Assessment of Groundfish Stocks Off the West Coast of Canada (1979)

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February 1980

Canadian Data Report of Fisheries and Aquatic Sciences No. 185

Government of Canada Fisheries and Oceans
Gouvernement du Canada Pêches et Océans

Canadian Data Report of Fisheries and Aquatic Sciences

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Cat. no. Fs 97-13/185 ISSN 0706-6465

ABSTRACT

Ketchen, K. S., editor. 1980. Assessment of groundfish stocks off the west coast of Canada (1979). Can. Data Rep. Fish. Aquat. Sci. No. 185: 213 P.

Fisheries Management (Pacific Region) requires a management plan for 1979 to deal with domestic and foreign fisheries for groundfish other than halibut in Canada's Pacific zone of extended jurisdiction. To meet this requirement, biological information -- much of it preliminary -- has been used to make best possible assessments of no fewer than 68 stocks representing 24 species of groundfish. Recommended total allowable catch (based on biological considerations only) for all stocks and species currently being exploited by Canada is 44,000 m.t. This compares with a Canadian catch of 31,000 m.t. in the preceding year, 1978. Inclusion of hake, a species yet to be fished domestically, raises the over-all total allowable catch to 89,000 m.t. Recommended total allowable catches are subject to management approval and are considered to be provisional, pending collection of more accurate information.

RÉSUMÉ

Ketchen, K. S., editor. 1980. Assessment of groundfish stocks off the west coast of Canada (1979). Can. Data Rep. Fish. Aquat. Sci. No. 185: 213 p.

Dans la zone portée à 200 milles dans la région du Pacifique, il fallait pour 1979 disposer d'un plan pour aménager la pêche, par les flottilles nationales et étrangères, des poissons de fond autres que le flétan. C'est ainsi que des données biologiques, pour la plupoart préliminaires, ont servi à évaluer le mieux possible les effectifs de pas moins que 68 stocks de 24 espèces. La prise totale permise qui a été recommandée (fondée uniquement sur les aspects biologiques) pour l'ensemble des stocks et des espèces actuellement pêchés au Canada, a été fixée à 44 000 tonnes métriques. L'an dernier, les prises canadiennes de ce genre de poissons se sont élevées à 31 000 t.m. Si l'on tient compte du merlu, espèce que le pays n'a pas encore exploitée, la prise totale permise s'élève à 89 000 t.m. Ces recommandations, à faire approuver par les gestionnaires des ressources halieutiques, ne sont que provisoires car des données plus exactes restent à recueillir.

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FOREWORD

This report contains proposed Total Allowable Catches (TACs) of groundfish for 1979 as recommended by scientists of the Resource Services Branch. They are based primarily on biological considerations, and may not necessarily be the same as those finally adopted by Fisheries Management, Pacific Region. The latter will be based on consultations which take into account not only biological considerations, but also economic, social, enforcement and other factors. As a consequence the TACs finally announced by Fisheries Management, may, in some cases be higher (but rarely lower) than those recommended by Resource Services.

SUMMARY

Staff of the Groundfish Program (Marine Fish Division, Resource Services) has reviewed and analysed all available information on important groundfish species (and albacore tuna) frequenting waters off the west coast of Canada, for the purpose of making stock assessments and recommending Total Allowable Catches (TACs) for 1979. The latter are consolidated in Table A and the following remarks summarize the conclusions.

Pacific ocean perch

Fisheries for Pacific ocean perch occur off west Vancouver Island (Areas 3C and 3D), in Queen Charlotte Sound (Areas 5A and 5B), and off west Queen Charlotte Islands (Area 5E)

Off west Vancouver Island, the stock(s) are severely depleted, and Canada-U.S. landings are negligible (barely 10% of pre-depletion levels). Low TACs of 50 m.t. for the Canadian portion of 3C, and 10 m.t. for Area 3D are deemed necessary to provide management flexibility with respect to fisheries for other species.

In Queen Charlotte Sound, Pacific ocean perch stock(s) are moderately depleted. Current Canada-U.S. landings are approximately one-third pre-depletion levels. Recommended TAC is 2,000 m.t., to provide for stock rehabilitation without drastic dislocation of the fishery. An additional limit of 200 m.t. is recommended for waters outside the Fishery Closing Line.

Off west Queen Charlotte Islands (Area 5E), Pacific ocean perch stocks north and south of 54°N lat. require individual attention. North of 54°, severe depletion is evident, and a rigorous rehabilitation is obviously necessary. South of 54°, exploitation has just begun on a modest-sized, apparently virgin population of old fish, with no evidence yet of abundant young fish for recruitment. Recommended TACs are 10 m.t. north of 54° lat. and 600 m.t. south of 54°N lat. (subject to mid-season review).

For the Canadian zone as a whole then the Pacific ocean perch TAC is 2,870 m.t.

Other Rockfish

Fisheries for rockfish species other than Pacific ocean perch occur in all areas, but the most important species (*Sebastes flavidus*, *S. pinniger*, *S. brevispinis*, *S. reedi*, and *S. paucispinis*) occur mainly on grounds off the open coast. Analytical difficulties arise because only recently have "other" rockfish landing records been segregated by species. Limited information available does not indicate serious stock depletion in any area.

For *S. flavidus*, principal production areas are west Vancouver Island (Areas 3B-3D), Queen Charlotte Sound (Areas 5A and 5B), and Hecate Strait (Areas 5C and 5D). Off Vancouver Island, most of the stock lies south of the provisional boundary between the 200-mile zones of Canada and United States. The recommended TAC for the Canadian portion of Areas 3C and 3D is 300 m.t. In Queen Charlotte Sound, recommended TAC is 3,000 m.t.; for Hecate Strait, 450 m.t. For the Canadian zone as a whole the recommended TAC is 3,850 m.t.

For *S. pinniger*, principal production areas are off northwest Vancouver Island (Area 3D) and Queen Charlotte Sound (Areas 5A and 5B), where recommended TACs are 500 and 60 m.t., respectively. Additional minor limits for other areas brings the total to 1,450 m.t.

For *S. brevispinis*, principal production areas are Queen Charlotte Sound (Areas 5A and 5B), Hecate Strait (Areas 5C and 5D), and off west Queen Charlotte Islands (Area 5E), where recommended TACs are 600, 300 and 750 m.t., respectively. These figures plus minor amounts for other areas bring the total to 1,500 m.t.

For *S. reedi*, principal production areas are Queen Charlotte Sound and off west Queen Charlotte Islands, where recommended TACs are 250 and 750 m.t. respectively. Of the former, 200 m.t. is to be the limit outside the Fishery Closing Line. Along with TACs for areas of minor importance the total is 1,150 m.t. For *S. paucispinis*, principal production areas are off northwest Vancouver Island (Area 3D) and Queen Charlotte Sound, where recommended TACs are 200 and 300 m.t., respectively. The total for all areas is 700 m.t.

For the remaining minor species recommended TACs are: *S. entomelas*, 550 m.t.; *S. proriger*, 625 m.t.; *S. aleutianus*, 150 m.t.; and *S. babcocki*, 340 m.t.

In summary, for the Canadian zone as a whole the recommended TAC for all Other rockfish is 10,475 m.t.

Sablefish (blackcod)

During the period 1973-77, the average annual landing of sablefish from the Canadian zone was 5,200 m.t., and in 1977, 4,150 m.t. Most of this was harvested by Japanese longline vessels. Estimates of maximum sustainable yield (MSY) from stock production models based on Japanese longline CPUE and fishing effort in the Canadian zone ranged from 3,400 to 6,200 m.t. per year. Recommended TAC will be 3,500 m.t. until the downward trend in CPUE has stabilized and a preliminary investigation of recruitment based on age composition data collected during 1977-78 can be completed. Additional recommendations are: (1) that the minimum size limit (4 lb or 1.8 kg, round weight; 55 cm FL; or 39 cm DL -- origin of first dorsal to fork of tail) be enforced aboard Japanese vessels as is in effect for Canada-U.S. vessels, and (2) that total catch estimates for processed catch weights be closely monitored to ensure accurate calculation of the total Japanese catch.

