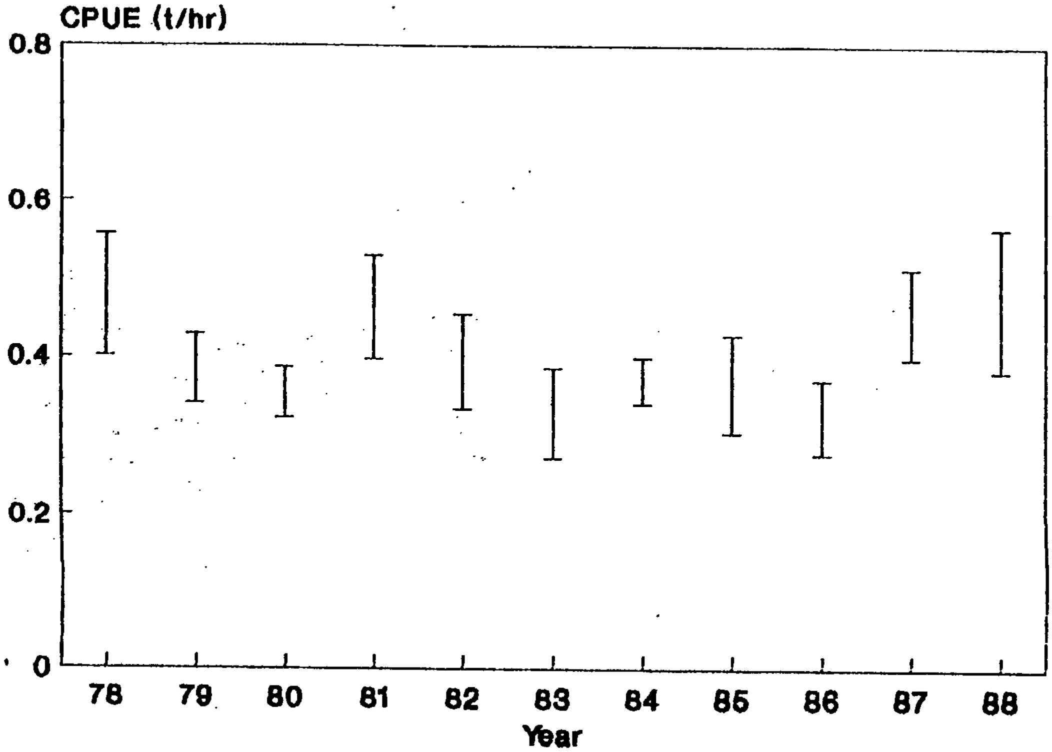


Fig. 10.3. Variance in estimates of nominal CPUE for silvergray rockfish in Queen Charlotte Sound. Bootstrap 80% confidence limits.

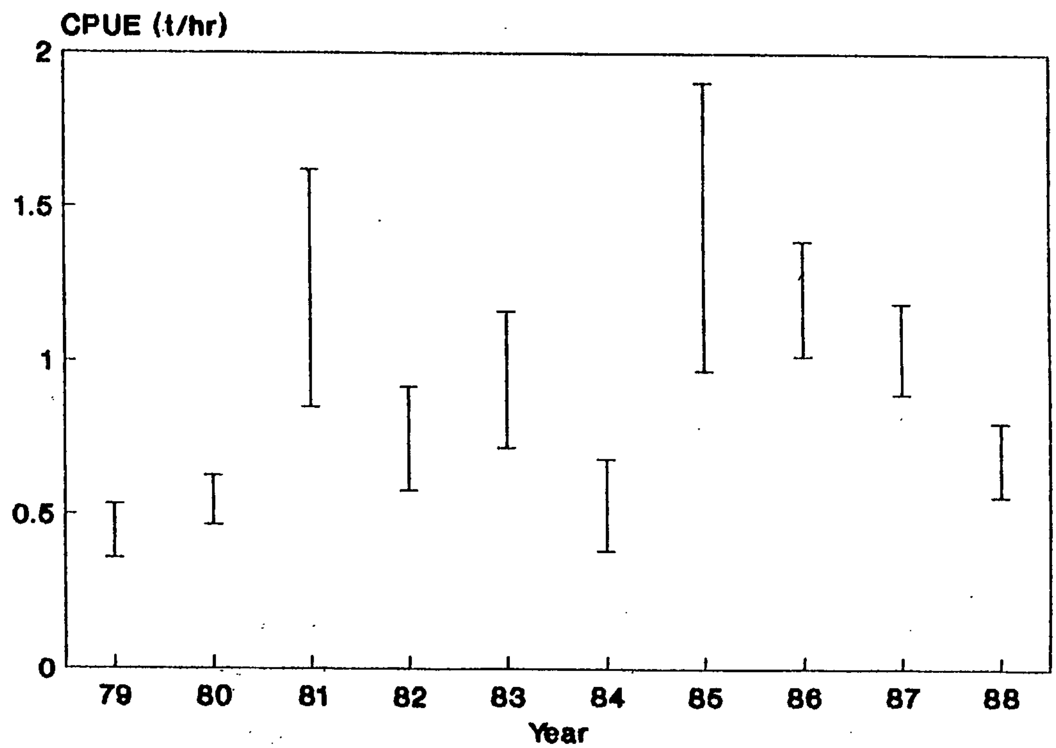


Fig. 10.4. Variance in estimates of nominal CPUE for silvergray rockfish in Moresby Gully. Bootstrap 80% confidence limits.

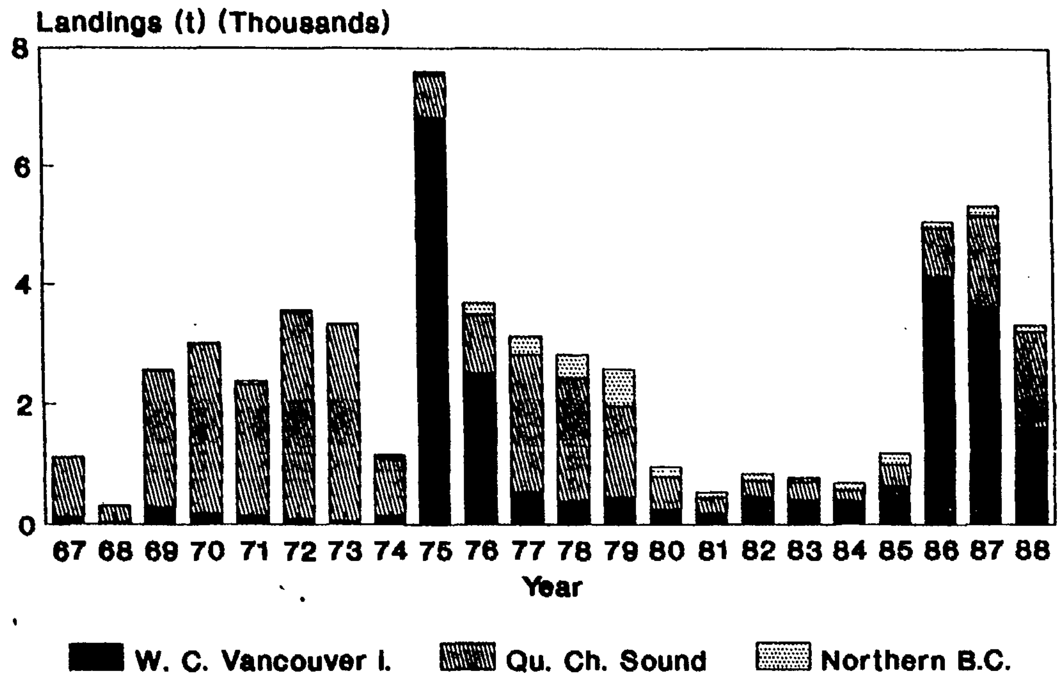


Fig. 10.5. Yellowtail rockfish landings from B.C. waters.

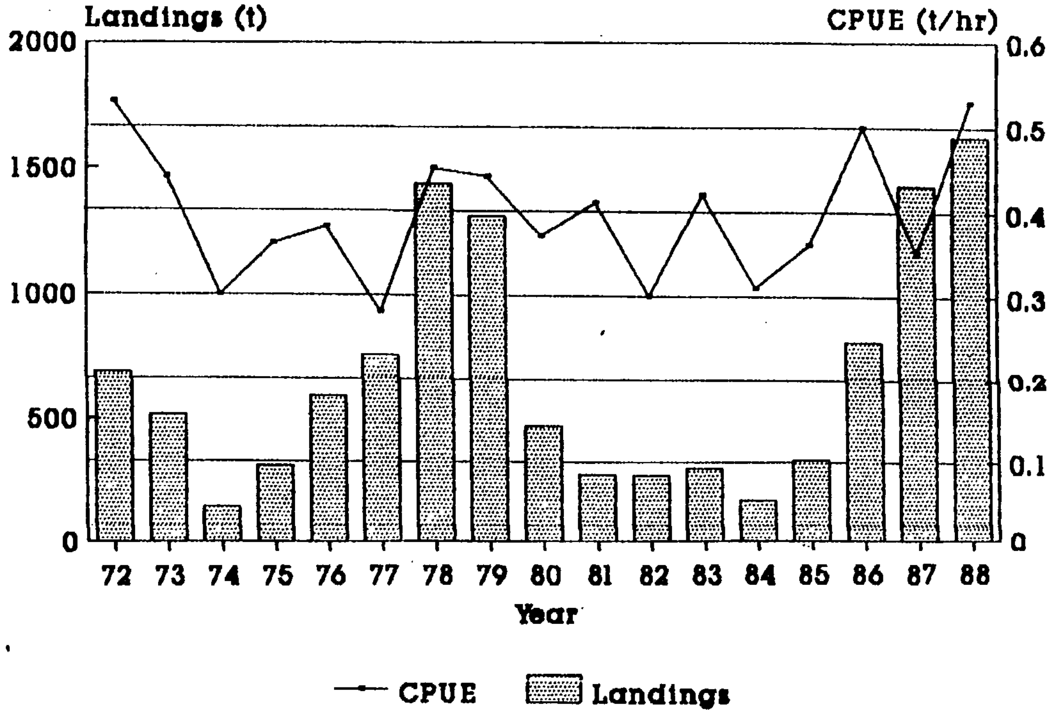


Fig. 10.6. Landings and bottom trawl CPUE for yellowtail rockfish in Queen Charlotte Sound.

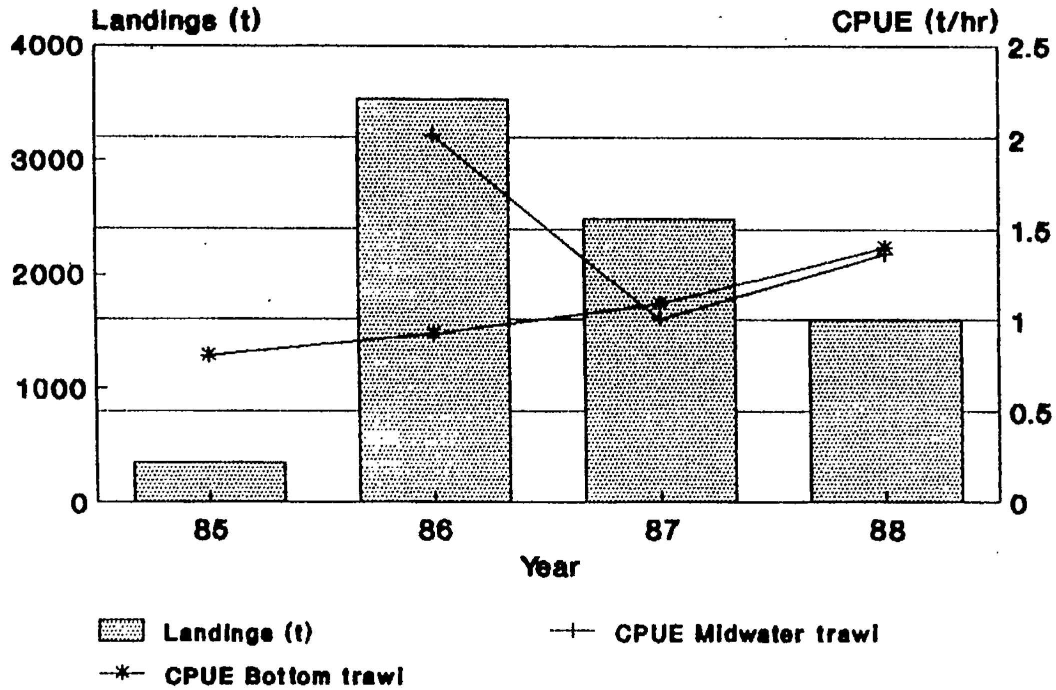


Fig. 10.7. Midwater and bottom trawl CPUE for yellotail rockfish off the west coast of Vancouver Island.