Pacific cod

Important fisheries for Pacific cod occur in all areas except off west Queen Charlotte Islands. Production fluctuates substantially among years due to extremely variable, and unpredictable, fluctuations in abundance. All stocks appear to be in satisfactory condition except that off southwest Vancouver Island (Area 3C). Recommended TACs for 1979, by area, are Georgia Strait, 900 m.t.; west Vancouver Island, 1,500 m.t.; Queen Charlotte Sound, 1,600 m.t.; and Hecate Strait, 2,000 m.t. for a coastwide total of 6,000 m.t. A further recommendation is that Area 3C be closed to all trawling during January-March to protect the predicted small spawning stock on Amphitrite Bank.

Lingcod

Important fisheries (primarily trawl) for lingcod exist off west Vancouver Island (Areas 3C and 3D) and in Queen Charlotte Sound (Area 5A-5B). The once-important line fishery in Georgia Strait (Area 4A) is now quite modest, and no explanation has been provided. Off west Vancouver Island, stocks appear to be in satisfactory condition, although annual production fluctuates fairly substantially. Recommended TAC is 800 m.t. for the Canadian portion of Area 3C, and 200 m.t. for Area 3D. In Queen Charlotte Sound, annual production has also fluctuated fairly substantially, but the gradual, long-term decline in CPUE causes some concern. Recommended TAC is 100 m.t. for Area 5A and 200 for Area 5B. Elsewhere TACs are nominal or not deemed necessary. Thus the total for the Canadian zone is 1,500 m.t.

Dogfish

Assessment of dogfish stocks has been hindered by the intermittent nature and type of fishery. A mathematical model has been developed to assess the overall potential production from the present dogfish stock, treating all dogfish in the Canadian zone as a single stock. Estimated MSY for large (> 78 cm) dogfish is 8,000-10,000 m.t., with approximately 3,000 m.t. assignable to Georgia Strait, site of the current fishery. Recommended TAC for Georgia Strait (Area 4B) is 3,000 m.t.; and for the remainder of Canadian waters, 6,000 m.t., for a total of 9,000 m.t.

Rock sole

Important fisheries for rock sole occur in Queen Charlotte Sound and Hecate Strait. In Queen Charlotte Sound, annual production has fluctuated moderately, but CPUE has exhibited no trend. In Hecate Strait, annual production has fluctuated moderately. CPUE exhibited no trend for Middle Hecate Strait, but in North Hecate Strait, CPUE levels are now lower than those during the mid- 1960s. Recommended TACs by area are: 150 m.t. in Queen Charlotte Sound; 300 m.t. in Middle Hecate Strait (Area 5C); and 500 m.t. in North Hecate Strait (Area 5D). Along with TACs for areas of minor important the total is 1,010 m.t.

Dover sole

Northern Hecate Strait is the only location of an important fishery for Dover sole in the Canadian zone, although modest quantities exist throughout the zone. In Northern Hecate Strait, Dover sole abundance has declined substantially in recent years. Recommended TAC is 200 m.t. for Northern Hecate Strait (Area 5D), and 10-100 m.t. elsewhere, except for free fishing off west Queen Charlotte Islands (Area 5E). For the coast as a whole the total is 520 m.t. In addition, it is recommended that Area 5E be closed to directed fishing for Dover sole during January-March, to protect spawning fish probably migrating from Area 5D.

English sole

Northern Hecate Strait (Area 5D) is the only location of an important English sole fishery in the Canadian zone. Generally, the Hecate Strait stock appears to be in good condition, although somewhat conflicting conclusions have been reached by independent analyses -- one concerned with environmental effects on stock abundance, and the other involving mathematical modelling with catch and effort statistics. Recommended TAC for North Hecate Strait (Area 5D) is 600 m.t., and for the coast as a whole, 820 m.t.

Petrale sole

No important directed fishery occurs in Canadian waters at the present time. Annual production has declined from 6,200 m.t. in 1948 to less than 500 m.t. in 1970, and since that time landings have averaged about 1,100 m.t. Published analyses by Canadian and United States scientists have concurred in the hypothesis that environmental factors were paramount in the decline of petrale stocks off Canada. Recommended TACs by area are 500 m.t. in Area 3C and 100 m.t. (applicable only to January-March) in Area 3D. Free fishing is recommended elsewhere. For the Canadian zone as a whole the total is 600 m.t.

Arrowtooth flounder (turbot)

Until 1972, processing problems precluded arrowtooth flounder from becoming an important component in the market for human consumption. Distribution is ubiquitous in Canadian waters. There is nothing to indicate that the "stocks" of arrowtooth flounder are fully utilized, although such a state may be approaching in some areas. Recommended TACs by area are: Georgia Strait (Area 4B), 50 m.t.; west Vancouver Island (Area 3C-3D), 400 m.t.; Queen Charlotte Sound (Area 5A-5B, 500 m.t.; Hecate Strait (Area 5C-5D), 2,100 m.t.; and off west Queen Charlotte Islands (Area 5E), 100 m.t. for a total of 3,150 m.t.

Butter sole

Commercial concentrations of butter sole occur in northern Hecate Strait (Area 5D) where the species was fished first for human consumption (1945-53) and later for animal food as well. Highest production (1,700 m.t.) was reached in 1952, and ranged from 120-910 m.t. in the succeeding 20 yr. From 1973 onwards, there have been no landings of butter sole, because of poor market conditions, and the stock is presumed to have returned to its primitive level of abundance. Free fishing is recommended on the main spawning grounds (Skidegate Inlet), but restrictions would be necessary if fishing were to resume on the summer feeding grounds (Hecate Strait flats) where the species mixes with juveniles of other, more valuable flatfishes.

Walleye pollock

Walleye pollock were not harvested for human consumption until 1976. Prior to 1975, modest quantities were landed intermittently for mink food. Estimated sustainable yields have been based primarily on surveys by research vessels. Recommended TACs, by area, are as follows: Georgia Strait (Area 4B) 4,000 m.t.; west Vancouver Island (Area 3C-3D), 500 m.t.; Queen Charlotte Sound and South Hecate Strait (Area 5A-5C), 1,300 m.t.; North Hecate Strait (Area 5D) 2,300 m.t.; and west coast Queen Charlotte Islands (Area 5E), 200 m.t., for a total of 8,300 m.t.

Pacific hake

Pacific hake are not exploited domestically in waters adjacent to Canada, and hence there are no fishery records to aid in stock assessment. Principal areas of hake abundance (in Canadian waters) are Georgia Strait (Area 4B) and seasonally off southwest Vancouver Island (Area 3C) as part of a stock occurring mainly off the United States coast. Recommended TAC for Georgia Strait is 10,000 m.t., and for Area 3C, 35,000 m.t., for a total of 45,000 m.t.

Albacore tuna

Albacore tuna is a pelagic species with a trans-Pacific and tropical to sub-tropical distribution. It makes seasonal migrations at various stages of its life history into the 200-mile zones of Japan, Mexico, U.S.A., and Canada. Stock definition is incomplete at this time, but some investigators believe that the current trans-Pacific fishery (ca 110,000 m.t.) is near MSY. It is recommended that no restraints be placed on Canadian fishing power or catch, until Japan and the United States, the major exploiters of albacore (98.8% of all production) issue an international call for controls.

Table A. A summary of recommended total allowable catches (TACs) of groundfish in waters along the British Columbia coast for 1979 (figures in metric tons).