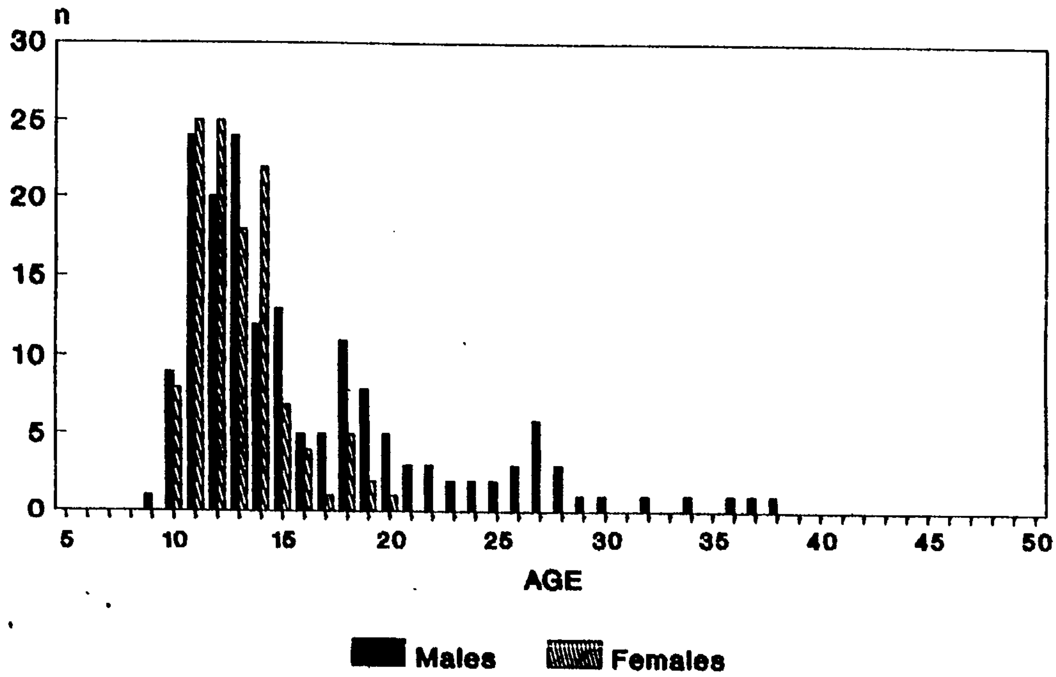


Fig. 10.8. Age composition of yellowtail rockfish from the one sample of 1988 midwater fishery off the west coast of Vancouver Island.

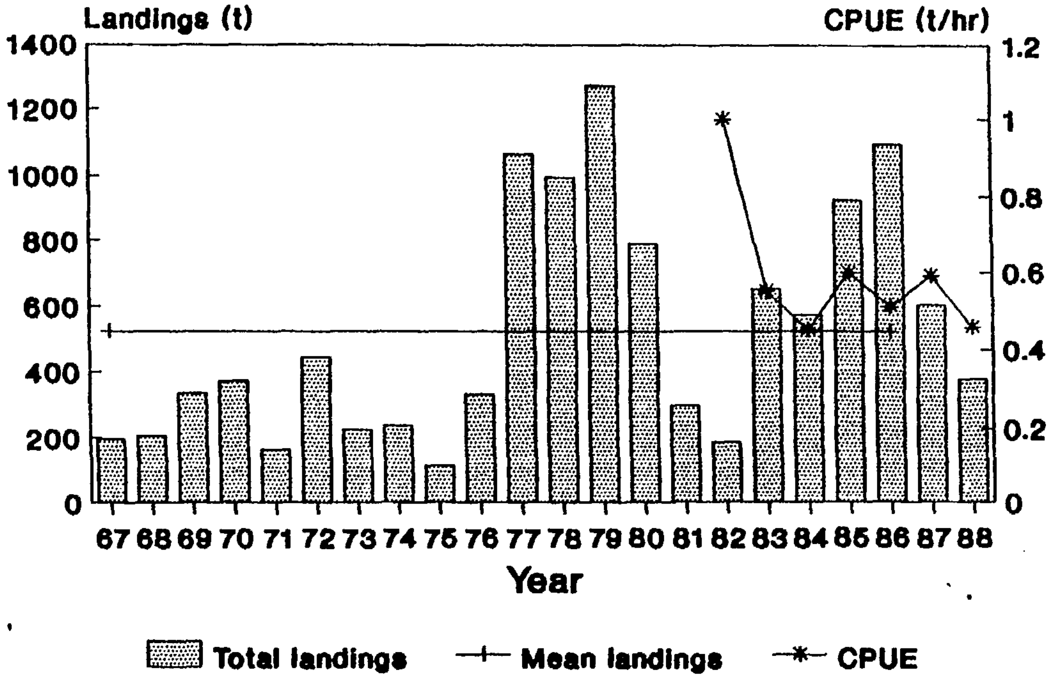


Fig. 10.9. Landings and bottom trawl CPUE for silvergray rockfish off the west coast of Vancouver Island.

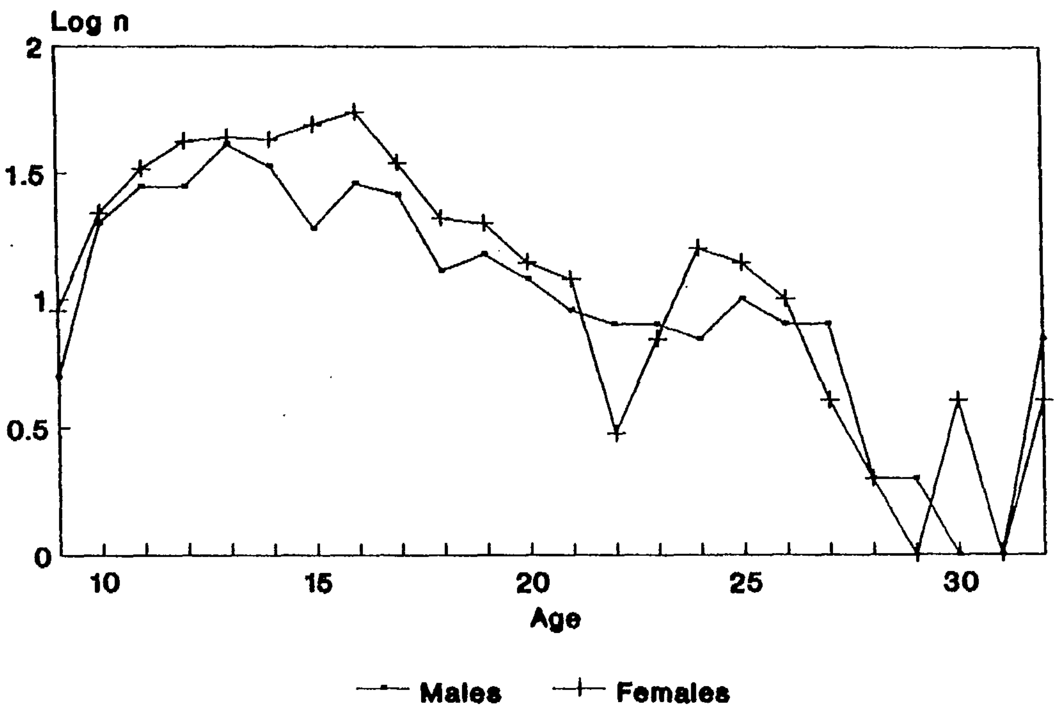


Fig. 10.10. Log_e frequency of numbers at age for silvergray rockfish from the 1985 and 1986 charters to the west coast of Vancouver Island.

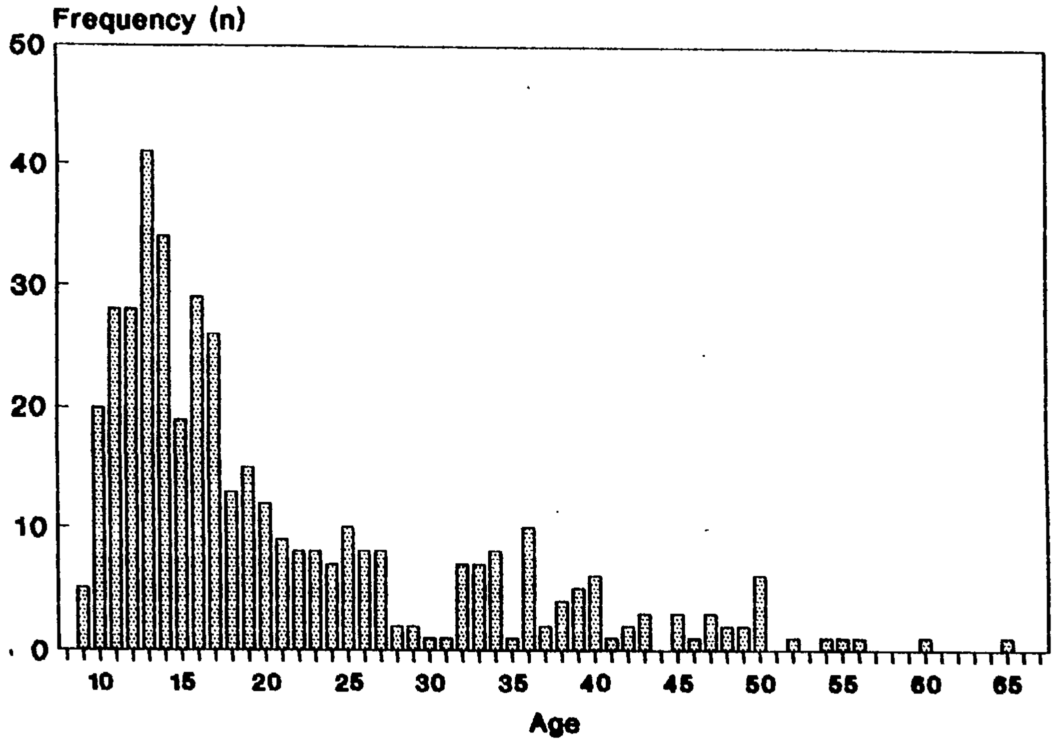


Fig. 10.11. Numbers at age for male silvergray rockfish from the 1985 and 1986 charters to the west coast of Vancouver Island.

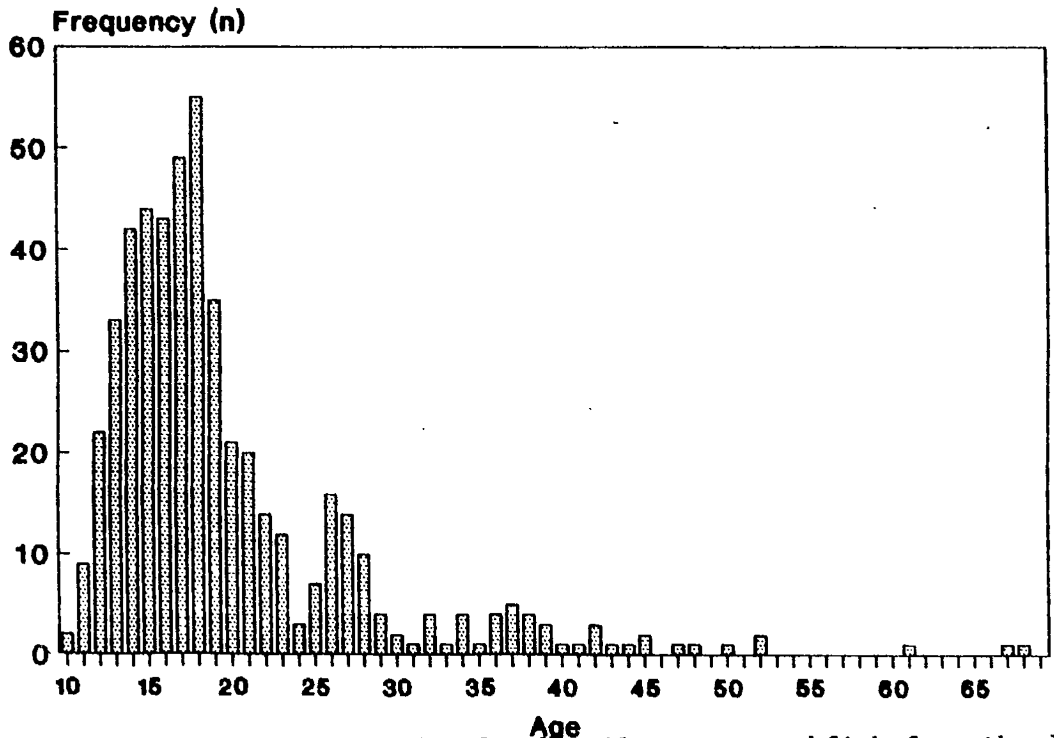


Fig. 10.12. Numbers at age for female silvergray rockfish from the 1985 and 1986 charters to the west coast of Vancouver Island.

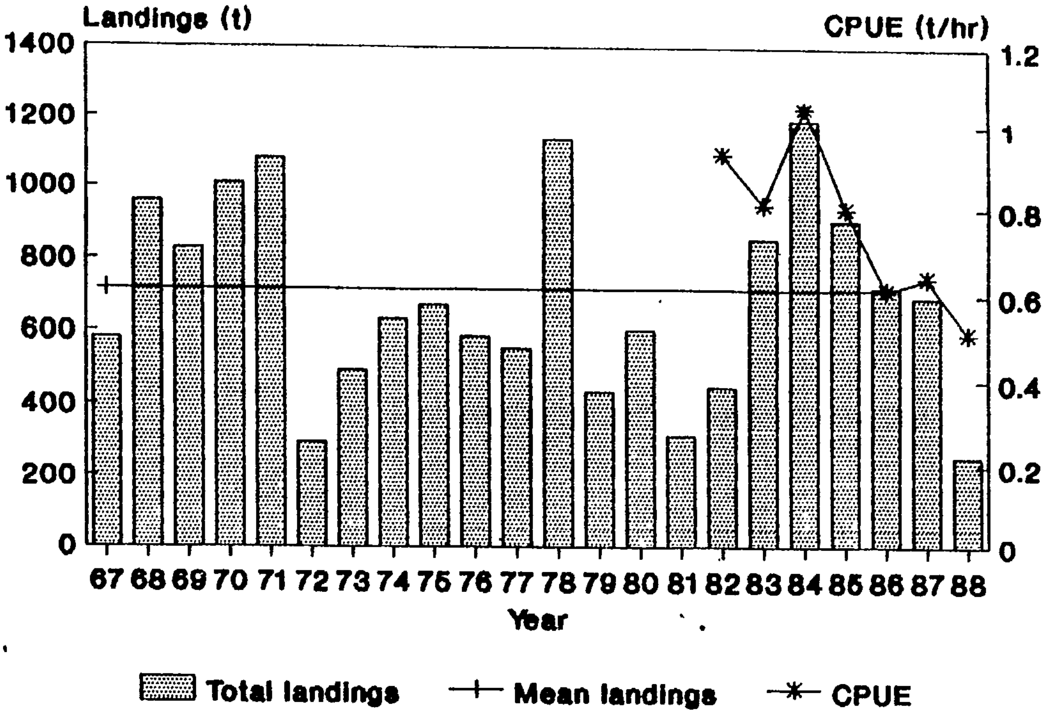


Fig. 10.13. Landings and bottom trawl CPUE for canary rockfish off the west coast of Vancouver Island.

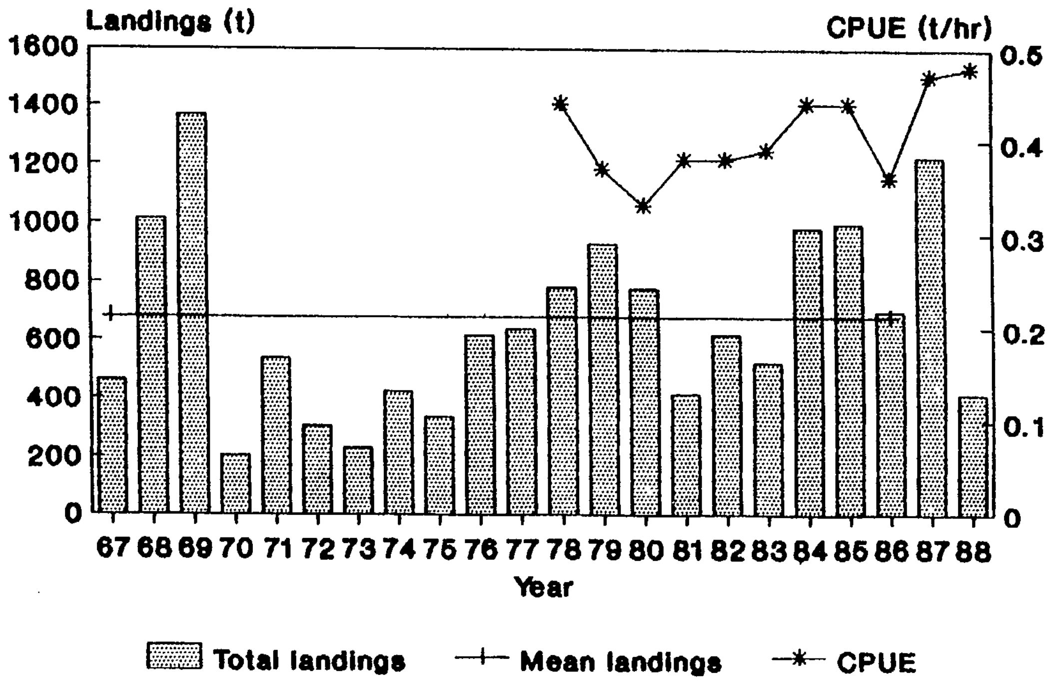


Fig. 10.14. Landings and bottom trawl CPUE for silvergray rockfish in Queen Charlotte Sound.

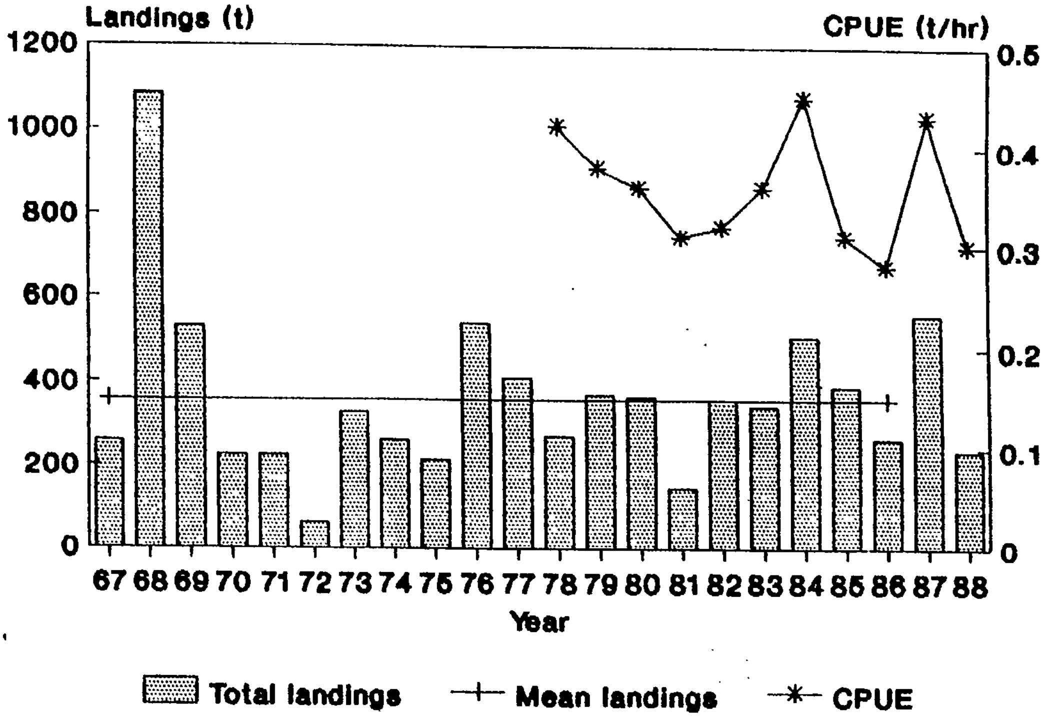


Fig. 10.15. Landings and bottom trawl CPUE for canary rockfish in Queen Charlotte Sound.

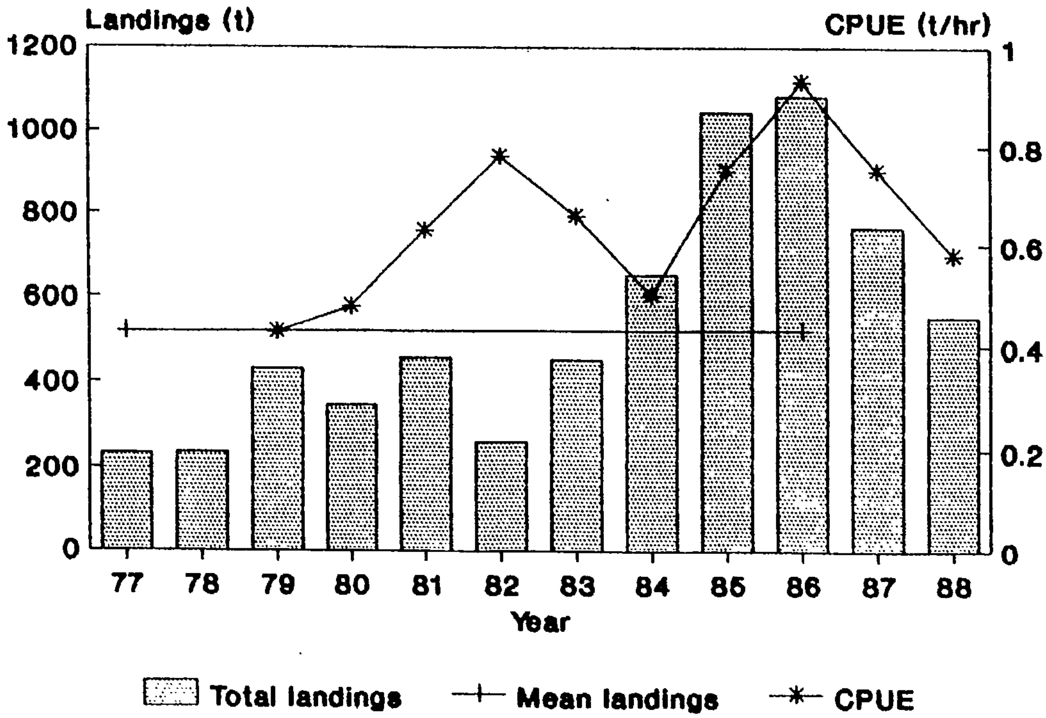


Fig. 10.16. Landings and bottom trawl CPUE for silvergray rockfish in Moresby Gully and Hecate Strait.