Species	4B Strait of Georgia	3C[a] SW Vancouver Island	3D NW Vancouver Island	5A Cape Scott	5B Goose Island	5-4 Outside closing line	5C S Hecate Strait	5D N Hecate Strait	5E West coast Q.C.I.	Total Allow. catch in 1979	Total Can. catch in 1978
1. Ocean perch *Sebastes alutus*	-	50	10	2000		200	F[b]	F	610[c]	2870	3864
2. Other rockfish											
S. flavidus	F	100	200	3000		-	450		100	3850	2124
S. pinniger	F	100	500	600		-	150		100	1450	441
S. brevispinis	F	100	150	600		-	300		350	1500	1111
S. reedi	F	50	50	50		200	50		750	1150	1082
S. paucispinis	F	50	200	300		-	100		50	700	224
S. entomelas	F	100	50	250		-	50		100	550	201
S. proriger	F	50	50	75		150	50		250	625	258
S. aleutianus	F	-	-	-		-	-		150	150	135
S. babcocki	F	20	20	200		-	75		25	340	109
Others	F	F	F	F		160	F		F	160	924
3. Pacific cod	900	1500		1600[d]		-	2000		F	6000	6750
4. Blackcod	F	3500								3500	831
5. Lingcod	F[e]	800[e]	200[e]	100	200		200		F	1500	2003
6. Dogfish	3000	6000								9000	3126
7. Rock sole	20	40		50	100	-	300	500	F	1010	1313
8. Dover sole	40	100	40	30	100	-	10	200	F	520	736
9. English sole	90	40	F	10	10	-	70	600	F	820	809

Table A (continued)

	Species	4B Strait of Georgia	3C[a] SW Vancouver Island	3D NW Vancouver Island	5A Cape Scott	5B Goose Island	5-4 Outside closing line	5C S Hecate Strait	5D N Hecate Strait	5E West coast Q.C.I.	Total Allow. catch in 1979	Total Can. catch in 1978
10.	Petrale sole	-	500	100[f]	F	F	-	F	F	F	600	230
11.	Turbot	50	200	200	500 (5A–5B)		-	100	2000	100	3,150	2326
12.	Pollock	4,000	500 (3C–3D)		1300 (5A–5C)				2300	200	4,700	2407
13.	Hake	10,000	35,000[g] (3C–3D)								45,000	2
14.	Butter sole	-	-	-	-	-	-	-	F	-	-	7
Total groundfish											89,145	31,013[h]
Albacore		-	F	F	F	F	F	F	F	F		23

[a]Area 3C refers to that portion of the area lying within the Canadian zone.

[b]F means free fishing.

[c]Includes 10 m.t. north of 54°N. For all other Area 5E TACs, figures refer to south of 54°N.

[d]In addition to the TAC, a closure of the Amphitrite Bank area is recommended for January-March, inclusive.

[e]A closure from November 1 to April 15 inclusive, to all types of commercial and recreational fishing and free fishing (except where bag limits apply) for the remaining months for 4B but December-March in 3C/3D.

[f]The TAC applies to January-March, inclusive, with free fishing thereafter.

[g]A suggested increase over the 1977 and 1978 TACs on the assumption that the TAC for the entire Canada-U.S. coast will be revised to 200,000 m.t. in 1979.

[h]Excludes 770 m.t. of miscellaneous minor spp., unidentified flatfish spp., and unidentified spp.used as animal food or for reduction.

ACKNOWLEDGEMENTS

This document represents the first attempt to produce a comprehensive assessment of all commercially important groundfish stocks off the west coast of Canada together with recommendations on catch limits for 1979. It also represents a total effort on the part of all the staff of the Groundfish Program (Marine Fish Division, Resource Services Branch). Principal contributors are R. Beamish, A. Cass, R. Foucher, D. Fournier, K. Ketchen, R. Kieser, L. Lapi, B. Leaman, M. Stocker, F. Taylor, J. Thompson, J. Westrheim, P. Wickett and C. Wood. Numerous other members of the staff play key roles in the collection and processing of catch statistics, collection of biological data at sea and at ports of landing, and the analysis of results.

The Province of British Columbia's Department of Conservation and Recreation contributed significantly to the completion of this report by providing funds for employment of 18 people during the 1978/79 fiscal year to assist in field and laboratory studies being conducted by the Groundfish Program.

Editing of original drafts for scientific content and consistency of format was carried out by K. Ketchen, and W. E. Ricker kindly undertook to review the final draft and made valuable suggestions for improvements of its contents.

INTRODUCTION

In 1977, extension of jurisdiction to include management of fisheries within a 200-mile zone along Canada's west coast placed an obligation on Resource Services and its Groundfish Program to make annual assessments of the actual and potential productivity of stocks occurring within the zone. Assessment documents forming the basis for management actions in 1977 and 1978 were concerned with species/stocks which were of continuing interest to foreign nations (other than the U.S.A.). However, the requirement for all-inclusive assessment of stocks whether they are fished internationally or domestically was not long in coming, because by 1978 an almost explosive demand for quality fish products (stimulated in part by the indirect effects of extended jurisdiction) resulted in the development of new domestic fisheries and increased fishing pressure on stocks of traditional interest. The need for information on stock conditions and sustainable yields was made even more urgent by recognition of the fact that the reciprocal fishing privileges agreement between Canada and the United States, which essentially provided for free fishing within each other's zone, would have to be renegotiated with explicit catch limits on species/stocks of mutual interest.

The mounting demand for fish products in general and Canada's rapidly changing relationship with other countries fishing within the Canadian zone presage a new era in the west coast groundfish fishery -- an era characterized by rational management of resources through limitation of fishing effort, limitation of catch and other measures as may be required to achieve optimum sustainable yield.

To meet the responsibilities of this new era the Groundfish Program has produced a comprehensive assessment of stocks of almost all commercially important species occurring in waters adjacent to Canadian coast together with recommendations concerning their exploitation.

Definition of terms

With the advent of extended jurisdiction, the term Total Allowable Catch or TAC has become widely recognized as the maximum yield to be permitted from a stock in a given year. It is the ultimate management decision upon which national allocations are made. Not so widely accepted is a term describing the catch, which, on the basis of biological consideration alone, is recommended by scientists to managers. While Allowable Biological Catch (ABC) is gaining recognition in some circles, it has been decided for the time being to use the expression RECOMMENDED TAC in order to avoid confusion.

A recommended TAC is what the biologist considers to be a desirable level of catch based on whatever information is available on the condition of a stock; its vital statistics of growth and natural mortality; its geographical and bathymetric (depth) distribution; its association with other stocks/species; and its ability to withstand or respond to various fishing intensities. A stock may be at a level where it is capable of sustaining only a modest yield. A greater yield would reduce the stock while a lesser one would permit the stock to increase to a higher, more economically attractive level of abundance. The biologist may recommend a relatively low TAC in order to achieve the increase as quickly as possible, and the manager may accept the biologist's advice. On the other hand the manager may decide, in consultation with industry and economists, that the recommended TAC is so low that its adoption would disrupt the fishery and force fishermen to suspend their operation or turn to other species whose productivity might be decreased by the additional fishing effort. Faced with this prospect, the manager may opt for a higher level of yield and hence a longer period for the stock to increase, in which case the TAC would be more than that recommended by the biologist.

Stock assessment techniques

The reader will quickly note a lack of uniformity in the treatment of the numerous species/stocks covered by this report. To a large extent this is a reflection of the quality and quantity of data available for stock assessment and the extent to which such data submit to conventional analytical techniques. For the majority of stocks conclusions regarding stock condition and TACs, for want of sufficient time or reliable data, are based on a rather superficial review of recent trends in catch, fishing effort and catch per unit of effort (CPUE). For new fisheries there is of course no past history and hence insufficient data, except possibly for results of research vessel surveys, upon which to base tentative conclusions. Finally for only a very few stocks has it been possible to make use of sophisticated mathematical modelling to arrive at TAC recommendtions, which is not to say that the conclusions are necessarily any more reliable than those reached by more primitive means. Indeed, it is important for the reader, particularly the fisheries manager, to recognize that ALL RECOMMENDED TACs ARE AT BEST ROUGH APPROXIMATIONS SUBJECT TO REVIEW AND MID-SEASON REVISION.

Except where indicated, we are not yet in a position to set confidence limits to our estimated TACs. Some may be overly generous while others may be unduly stringent. However, because the history of groundfish fisheries elsewhere in the world has been one of overexploitation followed by sometimes fruitless efforts at restoration, we have generally taken a conservative approach to our recommendations. Only a few species (e.g. Pacific cod and possibly pollock) seemingly possess the ability to rebound quickly should the catch limit mistakenly be set too high. For most other species, and particularly the large group of rockfishes, which are characterized by relatively slow growth and low rates of reproduction, errors can take a long time to repair. Some already have been decimated by foreign and domestic fisheries during the past decade and may require a decade or more to return to levels where they will support economically viable operations. Thus, managers are cautioned to exercise circumspection in setting TACs and to recognize the need for flexibility during this initial stage of management where the approach to management must be on a rather empirical basis.

Four other guiding considerations deserve mention at this time:

First, it must be recognized that groundfish fisheries are of extreme complexity mainly because the numerous species/stocks inhabiting particular areas are intermixed, or at least so finely separated from one another that a TAC cannot be imposed on one without affecting others. Once the TAC of a target species is taken, fishing effort will automatically be diverted to other species in the same area or to other areas along the coast. Because of this chain reaction or domino effect, imposition of a TAC on one species/stock inevitably calls for a TAC on almost all other species/stocks.

Second, there are about 23 stocks (of roughly 10 species) which are sufficiently important to be regarded as primary targets. These major stocks cannot be exploited without the incidental catch of a number of minor species in what may appear to be trivial amounts but which, in fact, constitute overfishing. In such cases TACs are fully warranted. For other minor species which perhaps are underfished, our recommended TACs should be merely regarded as an acknowledgement or endorsement of the existence of a fishery. They should not be regarded as strict management proposals. TACs for minor species regardless of stock condition must be integrated with TACs for major target species and modified, where necessary in light of management strategy, to prevent premature closure of the more valuable fisheries for target species.

Third, Pacific cod, the most important species in the Canadian groundfish fishery, is subject to highly variable short-term fluctuations in abundance which are as yet unpredictable. Thus accurate estimation of TACs should not be expected. Figures for Pacific cod are subject to review and possible mid-season revision, much in the way the magnitude of salmon runs must be assessed while the fishery is in progress.

Fourth, in addition to Pacific cod and a variety of other traditionally important, but more stable contributors to the groundfish fishery, there are several large resources which are only new coming into production (pollock and dogfish); are as yet to be exploited (hake in inshore waters); or, for the lack of priority in earlier years, are only now being subjected to investigation (arrowtooth flounder and numerous rockfishes other than Pacific ocean perch). For these species the scientific basis for estimating TACs is understandably weak, and the figures provided can be little better than informed guesses.

With the substantially increased support recently provided for groundfish stock assessment investigations, accumulation of the basic information needed for management is progressing more rapidly, and with that, a growing capability to provide sound advice. In the meantime, it is of vital importance, as emphasized earlier, to recognize the provisional nature of the TACs contained in this report and the need for a review and revision process during the course of the 1979 fishery.

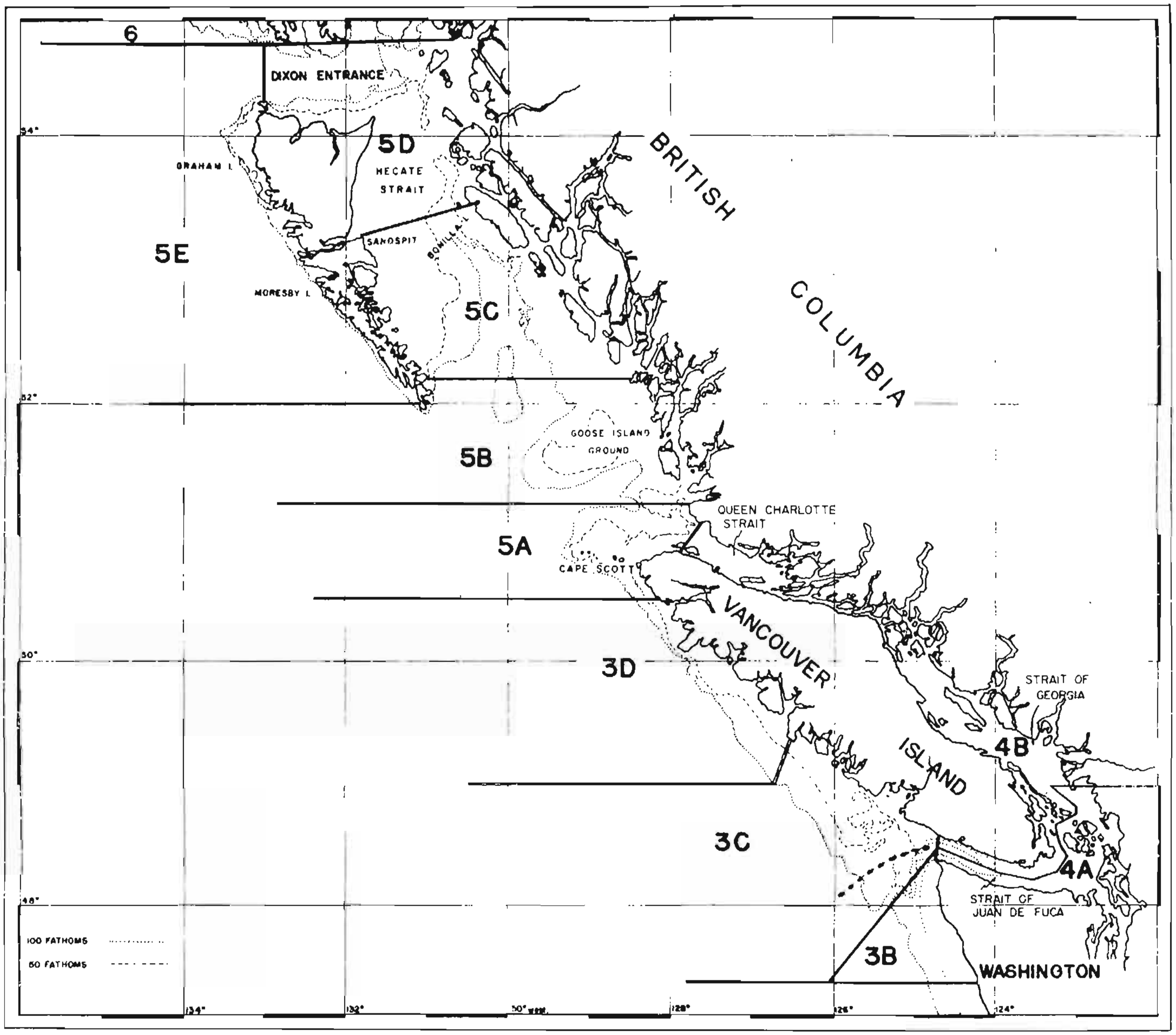

Fig. A. International (Pacific Marine Fisheries Commission) Statistical Areas along the British Columbia coast.

1. PACIFIC OCEAN PERCH STOCK ASSESSMENT

1.1 Introduction

Pacific ocean perch is the principal species in the rockfish catches off British Columbia. Commercially abundant stocks are located off West Queen Charlotte Islands, in Queen Charlotte Sound, off West Vancouver Island, and possibly in South Hecate Strait. The long-exploited stocks in Queen Charlotte Sound and off West Vancouver Island have been under joint study by Canadian and United States scientists since 1970. The West Queen Charlotte Islands stock was exploited exclusively by Japanese and USSR vessels prior to late 1976 when Canadian vessels began fishing inshore areas not available to foreign vessels. In South Hecate Strait, research vessel catch rates in 1973 and 1974 indicated the existence of a commercially abundant stock, but to date (September 1978) no commercial fishery has developed, despite declining catch rates on traditional grounds in Queen Charlotte Sound.

This report presents stock assessments for the various Pacific ocean perch stocks off British Columbia, by major region.

1.2 Vancouver Area (Area 3B, 3C, and 3D)

The Vancouver Area encompasses waters off West Vancouver Island and Northwest Washington State (approximating Statistical Area 3D, 3C, and 3B). Off West Vancouver Island (Area 3D and 3C), Pacific ocean perch ranks fourth in importance (12%), based on quantities landed, behind Pacific cod (33%), lingcod (21%), and other rockfish (17%). Canadian share of Pacific ocean perch landings has been negligible from the Vancouver Area.

Canada-U.S. landings from the Vancouver Area have declined substantially since 1966 when the Japanese and USSR vessels began fishing in the region. Currently, about 75% of the Canada-U.S. landings originate from the U.S. portion of the Vancouver Area.

The following section of this report was extracted from the draft update (to 1977) of the Canada-U.S. stock assessment report by Gunderson et al. (1976).

1.2.1 Catch and CPUE

North American (U.S.-Canada) landings for 1977 in the Vancouver Area were 945 m.t. (Table 1.1). This continues an upward trend since 1974 when catches were at an all-time low of 287 m.t. This catch, however, remains well below the 2,000 to 4,000 m.t. level existent in the early and mid-1960's. The non-North American landings have remained relatively low since 1975, and in 1977 were effectively zero in the Vancouver Area. In 1977, the U.S. prohibited all non-North American fishing in its zone and Canada allowed only incidental landings from the Canadian zone of the Vancouver Area.

Washington trawl CPUE declined from 0.308 m.t./hr in 1976 to 0.260 m.t./hr in 1977. CPUE values also remained below the levels observed in the early and mid-1960's.