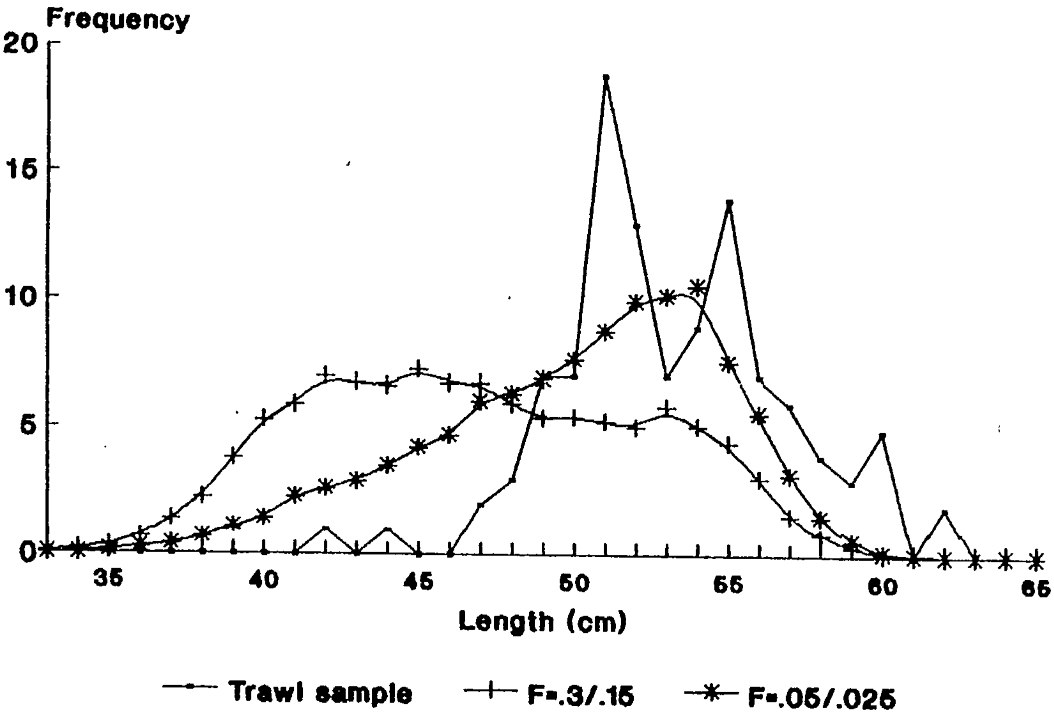


Fig. 10.17. Length frequency of male silvergray rockfish from a 1988 Hecate Strait sample in comparison with theoretical distributions. (F=.3/.15 assumes an F of 0.3 for 1984-1987, 0.15 for 1977-1983 and 0.0 for before 1977.)

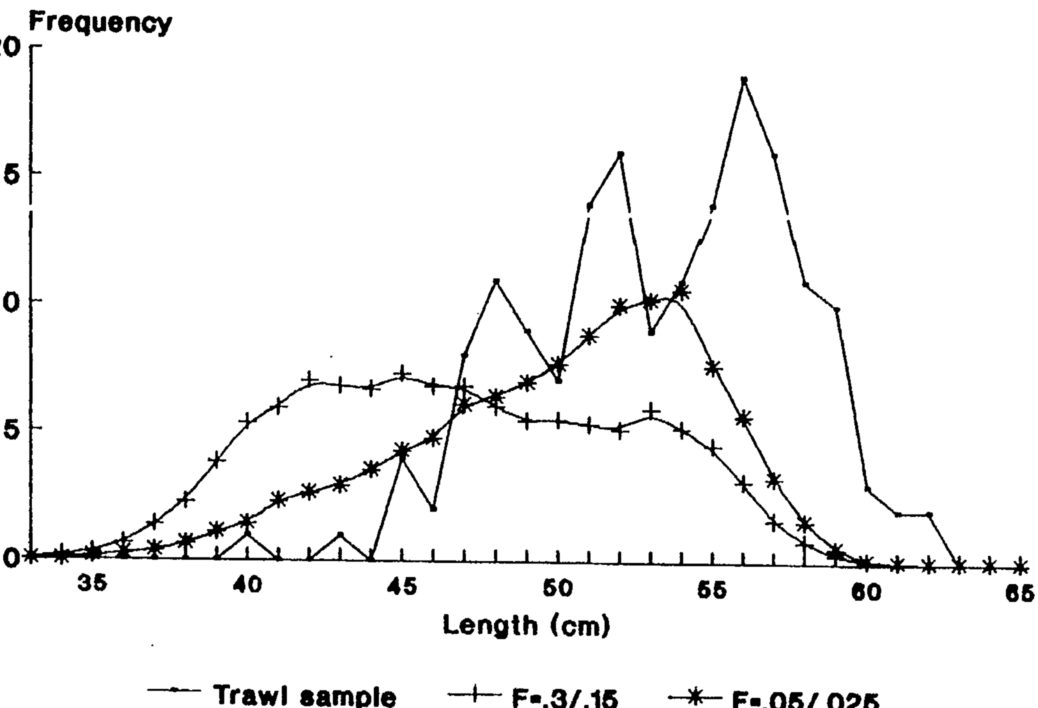


Fig. 10.18. Length frequency of female silvergray rockfish from a 1988 Hecate Strait sample in comparison with theoretical distributions. (F=.3/.15 assumes an F of 0.3 for 1984-1987, 0.15 for 1977-1983 and 0.0 for before 1977.)

11.0 INSHORE ROCKFISH

11.1 Coastwide

Yield options are not proposed on a coastwide basis.

11.2 Strait of Georgia and vicinity (Area 4B)

11.2.1 The Fishery

The inshore rockfish fishery occurs throughout the Strait of Georgia and adjacent inside waters of Vancouver Island (Fig 1.2). Most of the commercial vessels use handline/troll or longline gear. The commercial fishery in its present form began to expand about 1977 (Fig. 11.1). At that time a market developed for live rockfish to supply restaurants and retail outlets, primarily in Vancouver's Chinatown. Rockfish are also exploited by the sport fishery.

There were no restrictions on commercial catch prior to 1987. In 1987, a winter closure for Area 4B was implemented between Jan. 1 and Apr. 15. The closure was extended to Apr. 30 in 1988, with the exception of subareas 13-2 to 13-9, 13-11 and 13-27 which remain closed. The winter closure was designed to reduce overall levels of effort. It coincided with a lingcod closure and covered the major period of parturition for the most common rockfish species. An incidental catch of yelloweye rockfish (S. ruberrimus) was permitted during this closed period, however, to accommodate a longline dogfish fishery. The experimental 75-t quota placed on the Area 12 rockfish catch in 1987 (excluding the yelloweye rockfish catch), was not continued in 1988. The sport fishery has had a coastwide bag limit of eight rockfish per day since 1986.

Quillback rockfish (S. maliger) is the dominant species in the commercial handline/troll fishery and accounts for about 85% (by number) of the catch, based on commercial samples and the logbook program (Hand and Richards 1988). There are minor catches of several other species including copper rockfish (S. caurinus), yellowtail rockfish (S. flavidus), black rockfish (S. melanops), tiger rockfish (S. nigrocinctus), and yelloweye rockfish, as well as lingcod and kelp greenling (Hexagrammos decagrammus). Yelloweye rockfish is the dominant species in the commercial longline catch, with the exception of Areas 12 and 17-19 where both handline/troll and longline gear are used to target on quillback rockfish. Quillback rockfish, copper rockfish and yelloweye rockfish account for 54%, 23% and 15%, respectively, of the rockfish sport catch, based on the 1985 creel census (T. Shardlow and T. Hoyt, unpub. data).

11.2.2 Landing Statistics

Historically, most of the rockfish trawl catch was from Areas 18, 19 and 20 (Table 11.1). There were also significant trawl catches (over 10 t) in the 1950s and 1960s in Area 14 and in the late 1960s and early 1970s in Area 17. The annual trawl catch averaged 98 t between 1954-70. Since 1970 however, the annual trawl catch has decreased. The 1987 trawl catch is the lowest on record at 14.8 t. In general, the rockfish trawl catch has been incidental to other fisheries, especially the Pacific cod fishery, although a yellowtail rockfish fishery has existed in Area 20.

The rockfish catch by handline/troll and longline gear was historically less than the trawl catch, and averaged 65 t annually between 1954-76 (Table 11.2). The catch began to increase in 1976 and reached a maximum of 527 t in 1986. The 1987 catch of 404 t probably reflects the effect of the winter closure and the Area 12 quota in reducing fishing effort. Catches were reduced in all Statistical Areas between 1986 and 1987 except Areas 19, 20, 28 and 29. The Area 12 catch was reduced from 135 t in 1986 to 110 t (90 t excluding yelloweye rockfish) in 1987, 20% above the 75-t quota. Areas 12 and 13 accounted for 56% of the 1987 line catch.

The sport catch of rockfish, as estimated by the Strait of Georgia creel survey, averaged 167,000 pieces annually between 1982-87 (Table 11.3). Areas 12 and 20 were not covered by the survey, and the sport catch from these areas is not documented. The 1987 catch was below average at 136,000 pieces, or approximately 82 t (assuming a weight of 0.6 kg/fish). This is 24% of the total line catch from these areas.

The sport catch of rockfish is independently monitored by the tidal diary program. This program combines a sport diary and a visitors survey to estimate the total sport catch. The 1987 catch from the sport diary alone is 242,000 pieces or 145 t (the 1987 visitors survey is not yet available). This is 36% of the total line catch from these areas. It is not possible at this time to fully account for differences in estimated catch between the creel survey and tidal diary programs.

To provide a more meaningful analysis of commercial catch and CPUE, Statistical Areas within Area 4B are grouped by geographical area (Table 11.4). There is no available information on stock delineation, although tagging experiments conducted in Puget Sound suggest that at least as adults, quillback and copper rockfish are fairly sedentary (Mathews and Barker 1983). Nominal CPUE is based on catch and effort by handline/troll and longline from total rockfish landings of at least 50 kg as reported on sales slips (Richards 1988). For the last 5 y, catch and CPUE are also reported with the "red snapper" catch excluded. This is a market category that includes mainly yelloweye rockfish, but may also include canary rockfish (S. pinniger) and other "red" rockfish.

In Area 12, the main fishery has occurred between 1985-87. The 1987 catch was reduced to about the 1985 level by implementation of the 75-t quota and the winter closure. The value of CPUE is lower for the series that excludes the red snapper catch, but both series show the same trend. CPUE decreased in 1987 from the abnormally high value in 1986. In Area 13, catch peaked in 1983, and has since steadily declined. Total rockfish CPUE averaged 57.3 kg/d between 1976-83 during the build-up of the fishery, and 46.3 kg/d between 1983-87. In Areas 15 and 16, there have been no obvious trends in catch or CPUE. The percentage of red snapper in the total rockfish catch has increased, however, from 14% in 1985 to 19% in 1986 and 62% in 1987. There has also been an increase in the red snapper catch in the Gulf Islands. In 1986-87, red snapper accounted for 20% of the total rockfish catch there. There have been no obvious trends in CPUE from the Gulf Islands.

11.2.3 General Biological Information

The weight distribution of quillback rockfish in the Area 12 commercial samples may still be typical of a lightly exploited stock (Table 11.5). There is no evidence for a decrease in mean size over the course of the fishery, and the weight distributions of commercial samples are similar to those obtained from the 1986 and 1987 research surveys (Richards and Cass 1987, Richards and Hand 1987). Significant differences in mean fish size may occur among samples from different localities, seasons and depths (Cass et al. 1986). The small mean weight from the 1985 Area 12 sample is an anomaly and is indicative of the possible among-sample variance. Based on one 1986 sample aged to date, the mean age is 26 y with a range in age of 5-60 y.

In contrast to quillback rockfish in Area 12, the mean size of quillback rockfish in Area 13 has decreased since 1984. The mean weight from commercial samples of 0.48 kg in 1987 was identical to the mean weight obtained from research fishing surveys in the same area (Richards and Hand 1987). The one 1988 sample collected to date has the same size distribution as the 1987 samples. As weight at 50% maturity is about 0.5 kg, and as fish as large as 0.9 kg may be immature, a high proportion of fish landed by the fishery are immature. The mean age from a 1984 and a 1986 sample from Area 13 and a 1986 sample from Area 17 was 18 y with a range of 4-55 y.

Only two commercial samples have been collected from Area 17, and none from the remaining areas of the Strait of Georgia. Based on the commercial samples (Table 11.5) and the research program in Area 16 (Richards and Cass 1987) and Area 17 (Hand and Richards 1987), the size distribution of quillback rockfish landed in these areas is intermediate between the distributions in Areas 12 and 13.

Two samples from the yelloweye longline fishery in Area 17 were collected in 1988. Yelloweye rockfish in these samples had a mean size (SE) of 2.22 (0.08) kg and were considerably smaller than yelloweye rockfish from the North Coast and the west coast of Vancouver Island (Fig. 11.2). Although ageing techniques have not been verified for this species, the mean age of one of the samples is tentatively 33 y. Size at 50% maturity is about 1.7 kg for males and 1.6 kg for females, although fish larger than 4 kg may be immature.

11.2.4 Condition of the stock

Quillback rockfish stocks in Area 12 appear to be in relatively good condition. There has been no decrease in mean size over the course of the fishery, and there have been no clear trends in CPUE. In contrast, quillback rockfish stocks in Area 13 appear to be in relatively poor condition. These stocks were probably depleted by the fishery between 1982-1984, and have not had sufficient time to recover. The condition of stocks in Sechelt and the Gulf Islands is less certain, as there have been no clear trends in catch or CPUE.

Yelloweye rockfish account for an increasing proportion of the Area 4B rockfish catch (Table 11.6). Based on the experience of other rockfish fisheries, it is unlikely that the yelloweye rockfish stock can sustain increased fishing pressure. These stocks already show evidence of heavy exploitation, as mean size of yelloweye rockfish from Area 4B is smaller than from other areas of the coast.

11.2.5 Yield Options

Yield options for the inshore rockfish assemblage, excluding yelloweye rockfish, are derived from the historical rockfish catch. It is assumed that increments of 25 t are the minimum that can be managed in a Statistical Area. A 75-t quota is listed as low risk for Area 12 and sustainable for Area 13 because of the depletion that has already occurred in Area 13. The option for the other areas is equivalent to the 1986 catch. The high risk option for yelloweye rockfish is based on the 1987 red snapper catch. The 1987 catch is considered high risk, as the stock currently shows sign of depletion.

Yield option	Other rockfish			Yelloweye
	Area 12	13	14-20, 28,29	Area 4B
low risk sustainable	75 t	50 t	150 t	50 t
sustainable	100 t	75 t	200 t	75 t
high risk sustainable	150 t	100 t	250 t	100 t

These yield options are intended to act as guidelines for managers, and not to imply that management by quota is the best strategy. The winter closure in 1987 was apparently effective in reducing the catch by approximately 25%. There were also serious conflicts with the dogfish longline fishery, such that a longline fishery for yelloweye rockfish was conducted during the closed period.

An alternative to a closure favoured by some fishermen is a restricted size range of 1-2.5 lb (0.45-1.14 kg). This is the size range with the highest market value. This range limit would have a major effect in Area 13, where the average size of quillback rockfish in the commercial catch is less than 0.5 kg. The minimum size corresponds approximately to the size at 50% maturity for quillback rockfish.

Consideration should also be given to limiting the sport fishery, which accounts for at least 24% of the total rockfish line catch. This may be most important near Campbell River where local closures now apply to the commercial fishery.

11.3. West Coast Vancouver Island (Area 3C/D)

11.3.1 Landing Statistics

The nominal rockfish line catch off the west coast of Vancouver Island has increased dramatically since 1985, and now exceeds the Area 4B line catch (Fig. 11.1). The handline/troll catch doubled from 62 t in 1985 to 150 t in 1986, and the catch increased again to 187 t in 1987. Most of the catch is from Areas 24, 25 and 27. The increase in rockfish catch in the longline fishery has been more sudden, jumping from 40 t in 1985 to 364 t in 1986 (Table 11.8). The longline catch decreased in 1987 to 272 t. The rockfish longline fishery extends along the west coast of Vancouver Island, but the largest catch was recorded from Area 27. "Red snapper" (mainly yelloweye rockfish) accounts for just over half of the west coast line catch (Table 11.6).

Nominal red snapper CPUE is based on catch and effort by handline/troll and longline from red snapper landings of at least 50 kg as reported on sales slips. Similarly, other rockfish CPUE is based on line landings of rockfish of at least 50 kg excluding the red snapper catch. Both red snapper CPUE and other rockfish CPUE show the same trend (Table 11.6). CPUE increased between 1983-86 during the build-up of the fishery, peaked in 1986, and then decreased in 1987. With the short time series, it is not clear whether or not the decrease in CPUE in 1987 is indicative of a decrease in stock size.

11.3.2 General Biological Information

No samples of the commercial handline fishery have been collected from this area. One commercial sample of yelloweye rockfish was collected from the longline fishery in Area 25 in 1988. Mean fish size, 3.48 kg, was intermediate between samples from the Strait of Georgia and the North Coast (Fig. 11.2).

11.3.3 Yield Options

The low risk option is the average line catch over the 1956-85 period, prior to the build-up of the fishery. The sustainable option is based on the 1986-87 catch. It is not yet clear whether this level of catch has led to stock depletions. Because of the general uncertainty about appropriate yield levels, the high risk option is arbitrarily chosen to be 50% above the sustainable level. The yelloweye rockfish share of the quota should be approximately 50%.

Yield Option	Quota (t)
low risk sustainable	60
sustainable	500
high risk sustainable	750

These yield options are intended to act as guidelines for managers, and not to imply that management by quota is the best strategy. Future assessments will examine yield levels based on available habitat relative to the Area 4B yield.

11.4. North Coast (Area 5A/B/C/D/E)

11.4.1 Landing Statistics

The nominal rockfish line catch from the North Coast has increased dramatically since 1984, and now exceeds the Area 4B and the west coast of Vancouver Island catch (Fig. 11.1). The handline/troll fishery has traditionally been small on the North Coast (Table 11.7). In 1987, however, the handline/troll catch almost doubled to 88 t from the previous high of 47 t in 1985. The increased catch was taken mostly from Area 11, adjacent to the Area 12 fishery. Because of the winter closure in the Strait of Georgia, it is anticipated that the 1988 catch will have again increased over the 1987 level. The rockfish longline fishery has also been increasing, particularly since 1984 (Table 11.8). The 1987 catch was the highest on record at 490 t. Most of the catch was from the Queen Charlotte Islands (Statistical Areas 1-2), although there were also catches of over 30 t from Areas 5 and 6.

To further examine trends in catch and CPUE, the North Coast was divided into three regions, the Queen Charlotte Islands (Statistical Areas 1-2), the North Coast (Areas 3-5) and the Central Coast (Areas 6-11). "Red snapper" CPUE is based on catch and effort by handline/troll and longline from red snapper landings of at least 50 kg as reported on sales slips. Similarly, other rockfish CPUE is based on line landings of rockfish of at least 50 kg excluding the red snapper catch. Red snapper accounts for approximately half of the line catch, although the proportions are variable among years and areas (Table 11.6). The time series of CPUE is relatively short, and there are no clear trends. One generalization is that a high value of CPUE is associated with a high catch. This is typical of the developmental stage of a fishery.

11.4.2 General Biological Information

One sample of the commercial handline fishery was collected from Area 7 in 1988. Quillback rockfish accounted for 92% of the number of fish in the sample, and there were small numbers of copper rockfish, yelloweye rockfish and kelp greenling. The quillback rockfish had a smaller mean size than those sampled from Area 12 (Table 11.5), but this one sample may not be representative of the catch.

One commercial sample of yelloweye rockfish was collected from the longline fishery in Area 5E (Statistical Area 2) in 1986. Mean fish size, 4.15 kg, was larger than 1988 samples from the Strait of Georgia and the west coast of Vancouver Island (Fig. 11.2).

11.4.3 Yield Options

The low risk option is the average line catch between 1974-84, prior to the increase in the fishery. The sustainable option is the 1987 catch, as it is not yet clear whether this level of catch has led to serious stock depletions. Because of the general uncertainty about appropriate yield levels, the high risk option is arbitrarily chosen to be 50% above the sustainable level. The yelloweye rockfish share of the quota is approximately 50%.

Yield Option	Quota (t)
low risk sustainable	120
sustainable	580
high risk sustainable	870

These yield options are intended to act as guidelines for managers, and not to imply that management by quota is the best strategy. Future assessments will examine yield levels based on available habitat relative to the Area 4B yield.

Table 11.1. Nominal rockfish trawl catch (t) for Area 4B by Statistical Area, from Groundfish data files, 1954-87.

	Statistical Area											Area 4B
Year	12	13	14	15	16	17	18	19	20	28	29	Total
1954	5.0	0.3	29.5	0.0	0.0	7.7	11.4	0.7	60.7	0.0	4.8	120.1
1955	1.5	0.1	12.1	0.0	0.1	8.4	87.1	1.0	19.5	0.0	0.8	130.5
1956	5.6	0.6	15.3	0.0	0.0	9.1	4.3	17.2	18.1	0.0	1.4	71.6
1957	0.9	0.3	14.5	0.2	0.0	8.5	4.5	0.5	1.2	0.1	2.6	33.3
1958	1.2	0.8	8.0	0.0	0.0	9.9	2.0	3.1	27.2	0.0	1.2	53.3
1959	1.0	0.9	6.2	0.0	0.0	8.3	16.1	48.3	77.5	0.0	0.7	159.0
1960	0.8	0.3	7.2	0.0	0.1	6.1	8.3	7.6	144.8	0.0	0.7	175.7
1961	1.6	0.1	11.1	0.2	0.3	7.7	15.5	6.0	61.0	0.0	0.8	104.1
1962	2.4	0.8	9.0	0.0	0.5	9.1	12.6	0.3	56.9	0.0	1.0	92.7
1963	0.1	1.5	10.5	0.0	0.0	7.4	14.6	0.9	17.3	0.0	0.4	52.8
1964	0.3	5.0	5.7	0.0	0.0	8.9	20.1	4.5	71.4	0.0	1.2	117.1
1965	0.5	1.1	8.3	0.0	0.0	2.1	9.6	4.0	38.6	0.0	1.0	65.3
1966	2.2	0.0	7.5	0.0	0.0	1.7	7.8	0.8	118.8	0.0	0.0	138.8
1967	2.3	1.2	4.5	0.0	0.0	2.9	5.2	0.7	31.8	0.0	0.1	48.9
1968	1.4	0.0	6.3	0.0	0.0	21.7	4.2	0.9	64.4	0.0	0.1	98.9
1969	0.8	1.2	9.1	0.0	0.0	4.4	5.4	2.4	75.5	0.0	0.3	99.0
1970	0.0	0.0	5.9	0.0	0.0	12.5	7.8	0.1	75.9	0.0	0.2	102.4
1971	0.1	0.1	6.4	0.0	0.0	9.1	7.0	0.4	10.5	0.0	0.6	34.2
1972	0.0	0.0	6.1	0.0	0.0	7.4	2.9	0.1	29.1	0.0	0.0	45.6
1973	0.5	1.9	3.1	0.0	0.0	12.1	2.9	0.0	3.5	0.0	0.1	24.0
1974	0.0	0.2	5.3	0.0	0.0	5.6	5.7	0.1	4.1	0.0	0.6	21.7
1975	0.1	1.8	4.0	0.0	0.0	2.3	7.6	2.4	10.9	0.0	0.0	29.1
1976	0.2	1.0	3.3	0.0	0.0	2.0	9.1	1.1	14.3	0.0	0.0	31.1
1977	1.2	0.8	5.2	0.0	0.0	2.6	7.9	2.0	10.5	0.0	0.0	30.1
1978	9.8	0.4	5.6	0.0	0.0	1.7	12.3	5.7	16.6	0.0	0.1	52.0
1979	0.4	0.0	3.8	0.0	0.0	3.6	15.7	17.5	82.9	0.0	0.4	124.2
1980	0.1	0.1	1.2	0.0	0.0	5.2	6.4	6.1	20.7	0.0	0.1	39.8
1981	0.6	0.0	1.8	0.0	0.0	2.6	11.0	15.8	17.9	0.0	1.5	51.1
1982	0.0	0.1	2.9	0.0	0.1	5.2	9.7	11.5	19.2	0.0	0.2	48.7
1983	2.7	0.1	0.9	0.0	0.0	3.5	11.1	4.2	4.8	0.0	0.1	27.4
1984	0.1	0.0	1.1	0.0	0.0	1.8	15.4	7.7	12.3	0.0	0.4	38.8
1985	0.2	0.0	0.9	0.0	0.0	2.2	6.6	6.8	8.5	0.0	0.1	25.2
1986	0.0	0.1	1.1	0.0	0.0	4.3	5.0	1.4	33.8	0.0	0.0	45.6
1987	0.0	0.1	2.2	0.0	0.1	3.5	1.9	2.4	4.6	0.0	0.0	14.8