1.2.2 Age composition

Age composition data (Table 1.2) demonstrate the importance of strong year-classes to the fishery. These data show the progression of a group of strong year-classes centered around the 1961 year-class. In 1976 and 1977, another group of strong year-classes became evident which were centered around the 1970 year-class. The absolute strength of this group is unknown but in a relative sense appears to be rather strong. Similar appearances of these year-classes have occurred in Oregon landings and U.S. research vessel catches in the Columbia Area, and Canadian research vessel catches in Queen Charlotte Sound.

Recruitment of the 1961 year-class was observed to begin restoring abundance to former levels in 1970 (Gunderson et al. 1977). However, exploitation rates remained high and as a result this year-class was cropped off as it recruited to the fishing grounds. The same fate may be in store for year-classes centered around 1970. Indeed, in the Columbia Area (off Oregon) such has already come to pass. The 1970 year-class was greatly diminished while still only 6-7 years of age.

1.2.3 Biological statistics

Survival rates (S) and instantaneous total mortality rates (Z) of 14-18 year old perch were estimated for 1974-75, 1975-76, and 1976-77 (Table 1.3). As in previous assessments the Jackson method was used as follows:

$$S \doteqdot \frac{Y_{15} + Y_{16} + Y_{17} + Y_{18}}{Y_{14} + Y_{15} + Y_{16} + Y_{17}},$$

where Y_n = number of n age fish per unit of effort.

Estimates of Z in recent years have been generally lower than estimates from the late 1960's. Assuming, as has been done in the past, that M (instantaneous natural mortality rate) = 0.15, corresponding estimates of F (instantaneous fishing mortality rate) have consequently also decreased. In 1976-77, F = 0.10 -- the lowest value observed so far. This continues a generally declining trend since 1967-69 when heaviest removals occurred and F values ranged from 0.31 to 0.51.

1.2.4 Biomass estimates

The first biomass estimates available for the Vancouver Area was for 1966-68 when the mean landings (13,419 m.t.) were divided by the calculated exploitation rate (0.39) to yield an estimate of 34,000 m.t. (Westrheim et al. 1972). Subsequent estimates have been obtained by observing the decline in succeeding mean, weighted Washington CPUE values. These biomass estimates were 18,700 m.t. for 1969-71 (Technical Subcommittee, 1972) and 16,700 m.t. for 1972-74 (Gunderson et al. 1977).

Using this same technique we have calculated a mean 1975-77 biomass as follows:

Mean 1966-68 biomass of marketable fish = 34,000 m.t.
Mean, weighted 1966-68 Washington CPUE = 0.538 m.t./hr
Mean, weighted 1975-77 Washington CPUE = 0.281 m.t./hr
Mean 1975-77 biomass in the Vancouver Area =

$$\frac{0.281}{0.538}\ (34{,}000) = 17{,}800 \text{ m.t.}$$

In 1977, two additional biomass estimates were available. The first was from the 1977 U.S. rockfish survey and was calculated to be 10,304 m.t. This estimate was arrived at by expanding the survey estimate of 7,728 m.t. for the U.S. zone to the entire Vancouver Area by assuming U.S. fishing patterns (75% of the 1972-76 landings were from the U.S. zone) were proportional to actual stock distribution.

The second estimate from the results of a cohort analysis (Gunderson, pers. comm.) for Pacific ocean perch stocks in the Vancouver Area was 15,157 m.t. at M = 0.15 for 1976-77.

From these various estimates, biomass of Pacific ocean perch in the Vancouver area appears to be in the range of 10,000-18,000 m.t.

1.2.5 Exploitation rate

Once biomass estimates become available exploitation rate can be calculated directly from:

$$\mu = \frac{\text{catch}}{\text{biomass}}.$$

In the Vancouver Area, using the three sources of available data, estimates of μ are:

1. Survey data:

$$\mu = \frac{\text{1977 catch}}{\text{1977 survey biomass}} = \frac{945}{10{,}304} = 0.09$$

2. Fishery (weighted CPUE) data;

$$\mu = \frac{\text{mean 1975-77 catch}}{\text{mean 1975-77 biomass}} = \frac{1{,}095}{17{,}800} = 0.06$$

3. Cohort analysis data:

$$\mu = \frac{\text{mean 1976-77 catch}}{\text{mean 1976-77 biomass}} = \frac{1{,}171}{15{,}157} = 0.08$$

1.2.6 Stock condition

Stock condition remains poor but the recent appearance of a strong 1970 year-class, control of non-North American fishing, and low fishing and exploitation rates by North American fishermen should promote a rebuilding of the stock, providing the new year-classes are not fished prematurely.

Note: Canada-U.S. stock assessment considered Vancouver Area as a whole, but current management strategies must also consider the possibility of individual stocks of Pacific ocean perch within the Vancouver Area. Little information is available on latitudinal stock segregation, but the Washington State landing records by WSFD[1] Sub-area suggest that such stocks might exist (Table 1.4). Principal sub-areas, based on production, are Estevan (Sub-area 6), Ucluelet (Sub-area 8), and Cape Flattery Spit (Sub-area 13). These clusters of adult fish may not necessarily be genetically distinct. We do not yet understand the recruitment mechanism from larvae to adult, but adult fish do not appear to undertake latitudinal migrations. The peaks in catch in 1970 probably represent recruitment of the 1961-62 year-classes.

It is perhaps significant that recruitment appeared to be prolonged in the Cape Flattery Spit sub-area, where Japanese and USSR trawlers were excluded after the mid-1970's by the terms of bilateral agreements with the United States.

1.2.7 Recommendations

The Pacific perch stock(s) off West Vancouver Island are severely depleted, and the Canada-U.S. landings are negligible (barely 10% of pre-depletion levels). Small TACs of 50 m.t. for the Canadian portion of Area 3C and 10 m.t. for Area 3D are deemed necessary to provide management flexibility with respect to other fisheries. Research vessels will monitor the ocean perch stocks.

1.3 Queen Charlotte Sound (Areas 5A and 5B)

Pacific ocean perch is the most important species landed by the Canada-United States trawl fleet from Queen Charlotte Sound -- 43% of the mean annual landings during 1965-1974 (Westrheim 1977). Other important species are other rockfish (26%) and Pacific cod (12%). Canada-U.S. landings have declined steadily since USSR and Japanese trawlers began fishing, in 1965 and 1966, respectively.

The current view regarding distribution of Pacific ocean perch stocks in Queen Charlotte Sound may be summarized as follows: during the period from early winter to early spring, the species concentrates in relatively deep water on grounds to the west of the Cape St. James-Cape Scott fishery closing line. It is at this time of the year that vulnerability to foreign (principally Japanese) trawlers is highest. By May the perch begin an eastward migration, entering the

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[1] Washington State Department of Fisheries.

Goose Island and Mitchell's Gullies where they become available to the Canada-U.S. fishery until November-December, when they once again move westward. The picture is complicated by evidence that there may be a stock resident in deepwater which does not engage in the inshore-offshore movement and hence has been vulnerable to foreign fishing throughout the year.

Joint Canada-U.S. stock assessments were published for the period to 1970 (Westrheim et al, 1972) and 1974 (Gunderson et al. 1976). Parts of the present report are adapted from the draft update (for 1977) of the last published report.

1.3.1 Catch and CPUE

Canada-U.S. landings for 1977 in Queen Charlotte Sound were 2,104 m.t. (Table 1.5) -- a slight increase over 1976, but the second lowest annual total since 1962, when market demand was low. Japan was the only other nation participating in this fishery in 1977, reporting 980 m.t. of rockfishes caught during June-August within an allocation of 1,000 m.t. This catch, taken west of the fishery closing line, was reported as consisting of about 95% Pacific ocean perch, whereas, estimates made by Canadian observers aboard the Japanese vessels were as low as 11%. In 1976, the last year the Japanese fishery operated without regulation, the total catch of so-called Pacific ocean perch was reported as 1,882 m.t., a substantial decrease from the 1974 peak of 7,983 m.t., and the 1969 peak of 6,268 m.t.

CPUE in 1977 was 0.671 m.t./hr for Canadian vessels and 0.420 m.t./hr for United States vessels (Table 1.5). Canadian CPUE continues to decline from the 1973 peak of 1.234 m.t./hr and the 1960-66 plateau of 0.939-1.297 m.t./hr. United States CPUE in 1977 was slightly higher than that in 1976 (0.361 m.t./hr), but was also substantially lower than the 1973 peak of 0.812 m.t./hr and still lower than the 1966 peak of 1.132 m.t./hr.

Detailed records of the 1977 U.S. catch statistics for Goose Island and Mitchell's Gullies are not available at this time (October 1978).

Detailed catch statistics of Japanese vessels operating off Queen Charlotte Sound indicate declining trends, for the April-September and October-March fisheries in all-species catch (Table 1.6), and for so-called Pacific ocean perch catch and CPUE (Table 1.7). For ocean perch, April-September production from Block 029503 (Table 1.5), the most productive, declined from 3,773 m.t. in 1974 to 382 m.t. in 1976. Corresponding CPUE values were 2.699 m.t./hr and 0.550 m.t./hr, respectively. Similarly for October-March, production declined from 2,730 m.t. in 1973-74 to 213 m.t. for 1975-76. Corresponding CPUE values were 3.750 m.t./hr and 1.566 m.t./hr, respectively. The October-March fishery is considered to exploit the same ocean perch stock exploited by the Canada-U.S. vessels inside Queen Charlotte Sound during April-October[2]. The April-September fishery is considered to exploit primarily an offshore stock of ocean perch which does not migrate into Queen Charlotte Sound, where the Canada-U.S. fishery takes place.

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[2] Subsequent to publication of the report by Gunderson et al. (1977), data on the Japanese fishery have been rearranged to correspond better with the hypothesis that most of the Queen Charlotte Sound Pacific ocean perch were available to Japanese vessels only during the period December to April. Re-analysis is still in progress.

1.3.2 Age composition

Heretofore, age composition of Pacific ocean perch landed from Queen Charlotte Sound by Canada-U.S. vessels had been reported in numbers landed per hour trawled, and various estimates of mortality rates were derived from these data. In recent years, the relationship between landings and CPUE has raised doubts about the validity of CPUE as an index of abundance for ocean perch. Specifically, during 1970-77, Canada-U.S. landings declined substantially, despite a strong market, but nominal CPUE values for Canadian and United States vessels imperfectly reflected this decline. Canadian CPUE values remained relatively constant during 1972-76, and United States CPUE values remained relatively constant during 1970-74. Canadian scientists are investigating this situation, and their initial efforts are directed to standardizing effort. In the meantime, age composition will be reported in qualitative terms (‰) until the CPUE problem can be resolved.

Age composition of Pacific ocean perch landed by Canadian vessels from Queen Charlotte Sound continues to reflect variation in year-class strength (Table 1.8). In Goose Island Gully, the 1977 age composition was multi-modal at ages 7, 11, 14, and 19. The 1963 year-class retained its dominance established in 1975. This relative dominance is probably by default, as the 1961-62 year-classes, which had been dominant in research vessel catches since 1964, were greatly reduced by fishing prior to what appears to have been delayed entry of the 1963 year-class. For Mitchell's Gully, the 1977 age composition was also multi-modal, but at ages 9, 12, and 18. Dominant year-class was 1965, compared to 1963 in 1975, and 1962 in 1973.

1.3.3 Biomass estimates

Since 1965, Canadian scientists have used the swept-area method to estimate the biomass of marketable ($\geq$ 31 cm) Pacific ocean perch in Queen Charlotte Sound. Nine such estimates have been made for Goose Island Gully, and six for Mitchell's Gully -- with mixed results (Table 1.9). United States scientists made one estimate, in 1976, for Goose Island Gully. The methodology is currently undergoing a rigorous review, and hence the absolute values are not necessarily accepted at this time. Nevertheless, the relative decline in biomass values is considered to reflect the decline in abundance of Pacific ocean perch.

1.3.4 Stock condition

Quantitative assessment of Pacific ocean perch stocks in and off Queen Charlotte Sound is difficult at present, in part because of unresolved problems with CPUE for Canada-U.S. fleet, species composition of catches by Japanese trawlers, and methodology for estimating biomass. However, production records alone clearly indicate that abundance of Pacific ocean perch has declined substantially during the last 10 years, and that since 1970, the Japanese fishery has been the principal cause of this decline.

In 1978 Japan was denied an allocation of Pacific ocean perch and Other rockfish, and North American vessels were limited to 2,500 m.t. Continued restrictions are required in order to effect recovery of the stock to a more economically attractive level.

1.3.5 Recommendations

A TAC of 2,000 m.t. is recommended, based on the Canada-U.S. landings in 1976 (1,967 m.t.) and 1977 (2,104 m.t.). Abundance of recruiting year-classes appears to be increasing now. The 1969-70 group appear to be particularly abundant. If the removals are limited to 2,000 m.t./annum, stock rehabilitation should proceed satisfactorily without drastic dislocation of the fishery.

1.4 West Queen Charlotte Islands (Area 5E)

Rockfish exploitation off West Queen Charlotte Islands, Area 5E was initiated by USSR trawlers in 1965, followed by Japanese vessels in 1966. Soviet vessels abandoned the fishery by 1970, and Canadian vessels entered the fishery in late 1976. Available catch records for USSR vessels are inadequate for analysis. Catch records for Japanese vessels are generally good, but are lacking in accurate species segregation.

The USSR-Japanese fishery was centered north of 54°00'N lat.-- 80% of the Japanese catch was taken in one offshore, 30-mi × 30-mi block (033540). The Canadian fishery has centered on inshore grounds south of 54°00'N, and appears to be exploiting a stock of ocean perch not accessible to the foreign fleets.

1.4.1 Production

The production trend for the foreign fishery for rockfish is the now-familiar brief period of high catches followed by a precipitous decline, and then a levelling off at a substantially lower level. In this case, catches were: 25,000 m.t. in 1965; 17,000 m.t. in 1966; 5,000 m.t. in 1967; and about 2,000 m.t. during 1971-76 (Table 1.10). We suspect that ocean perch may not have been the principal species in the catches after 1967. No significant concentrations were located during the G.B. REED survey off Langara Spit (Block 033540)[3] during August 1970 (Westrheim 1972). The peak in 1968 (8,000 m.t.) and subsequent sustained production of ca 2,000 m.t./yr probably reflects targetting from 1968 onwards on rough-bottom rockfish species, which were also noted in the G.B. REED echograms in 1970. In 1977, Canadian observers aboard Japanese trawlers reported that Pacific ocean perch amounted to 23% of the rockfish catches in Block 033540, while the captains' estimates averaged 52%.

The production trend for the domestic fishery is difficult to assess because the fishery is less than two years old. During January-July 1977, Canadian landings totalled 1,158 m.t., and during January-July 1978, 1,035 m.t. (Table 1.10). These represented 60% and 59%, respectively, of the Canadian rockfish landings from Area 5E. In 1978, the Canadian fishery remained south of 54°N lat., but expanded into new grounds. Comparable catch and CPUE data for Buck Point and Rennell Sound are shown on the following page, and suggest a fairly substantial decline in abundance.

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[3] Japanese statistical grid system that indicates the southeast longitude-latitude corner of each block.

January-July		Rennell Sound	Buck Point
1977	Catch (m.t.)	747.54	287.59
	CPUE (m.t./hr)	2.42	1.91
1978	Catch (m.t.)	234.00	193.76
	CPUE (m.t./hr)	1.56	1.30

Off Rennell Sound, catch dropped 69% and CPUE, 36%, while at Buck Point, corresponding declines were 33% and 32%. For Area 5E as a whole, Pacific ocean perch catches have decreased 16%, although effort increased 7%.

Size and age composition data are limited, but the salient feature is that ocean perch are large (mode 42-44 cm in 1977 and 1978) and old (mode 21 yr in 1977). This suggests a virgin stock of old fish with no significant recruitment in sight, unless the younger fish are abundant on untrawlable bottom.

1.4.2 Stock condition

Pacific ocean perch stocks in Area 5E north and south of 54°00'N lat. require individual consideration. North of 54°, severe depletion is evident, and a rigorous rehabilitation program is obviously necessary. South of 54°, exploitation has just begun on a modest-sized, apparently virgin population of old fish, with no evidence yet of abundant young fish for recruitment. Until more definitive information becomes available, a most conservative policy for exploitation is necessary.

1.4.3 Recommendations

It is recommended that the 1979 TAC north of 54°00'N be 10 m.t. to provide for incidental catches. Should a substantial fishery develop on other species this TAC should be reviewed in mid-season. For waters south of 54°00'N the TAC should be 600 m.t., likewise subject to mid-season review.