Table 11.2. Nominal rockfish handline/troll and longline catch (t) for Area 4B by Statistical Area, from British Columbia catch statistics, Annual Reports, 1954-87.

	Statistical Area											Area 4B
Year	12	13	14	15	16	17	18	19	20	28	29	Total
1954	6.3	6.8	0.8	0.6	6.8	15.1	6.1	0.0	0.0	0.4	0.0	43.0
1955	6.3	6.8	0.8	0.6	6.8	15.1	6.1	0.0	0.0	0.4	0.0	43.0
1956	6.8	2.0	0.2	1.0	5.0	19.0	5.5	0.1	0.1	0.0	0.2	39.9
1957	5.7	6.1	2.5	2.8	14.5	26.0	7.0	6.5	0.0	0.1	1.1	72.4
1958	8.0	10.8	9.8	6.0	15.4	29.3	15.8	6.3	3.2	0.0	2.0	106.6
1959	13.2	16.4	9.3	10.7	10.9	36.4	4.0	3.9	0.5	0.1	0.7	106.1
1960	10.1	20.1	4.8	11.8	11.2	19.8	3.5	3.2	0.9	0.4	0.1	86.0
1961	10.4	16.9	6.5	2.7	4.9	16.2	3.2	1.4	0.6	0.1	1.5	64.5
1962	52.8	15.1	4.7	5.8	3.1	19.7	2.4	2.5	0.6	0.2	0.5	107.5
1963	39.1	7.8	3.7	1.6	6.2	16.4	2.8	0.9	0.2	0.0	0.2	78.8
1964	11.1	4.6	2.1	0.9	12.8	8.8	2.8	1.1	0.7	0.0	0.1	45.1
1965	10.2	3.5	2.1	0.1	10.3	9.3	3.3	0.4	0.1	0.0	0.3	39.6
1966	4.2	3.6	3.8	0.5	13.0	4.1	4.1	0.2	0.1	0.1	0.0	33.8
1967	9.9	7.6	5.9	3.4	16.7	6.3	1.9	0.1	0.1	0.0	0.0	51.9
1968	11.8	8.2	5.0	1.0	19.0	10.3	1.4	0.2	0.1	0.0	0.0	57.0
1969	25.3	12.0	3.8	3.5	16.6	8.8	4.2	0.3	0.9	0.0	0.1	75.6
1970	23.8	16.9	4.0	5.0	9.8	16.1	1.5	0.6	0.8	0.0	0.0	78.9
1971	28.6	9.4	2.7	5.1	6.8	12.2	1.0	0.3	0.0	0.0	0.0	66.1
1972	26.3	14.1	5.0	4.5	11.8	12.2	0.9	0.5	0.0	7.0	0.0	82.3
1973	30.8	11.4	2.7	7.2	14.9	10.5	1.4	0.0	0.0	12.3	0.0	91.2
1974	8.6	7.3	3.2	8.2	2.8	12.2	2.8	0.0	0.0	0.8	0.0	45.7
1975	5.9	5.9	2.3	6.3	1.9	9.1	4.5	0.5	0.0	1.7	0.0	37.9
1976	10.9	10.4	5.0	7.7	2.7	7.3	2.7	0.0	0.9	3.3	0.0	50.9
1977	55.8	17.7	9.1	15.9	5.4	10.9	15.0	2.7	0.9	13.8	1.0	148.1
1978	21.0	30.0	7.0	15.0	19.0	29.0	32.0	5.0	1.0	1.0	3.0	163.0
1979	40.0	63.0	12.0	16.0	22.0	37.0	46.0	5.0	1.0	2.0	5.0	249.0
1980	27.0	43.0	10.0	12.0	20.0	20.0	35.0	5.0	2.0	3.0	0.0	177.0
1981	20.7	55.6	12.0	27.2	29.7	20.8	40.1	3.1	0.0	0.4	1.4	211.0
1982	21.5	106.3	9.0	74.5	34.2	10.0	18.5	2.0	0.0	0.2	1.7	277.9
1983	11.6	199.7	9.4	11.4	30.4	15.0	16.1	1.9	0.3	1.8	0.8	298.4
1984	32.7	198.0	3.3	13.3	22.8	38.0	23.6	7.7	2.0	0.2	1.4	342.6
1985	106.3	153.1	4.9	17.6	22.9	84.5	34.7	9.0	1.4	0.0	1.7	436.1
1986	135.3	142.7	18.4	24.9	58.7	63.0	45.8	23.7	9.3	0.0	5.3	527.1
1987	109.8	116.7	9.4	18.7	17.8	30.4	30.1	35.0	12.3	12.8	10.7	403.7

Table 11.3. Rockfish sport catch (thousands of pieces) for the Strait of Georgia by Statistical Area from the creel survey (Shardlow and Hoyt, unpub. data), and the total for the same areas from the sport diary program and visitors survey (Bijsterveld, unpub. data), 1982-87.

	Statistical Area[a]											
Year	13	14	15	16	17	18	19	28	29	Creel total	Diary total	Visit. total
1982[b]	25.0	15.6	4.5	38.6	26.1	29.8	12.0	36.1	8.7	194.7	250.8	-[c]
1983	37.2	17.9	3.8	42.0	23.4	23.6	37.3	14.8	9.1	209.1	171.0	15.7
1984	22.7	14.4	4.3	16.1	35.3	20.3	26.7	10.8	8.0	158.7	180.1	19.9
1985	14.4	12.4	1.7	38.5	20.9	12.1	20.3	7.2	6.5	134.0	-[c]	28.0
1986	21.2	20.7	2.7	48.9	18.4	12.9	28.6	7.0	7.2	167.8	365.9	65.6
1987	16.4	22.7	3.0	20.6	23.0	14.9	27.9	4.2	3.6	136.3	241.7	-[c]

[a]Areas 12 and 20 are not covered by the creel survey.
[b]Mean of 1980-82 estimates from creel survey.
[c]Estimates not available.

Table 11.4. Nominal total rockfish line catch (t), rockfish line catch excluding the 'red snapper' catch (t), rockfish CPUE (kg/d), rockfish CPUE with 'red snapper' excluded, effort (d), and the number of vessels that made a 50 kg qualified catch by geographical area, 1967-87. Effort is calculated from the ratio of total rockfish catch to CPUE.

a) Area 12, Port Hardy

	Catch		CPUE			
Year	Total	Ex red	Total	Ex red	Effort	No. of vess.
1967	9.9		89.4		111	
1968	11.8		34.3		344	
1969	25.3		64.0		395	
1970	23.8		72.3		329	
1971	28.6		65.7		435	
1972	26.3		41.2		638	
1973	30.8		102.4		301	
1974	8.6		36.6		235	
1975	5.9		36.2		163	
1976	10.9		47.5		225	
1977	55.8		80.8		691	
1978	21.0		52.1		403	
1979	40.0		55.0		728	71
1980	27.0		48.7		554	45
1981	20.7		57.3		361	42
1982	21.5		54.9		392	47
1983	11.6	8.4	63.1	52.0	184	37
1984	32.7	17.1	78.9	49.3	415	60
1985	106.5	80.0	70.1	56.6	1519	65
1986	135.3	100.5	86.9	69.1	1556	66
1987	109.8	89.9	71.1	59.6	1545	104

Table 11.4 (cont'd)

b) Area 13, Campbell River

Year	Catch		CPUE		Effort	No. of vess.
	Total	Ex red	Total	Ex red		
1967	7.6		47.8		159	
1968	8.2		60.7		135	
1969	12.0		106.4		113	
1970	16.9		59.6		283	
1971	9.4		61.2		154	
1972	14.1		45.8		308	
1973	11.4		63.7		179	
1974	7.3		52.2		140	
1975	5.9		81.3		73	
1976	10.4		49.8		209	
1977	17.7		51.1		346	
1978	30.0		56.3		533	
1979	63.0		66.9		942	98
1980	43.0		57.7		743	65
1981	55.6		62.8		885	86
1982	106.3		62.2		1709	114
1983	199.7	186.6	51.5	49.5	3876	127
1984	198.0	180.1	47.3	43.7	4186	125
1985	153.1	124.1	46.4	38.1	3302	101
1986	142.7	134.9	44.8	42.5	3184	87
1987	116.7	110.2	45.7	43.6	2554	125

Table 11.4 (cont'd)

c) Areas 15 and 16, Sechelt

Year	Catch Total	Catch Ex red	CPUE Total	CPUE Ex red	Effort	No. of vess.
1967	20.1		56.1		359	
1968	20.0		76.3		262	
1969	20.1		74.7		269	
1970	14.8		47.5		311	
1971	11.9		32.7		364	
1972	16.3		28.2		578	
1973	22.1		67.7		326	
1974	11.0		61.0		180	
1975	8.2		24.7		333	
1976	10.4		39.3		265	
1977	21.3		71.0		300	
1978	34.0		60.1		566	
1979	38.0		84.2		451	162
1980	32.0		65.1		491	117
1981	56.9		104.9		542	88
1982	108.8		79.9		1361	67
1983	41.8	37.0	63.7	64.5	656	71
1984	36.1	35.4	56.1	55.0	644	81
1985	40.5	34.9	84.7	70.8	478	86
1986	83.6	67.9	95.1	87.7	879	97
1987	36.4	13.8	64.1	35.6	568	79

Table 11.4 (cont'd)

d) Areas 14, 17-19, Gulf Islands

Year	Catch Total	Catch Ex red	CPUE Total	CPUE Ex red	Effort	No. of vess.
1967	14.2		40.7		349	
1968	16.9		31.5		536	
1969	17.1		27.9		613	
1970	22.2		38.0		584	
1971	16.2		58.0		279	
1972	18.6		25.4		733	
1973	14.6		36.8		397	
1974	18.2		28.7		634	
1975	16.4		58.9		278	
1976	15.0		49.3		304	
1977	37.7		55.2		683	
1978	73.0		53.7		1360	
1979	100.0		53.5		1871	65
1980	70.0		50.8		1377	54
1981	76.0		69.5		1093	60
1982	39.5		42.1		938	98
1983	42.4	36.8	42.5	39.4	997	43
1984	72.6	66.5	45.7	43.4	1590	41
1985	133.1	114.2	64.4	57.9	2068	42
1986	150.9	117.9	79.6	66.3	1896	47
1987	104.9	81.1	64.2	58.3	1634	151

Table 11.5. Number of quillback rockfish samples from the commercial handline fishery, mean weight (g) with one standard error, and sample size by sex, Statistical Area and year.