Table 1.1. Pacific ocean perch catch (m.t.) by nation and CPUE (m.t./hr) for United States vessels in the Vancouver area, 1956-77.

Year	Canada-U.S.A.	Japan	U.S.S.R.	Bulgaria[a]	Poland	E. Germany[a]	Total	CPUE (m.t./hr) U.S.A.
1956	1,084	-	-	-	-	-	1,084	?
1957	1,154	-	-	-	-	-	1,154	?
1958	675	-	-	-	-	-	675	?
1959	968	-	-	-	-	-	968	0.341
1960	1,575	-	--	-	-	-	1,575	0.254
1961	2,485	-	-	-	-	-	2,485	0.327
1962	3,857	-	-	-	-	-	3,857	0.350
1963	3,867	-	-	-	-	-	3,867	0.435
1964	2,499	-	-	-	-	-	2,499	0.404
1965	3,046	-	500	-	-	-	3,546	0.718
1966	2,358	few	14,000	-	-	-	16,358+	0.640
1967	805	6,678	6,000	-	-	-	13,483	0.434
1968	552	4,751	5,114	-	-	-	10,417	0.247
1969	583	1,787	1,040	-	-	-	3,410	0.242
1970	1,955	2,186	182	-	-	-	4,323	0.298
1971	1,155	1,838	900	-	-	-	3,893	0.317
1972	624	1,580	401	-	-	-	2,605	0.312
1973	344	2,989	490	-	-	-	3,823	0.228
1974	287	1,084	70	-	32	-	1,473	0.202
1975	440	352	152	-	-	-	944	0.271
1976	876	286	187	23	-	25	1,397	0.308
1977	945	T	T	T	T	T	945	0.260

[a] Estimates assuming similar fishing patterns and catch composition as the U.S.S.R. fleet.

T = Trace.

Table 1.2. Age composition (no./hr) of Pacific ocean perch in U.S. commercial landings from the Vancouver area, 1966-77.

Age (yr)	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
5	-	1	-	-	1	-	1	2	1	3	5	1
6	-	1	1	-	2	-	2	3	1	4	20	7
7	-	8	2	3	8	5	7	6	2	4	18	37
8	-	8	3	6	32	16	20	8	5	6	25	15
9	10	17	7	3	104	69	44	26	16	16	25	18
10	33	36	15	17	72	124	93	63	41	36	51	22
11	111	61	27	44	54	69	141	106	72	52	69	36
12	152	73	50	87	46	50	56	117	89	54	65	37
13	211	96	51	87	41	37	32	48	66	50	48	35
14	128	80	48	59	46	37	29	23	25	47	36	30
15	103	52	44	63	40	35	25	20	18	11	23	21
16	75	49	36	27	48	31	25	17	13	12	11	18
17	37	45	27	7	32	25	16	18	12	12	10	12
18	23	25	21	10	22	12	19	14	11	11	9	9
19	26	19	16	4	12	11	10	13	7	10	6	9
20	0	9	13	-	6	6	4	9	7	5	7	7
21	19	3	7	-	2	3	4	6	7	3	3	3
22	-	4	4	-	-	1	3	2	5	2	5	1
23	-	1	1	-	-	-	1	1	3	2	3	1
24	-	1	-	-	-	-	-	-	1	1	4[a]	-
Total	928	589	373	417	568	531	532	502	402	341	443	319
No. of otoliths	216	707	502	296	1,124	1,460	1,036	1,335	1,598	1,103	1,023	1,097

[a]Age 24 = 3, age 25 = 1.

Table 1.3. Biological statistics for 14-18 yr old Pacific ocean perch in the Vancouver area.

Year	Survival (S) estimator	S	A	Z	F
1966-67	$\frac{52+49+45+25+19}{128+103+75+37+23}$	0.52	0.48	0.66	0.51
1967-68	$\frac{44+36+27+21+16}{80+52+49+45+25}$	0.57	0.43	0.56	0.41
1968-69	$\frac{63+27+7+10+4}{48+44+36+27+21}$	0.63	0.37	0.46	0.31
1969-70	$\frac{40+48+32+22+12}{59+63+27+7+10}$	0.93	0.07	0.08	[a]
1970-71	$\frac{35+31+25+12+11}{46+40+48+32+22}$	0.61	0.39	0.50	0.35
1971-72	$\frac{25+25+16+19+10}{37+35+31+25+12}$	0.68	0.32	0.39	0.24
1972-73	$\frac{20+17+18+14+13}{29+25+25+16+19}$	0.72	0.28	0.33	0.18
1973-74	$\frac{18+13+12+11+7}{23+20+17+18+14}$	0.66	0.34	0.42	0.27
1974-75	$\frac{11+12+12+11+10}{25+18+13+12+11}$	0.71	0.29	0.34	0.19
1975-76	$\frac{23+11+10+9+6}{47+11+12+12+11}$	0.63	0.37	0.46	0.31
1976-77	$\frac{21+18+12+9+9}{36+23+11+10+9}$	0.78	0.22	0.25	0.10

[a]The estimation procedure produced unrealistically low values of Z and F.

Table 1.4. Washington State landings (1,000 lb) of Pacific ocean perch from Area 3D, 3C, and 3B, by sub-area, 1963-76.

	Area 3D			Area 3C					Area 3B		
Year[a]	Cape Cook (4)	Esperanza (5)	Estevan (6)	Sydney Inlet (7)	Ucluelet (8)	Forty-Mile (10)	Swiftsure (11)	Cape Flattery Spit (13)	Flattery (12)	Quillayote (14)	Destruction Island (15)
1963	1	29	1,753	46	2,124	770	-	2,414	601	122	445
1964	3	42	917	21	998	180	-	1,362	302	173	518
1965	-	9	501	11	2,229	984	-	2,366	189	27	212
1966	41	4	349	51	1,039	272	-	2,747	164	237	129
1967	T	2	178	34	599	39	-	739	107	4	24
1968	18	23	106	5	76	11	-	327	61	531	1
1969	-	65	179	5	84	9	-	578	85	245	13
1970	-	158	345	15	156	556	-	866	56	172	341
1971	6	57	113	5	66	24	-	870	93	205	144
1972	7	63	117	8	77	201	-	320	20	46	251
1973	-	7	78	-	2	96	-	330	83	44	115
1974	-	7	38	-	41	14	-	480	18	13	20
1975	-	3	116	2	8	60	-	445	144	15	158
1976	-	22	119	-	19	123	1	1,247	26	122	246

[a] No published records for years prior to 1963.

Table 1.5. Pacific ocean perch catch (m.t.) by nation and CPUE (m.t./hr) for Canadian and U.S. vessels in Queen Charlotte Sound, 1956-77.

	Catch (m.t.)				CPUE (m.t./hr)	
Year	Canada-U.S.A.	Japan	U.S.S.R.[a]	Total	Canada	U.S.A.
1956	1,236	-	-	1,236	-	-
1957	758	-	-	758	-	-
1958	933	-	-	933	-	-
1959	1,915	-	-	1,915	-	0.672
1960	1,680	-	-	1,680	1.139	0.577
1961	1,201	-	-	1,201	1.116	0.654
1962	1,838	-	-	1,838	1.034	0.661
1963	3,712	-	-	3,712	1.297	0.841
1964	3,507	-	-	3,507	0.939	0.731
1965	4,889	-	7,000	11,889	1.285	1.040
1966	8,254	few	18,800	27,054+	1.270	1.132
1967	5,745	3,196	17,800	26,741	0.884	0.800
1968	6,051	5,614	1,827	13,492	0.963	0.722
1969	6,628	6,268	55	12,951	0.743	0.656
1970	6,077	3,775	2	9,854	0.674	0.710
1971	4,165	702	few	4,867+	0.567	0.670
1972	5,561	2,281	0	7,842	0.941	0.710
1973	3,626	958	0	4,584	1.234	0.812
1974	3,618	7,983	0	11,601	0.961	0.610
1975	2,707	3,888	0	6,590	0.808	0.486
1976	1,967	1,182	0	3,046	0.848	0.361
1977	2,104	980	0	3,084	0.671	0.420

[a] Soviet statistics are currently undergoing re-evaluation, as their accuracy is suspect.