Area	Year	No. of samples	Males			Females			Combined sexes		
			N	Mean	SE	N	Mean	SE	N	Mean	SE
07	88	1	138	620	22	95	586	26	233	606	17
12	85	1	140	811	19	121	790	20	261	801	14
12	86	2	220	878	28	261	1156	32	481	1029	22
12	87	3	370	907	21	392	954	24	762	932	16
12	88	1	91	954	50	112	1008	44	203	984	33
13	84	4	354	837	18	436	921	19	790	884	13
13	85	2	466	654	13	339	709	18	805	677	11
13	86	2	294	655	17	313	742	20	607	700	13
13	87	2	268	475	14	253	486	15	521	481	10
13	88	1	27	469	37	17	515	50	44	487	30
17	86	2	123	815	27	199	965	26	323	909	20

Table 11.6. Nominal 'red snapper' handline/troll and longline catch (t), CPUE (kg/d) and effort (d) and other rockfish catch (t), CPUE (kg/d) and effort (d) by geographic region. CPUE is based on landings of at least 50 kg. Effort is calculated from the ratio of catch to CPUE. Source: British Columbia catch statistics data files, 1983-1987.

	Red snapper			Other rockfish		
Year	Catch	CPUE	Effort	Catch	CPUE	Effort
A) East Coast Vancouver Island, Statistical Areas 12-20, 28, 29						
1983	26.8	44.0	609	270.9	49.3	5495
1984	46.3	37.9	1222	300.8	44.8	6714
1985	83.2	35.2	2364	354.8	50.2	7068
1986	132.9	76.2	1744	433.3	59.5	7282
1987	91.5	56.5	1619	312.1	53.1	5878
B) West Coast Vancouver Island, Statistical Areas 21-27						
1983	32.2	69.3	465	49.7	36.3	1369
1984	60.1	120.2	500	55.6	56.4	986
1985	91.2	167.1	546	64.9	67.4	963
1986	323.0	197.4	1636	191.2	117.7	1624
1987	243.4	138.8	1754	223.7	88.7	2522
C) Queen Charlotte Islands, Statistical Areas 1-2						
1983	17.6	63.0	279	22.0	40.1	549
1984	26.5	51.7	513	72.1	137.2	526
1985	76.2	136.9	557	74.4	106.6	698
1986	110.6	185.0	598	82.3	131.4	626
1987	105.2	160.2	657	150.9	128.2	1177
D) North Coast, Statistical Areas 3-5						
1983	9.0	56.5	159	4.9	23.2	211
1984	19.9	131.7	151	6.2	28.3	219
1985	22.9	75.5	303	16.4	40.4	406
1986	17.2	70.3	245	22.3	70.9	315
1987	45.7	103.2	443	24.9	57.4	434
E) Central Coast, Statistical Areas 6-11						
1983	5.5	49.0	112	26.5	52.8	502
1984	13.6	93.5	145	25.9	39.6	654
1985	34.7	77.9	445	49.9	67.6	738
1986	11.5	67.0	172	68.2	83.8	814
1987	103.6	113.6	912	146.5	83.0	1765

Table 11.7. Nominal rockfish handline/troll catch (t) by Statistical Area for the North Coast and the west coast of Vancouver Island, from British Columbia catch statistics, Annual Reports, 1956-87.

Year	Statistical Area																NC	WC
	1	2	3	4	5	6	7	8	9	10	11	21	23	24	25	26	27	1-11	21-27
1956	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.1	1.6	0.2	0.0	0.5	0.4	2.4
1957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.5	0.4	0.7	2.1	0.0	4.9
1958	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.7	0.8	0.6	1.3	0.1	4.6
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.8	1.0	0.9	0.7	0.0	6.1
1960	0.0	0.0	0.0	0.1	0.0	0.0	0.5	0.1	0.1	2.4	0.2	0.0	0.5	3.9	1.1	0.5	1.5	3.4	7.5
1961	0.0	0.0	0.0	0.0	0.0	0.0	6.6	0.3	0.2	2.3	0.1	0.0	1.2	1.5	1.1	0.6	2.9	9.5	7.3
1962	0.2	0.0	0.0	0.0	0.0	0.0	6.3	0.5	0.2	3.3	0.7	0.5	2.4	7.5	3.6	1.9	4.6	11.2	20.5
1963	0.1	0.0	0.0	0.0	0.5	0.4	8.2	3.9	1.4	2.9	4.0	0.4	5.2	1.3	4.6	3.5	4.9	21.4	19.9
1964	0.0	0.4	0.0	0.0	0.0	0.0	2.5	0.5	0.3	0.0	0.0	0.1	0.8	0.3	0.2	0.3	3.0	3.7	4.7
1965	0.0	0.0	0.0	0.0	0.1	0.6	0.0	0.9	0.0	0.4	0.4	0.2	1.0	0.8	0.6	0.9	1.5	2.4	5.0
1966	0.0	0.0	0.0	0.0	0.3	0.0	1.0	0.6	0.0	0.8	1.8	0.1	0.7	0.1	0.9	1.2	1.1	4.5	4.1
1967	0.1	0.0	0.0	0.0	0.1	3.8	2.9	0.6	0.1	2.0	0.2	0.0	1.1	1.8	1.6	2.3	0.7	9.8	7.5
1968	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.9	1.3	0.4	0.1	0.2	0.8	1.0	1.7	0.8	2.7	4.3	7.2
1969	0.0	0.0	0.0	0.0	0.0	0.5	0.9	0.0	1.0	2.1	0.0	1.2	1.5	4.7	3.7	2.0	1.8	4.5	14.9
1970	0.0	0.1	0.6	0.0	6.8	2.7	17.3	2.3	2.0	0.5	0.0	2.3	2.5	7.3	5.4	6.8	7.0	32.3	31.3
1971	0.0	0.1	0.1	0.0	3.4	1.4	6.8	1.3	0.5	0.3	0.8	1.6	5.3	3.8	2.9	2.7	0.7	14.7	17.0
1972	0.0	0.0	0.0	0.0	9.6	4.9	7.5	2.4	0.0	0.7	2.0	1.8	9.7	10.7	9.5	15.6	15.9	27.1	63.2
1973	0.5	2.3	0.2	0.5	0.2	0.2	0.9	0.5	0.5	0.2	0.9	1.4	6.4	6.8	0.5	8.2	4.1	6.9	27.4
1974	0.5	1.1	0.2	0.5	0.5	0.9	0.9	1.4	0.2	0.9	2.3	2.7	13.2	20.9	5.9	11.8	5.9	9.4	60.4
1975	0.9	1.0	0.9	0.2	1.4	0.5	1.8	1.4	0.2	0.2	0.5	4.1	14.1	8.6	1.8	6.4	6.8	9.0	41.8
1976	0.2	1.4	0.5	0.5	0.5	0.9	4.1	1.8	0.5	0.9	1.4	2.7	11.8	8.2	1.8	5.9	6.4	12.7	36.8
1977	0.2	3.6	0.5	0.9	1.4	0.9	3.6	1.4	0.9	0.5	11.3	3.6	16.8	12.7	2.7	5.9	5.9	25.2	47.6
1978	2.0	5.0	0.5	6.0	0.5	1.0	2.0	4.0	1.0	1.0	7.0	1.0	14.0	11.0	3.0	6.0	5.0	30.0	40.0
1979	1.0	5.0	1.0	1.0	0.5	3.0	3.0	1.0	1.0	1.0	8.0	3.0	25.0	20.0	7.0	6.0	9.0	25.5	70.0
1980	4.0	3.0	3.0	4.0	4.0	4.0	4.0	0.5	1.0	1.0	7.0	4.0	18.0	16.0	6.0	7.0	12.0	35.5	63.0
1981	2.4	5.3	0.4	1.2	0.7	1.2	0.9	1.2	0.2	0.7	3.4	1.0	11.8	26.1	5.2	8.4	8.5	17.6	61.0
1982	1.7	5.4	0.4	1.1	0.8	0.2	1.8	0.5	0.9	0.4	5.8	2.7	6.9	14.1	6.8	4.5	11.6	19.0	46.6
1983	3.1	2.0	0.8	4.7	0.3	3.1	0.8	2.3	1.6	1.5	8.5	5.2	17.1	15.3	8.7	7.5	12.3	28.7	66.1
1984	3.8	6.7	6.0	2.6	6.7	3.3	2.2	2.5	0.0	0.2	8.1	0.7	6.5	9.8	1.7	2.7	24.0	42.1	45.4
1985	1.5	4.2	1.3	10.7	1.4	5.4	5.5	0.4	0.1	4.1	12.6	0.2	13.6	11.3	2.6	6.6	27.9	47.2	62.2
1986	3.4	4.6	0.2	7.0	4.3	6.7	7.4	1.3	0.4	1.1	9.2	2.2	31.2	50.8	9.6	10.6	45.6	45.6	150.0
1987	2.9	5.2	1.4	6.1	4.5	8.1	3.6	6.4	0.4	12.3	37.0	5.8	22.4	62.6	37.1	13.1	46.1	87.9	187.1

Table 11.8. Nominal rockfish longline catch by Statistical Area for the North Coast and the west coast of Vancouver Island, from British Columbia catch statistics, Annual Reports, 1956-87.

Year	Statistical Area																	NC	WC
	1	2	3	4	5	6	7	8	9	10	11	21	23	24	25	26	27	1-11	21-27
1956	0.2	1.5	0.0	0.1	0.0	0.6	3.1	0.2	0.3	1.0	0.7	0.1	0.6	1.5	0.0	2.2	18.8	7.7	23.2
1957	1.2	7.9	0.3	0.0	0.0	0.2	3.9	1.4	0.0	0.0	0.0	0.0	2.9	6.8	3.1	3.9	23.4	14.9	40.1
1958	0.1	0.5	0.1	0.0	0.0	0.3	0.6	1.5	0.0	0.0	0.0	0.8	1.0	0.0	6.0	6.8	17.7	3.1	32.3
1959	0.1	0.7	0.0	0.0	0.0	0.1	1.0	1.6	0.2	0.7	0.0	0.0	0.3	2.1	3.0	5.0	25.2	4.4	35.6
1960	1.6	6.9	0.3	1.5	0.1	0.8	0.0	1.5	2.0	0.1	3.0	0.0	0.6	1.2	5.9	5.2	25.7	17.8	38.6
1961	0.8	2.9	0.0	0.0	0.7	1.0	0.3	0.0	0.0	0.6	1.0	0.1	2.2	1.3	5.9	24.4	16.9	7.3	50.8
1962	0.0	13.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	1.8	0.4	3.2	2.5	5.6	23.5	21.0	17.2	56.2
1963	0.0	13.2	0.0	1.9	0.4	2.2	3.9	1.2	0.0	0.1	0.1	0.0	2.8	1.4	0.9	13.6	11.2	23.0	29.9
1964	0.0	2.5	0.0	0.2	0.0	0.2	0.0	0.3	0.0	0.8	0.7	1.5	1.1	1.0	0.8	8.6	14.9	4.7	27.9
1965	0.0	10.1	0.1	0.7	0.2	1.4	0.1	0.0	1.0	0.0	0.1	0.6	1.2	0.0	1.6	8.9	9.5	13.7	21.8
1966	2.7	3.7	0.0	0.2	0.0	1.1	3.4	0.3	0.4	0.8	0.0	0.1	1.4	0.0	1.7	14.3	8.4	12.6	25.9
1967	0.9	8.4	0.0	0.8	6.4	0.0	1.1	0.8	0.0	0.0	0.0	0.6	1.0	1.5	4.6	18.9	9.1	18.4	35.7
1968	1.5	1.3	0.0	0.0	0.0	0.0	1.2	2.0	0.0	0.0	0.0	0.1	2.7	0.0	1.4	6.7	17.1	6.0	28.0
1969	0.0	10.5	0.0	0.5	0.0	2.9	15.9	1.0	0.2	3.4	1.8	1.3	1.2	0.5	2.7	19.9	0.8	36.2	26.4
1970	0.0	12.7	0.0	0.2	3.8	24.4	9.3	6.8	0.0	0.4	1.2	0.5	4.2	3.6	0.9	8.2	8.4	58.8	25.8
1971	2.0	25.1	0.0	1.1	5.6	4.3	2.7	9.0	3.1	2.0	1.8	0.0	1.2	0.8	0.0	1.9	2.1	56.7	6.0
1972	0.0	19.0	0.0	2.6	4.9	0.3	7.5	6.4	0.5	0.0	6.0	0.3	1.1	0.0	0.5	8.6	7.2	47.2	17.7
1973	0.0	11.5	2.7	2.7	8.8	8.2	0.2	6.1	0.0	3.4	6.1	0.7	0.7	0.7	0.7	3.4	7.5	49.7	13.7
1974	0.7	36.3	0.7	8.8	11.6	15.0	0.2	4.1	0.0	1.6	3.4	0.0	0.7	0.7	0.0	1.4	4.1	82.4	6.9
1975	3.4	69.4	0.7	8.2	7.5	6.1	8.2	2.0	2.0	4.1	2.7	1.4	1.4	0.0	0.7	0.0	8.8	114.3	12.3
1976	4.1	17.3	0.9	1.8	9.1	5.4	19.5	4.5	0.0	1.4	2.7	2.7	1.8	0.2	0.2	0.2	12.2	66.7	17.3
1977	2.3	29.5	0.5	3.6	7.3	4.5	8.2	5.0	0.2	0.2	23.1	0.2	0.5	0.9	0.5	0.9	15.0	84.4	18.0
1978	3.0	51.0	8.0	14.0	5.0	4.0	11.0	8.0	1.0	0.5	9.0	0.0	1.0	2.0	0.5	1.0	13.0	114.5	17.5
1979	15.0	66.0	2.0	3.0	8.0	6.0	7.0	5.0	1.0	3.0	27.0	1.0	1.0	3.0	3.0	5.0	30.0	143.0	43.0
1980	22.0	61.0	1.0	3.0	4.0	5.0	4.0	3.0	1.0	0.5	20.0	0.5	6.0	0.5	4.0	7.0	22.0	124.5	40.0
1981	17.1	46.4	2.5	3.7	4.7	1.5	1.5	6.2	0.0	0.6	18.1	0.8	1.0	0.5	2.7	4.3	11.1	102.3	20.4
1982	8.2	33.5	2.1	3.7	1.7	5.2	2.6	1.1	0.9	0.3	11.3	0.4	1.1	2.9	0.0	2.0	10.5	70.6	16.9
1983	10.1	26.3	0.6	6.2	1.0	4.2	1.4	1.0	0.0	0.0	9.2	0.5	2.5	0.1	1.4	0.5	23.5	60.0	28.5
1984	8.3	81.6	2.6	12.0	1.0	1.7	2.3	0.6	0.5	2.9	13.8	0.8	6.5	1.3	0.0	0.9	63.3	127.3	72.8
1985	29.5	119.9	6.3	15.2	4.9	9.3	4.9	7.6	0.0	1.6	32.8	3.9	0.0	4.5	5.5	8.7	16.9	232.0	39.5
1986	24.9	159.8	3.7	9.4	14.5	18.2	5.1	19.7	0.1	0.3	55.9	2.0	36.3	56.9	75.6	76.8	116.3	311.6	363.9
1987	55.1	193.5	5.8	12.9	39.9	31.7	19.3	21.6	1.5	17.4	90.8	22.2	30.3	37.8	40.4	37.7	104.0	489.5	272.4

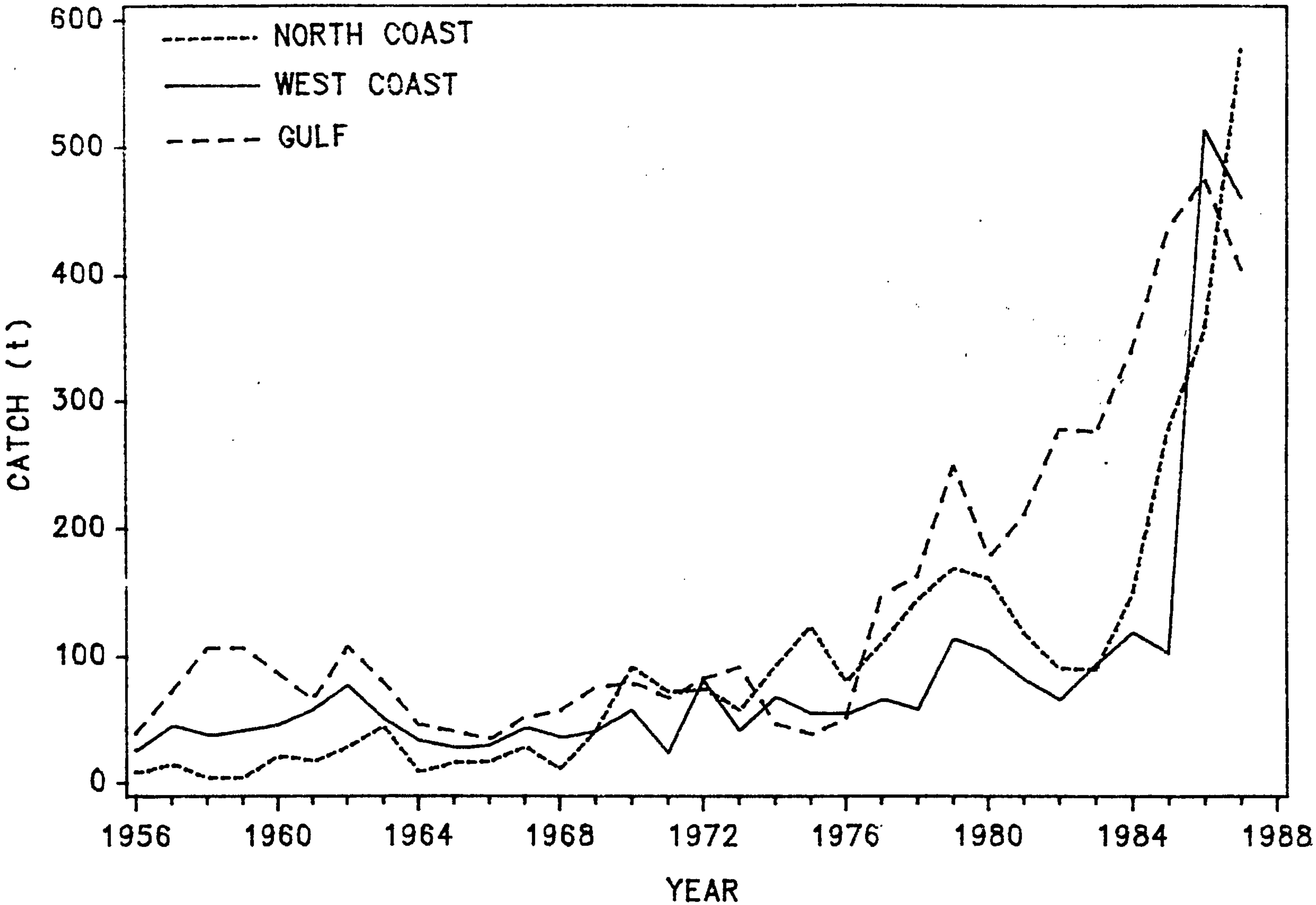


Fig. 11.1. Nominal rockfish handline/troll and longline catch from Area 4B (Gulf), the west coast of Vancouver Island, and the North Coast, 1956-87.

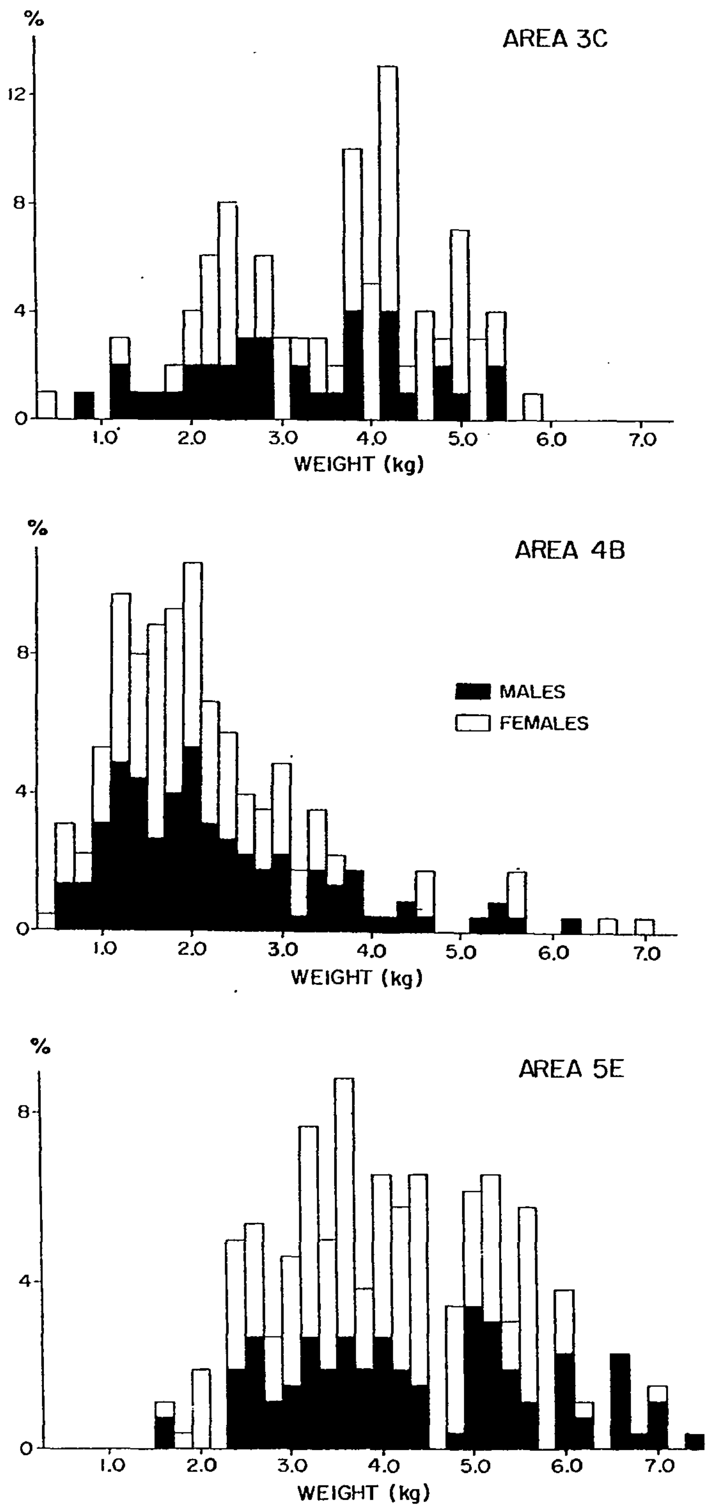


Fig. 11.2. Size frequency distribution by sex of commercial yelloweye rockfish samples from Area 4B (n=225) and Area 3C (n=100) in 1988 and Area 5E (n=260) in 1986.

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