Table 1.6. All-species catch (m.t.) effort (hr), and CPUE (m.t./hr) for Japanese trawlers operating off Queen Charlotte Sound (50°30'N-51°59'N) by season, by area, 1967-76.[a]

	April-September				October-March		
Year	m.t.	hr	m.t/hr	Year	m.t.	hr	m.t./hr
				50°30'N-50°59'N			
1967	381	33	11.546	1967-68	461	103	4,476
1968	616	185	3.330	1968-69	578	90	6,422
1969	1,696	368	4,609	1969-70	443	123	3.602
1970	-	0	-	1970-71	-	0	-
1971	114	9	12.667	1971-72	371	51	7.275
1972	1,186	150	7,907	1972-73	2,659	543	4.897
1973	2,334	104	22.442	1973-74	5,071	728	6.966
1974	6,757	1,398	4.833	1974-75	3,004	615	4.949
1975	3,098	768	4.034	1975-76	598	136	4.937
1976	1,836	694	2.646				
				51°00'N-51°29'N			
1967	602	50	12.040	1967-68	2,782	916	3.037
1968	1,393	344	4.049	1968-69	1,917	546	3.511
1969	1,151	444	2.592	1969-70	1,891	545	3.470
1970	1,120	219	5.114	1970-71	1,164	193	6.031
1971	6	5	1.200	1971-72	793	146	5.432
1972	423	60	7.050	1972-73	1,875	379	4.947
1973	1,077	166	6.448	1973-74	1,571	307	5.117
1974	546	120	4.550	1974-75	412	109	3.780
1975	1,273	372	3.422	1975-76	927	205	4.522
1976	265	114	2.325				
				51°31'N-51°59'N			
1967	177	22	8.046	1967-68	458	53	8.642
1968	730	137	5.329	1968-69	1,589	399	3.983
1969	401	99	4.051	1969-70	591	111	5.324
1970	5	8	0.625	1970-71	-	0	-
1971	-	0	-	1971-72	62	5	12.400
1972	10	2	5.000	1972-73	28	11	2.546
1973	102	19	5.368	1973-74	88	28	3.143
1974	19	9	2.111	1974-75	0	0	0
1975	50	10	5.000	1975-76	0	0	0
1976	23	12	1.917				

[a]Among areas, percent rockfish (including Pacific ocean perch) was 90, 89, and 86, respectively, from south to north.

Table 1.7. Pacific ocean perch catch (m.t.), effort (hr), and CPUE (m.t./hr) for Japanese trawlers operating off Queen Charlotte Sound (50°30'N-51°59'N) by season, by area, 1967-76.

April-September				October-March			
Year	m.t.	hr	m.t./hr	Year	m.t.	hr	m.t./hr
				50°30'N-50°59'N			
1967	260	33	7.879	1967-68	248	103	2.408
1968	559	185	3.022	1968-69	505	90	5.611
1969	1,274	368	3.462	1969-70	275	123	2.236
1970	-	0	-	1970-71	-	0	-
1971	110	9	12.222	1971-72	336	51	6.588
1972	861	150	5.740	1972-73	503	543	0.926
1973	133	104	1.279	1973-74	2,730	728	3.750
1974	3,773	1,398	2.699	1974-75	957	615	1.556
1975	1,716	768	2.234	1975-76	213	136	1.566
1976	382	694	0.550				
				51°00'N-51°29'N			
1967	421	53	8.420	1967-68	2,118	916	2.312
1968	1,174	344	3.413	1968-69	1,554	546	2.846
1969	869	444	1.957	1969-70	1,428	545	2.620
1970	939	219	4.288	1970-71	875	193	4.534
1971	5	5	1.000	1971-72	693	146	4.747
1972	375	60	6.250	1972-73	190	379	0.501
1973	290	166	1.747	1973-74	912	307	2.971
1974	250	120	2.083	1974-75	238	109	2.183
1975	750	372	2.016	1975-76	490	205	2.390
1976	112	114	0.982				
				51°30'N-51°59'N			
1967	101	22	4.591	1967-68	183	53	3.453
1968	607	137	4.431	1968-69	1,282	399	3.213
1969	373	99	3.768	1969-70	545	111	4.910
1970	4	8	0.500	1970-71	-	0	-
1971	-	0	-	1971-72	60	5	12.000
1972	10	2	5.000	1972-73	26	11	2.364
1973	18	19	0.947	1973-74	53	28	1.893
1974	10	9	1.111	1974-75	0	0	0
1975	21	10	2.100	1975-76	0	0	0
1976	3	12	0.250				

Table 1.8. Pacific ocean perch age composition (‰) in Canadian landings from Queen Charlotte Sound, by Gully, 1963-77.

Age (yr)	Goose Island Gully								Mitchells Gully		
	1963	1965	1967	1969	1971	1973	1975	1977	1973	1975	1977
4	-	-	-	-	-	1	-	1	-	-	-
5	3	1	-	6	1	0	2	6	1	6	-
6	0	3	4	3	10	0	0	8	1	11	3
7	11	2	0	22	39	4	0	41	13	8	54
8	16	5	1	50	26	18	5	38	20	5	61
9	34	25	13	76	88	63	20	44	36	51	105
10	69	51	39	53	225	91	49	55	54	110	61
11	207	66	63	46	91	207	75	126	122	146	126
12	174	169	97	43	33	195	119	118	100	228	129
13	167	273	138	108	19	63	108	147	44	188	116
14	79	137	168	86	48	36	54	150	54	54	95
15	46	73	173	109	35	19	53	93	62	37	51
16	42	36	86	97	85	40	59	33	67	24	31
17	38	37	57	78	66	34	69	11	85	30	17
18	36	26	61	64	51	41	76	13	73	29	37
19	32	31	32	37	82	44	53	24	66	30	20
20	18	18	25	32	23	40	81	22	67	18	20
> 20	30	47	41	90	78	103	176	70	134	25	71
Total	1,002	1,000	998	1,000	1,000	999	999	1,000	999	1,000	997

Table 1.9. Biomass estimates (m.t.) for marketable ($\geq$ 31 cm) Pacific ocean perch in Queen Charlotte Sound, by Gully, 1965-77.

Year	Month	Mitchells Gully (m.t.)	Goose Island Gully (m.t.)
1965	August	-	63,600
1966	August	-	45,500
1967	September	-	54,200
1969	September	-	51,800
1970	June	-	36,800
1971	August	20,600	-
	October	-	39,100
1972	June	8,300	-
1973	September	18,600	22,300
1974	September	20,600	-
1976	September (Canada)	19,400	33,100
	(U.S.A.)	-	18,900
1977	August	11,200	23,000

Table 1.10. Reported "Pacific ocean perch" production off the west coast of the Queen Charlotte Islands (PMFC Area 5E). Catches in m.t. and CPUE in m.t./hr.

Year	U.S.S.R.[a]	Japan	Canada	Total	Japan CPUE
1964	-	-	-	-	-
1965	24,740	-	-	24,740	-
1966	15,896	300	-	16,196	4.17
1967	2,847	5,216	-	8,163	3.71
1968	1,054	8,042	-	9,096	2.57
1969	159	4,169	-	4,328	2.46
1970	-	1,894	-	1,671	2.12
1971	-	3,033	-	3,033	2.62
1972	-	4,469	-	4,469	2.95
1973	-	3,514	-	3,514	2.40
1974	-	2,442	-	2,442	1.73
1975	-	1,833	-	1,833	1.11
1976	-	1,992	-	1,992	1.20
1977	-	1,270	1,551	2,821	0.91

[a]All U.S.S.R. statistics are estimated from surveillance and are in process of revision.

2. STOCK ASSESSMENT OF ROCKFISHES OTHER THAN PACIFIC OCEAN PERCH

2.1 Introduction

Until the mid-1970's rockfish other than Pacific ocean perch received little attention from Canadian fishermen because of poor market demand. In contrast, United States fishermen have been much more active in exploiting these species, but it has not been until relatively recent years that catches have been accurately identified by species. Hence historical records are of little or no value in making assessments of stock conditions and potential. This is a grave deficiency, for as a group, rockfishes are slow growing and long-lived, taking 6 to 10 years to reach commercial size and in most cases even longer to reach maturity. They comprise a "low volume" production system, unable to sustain yields which represent more than about 10-20% of the standing stock. Thus rockfish stocks are highly vulnerable to overfishing.

The present analysis, limited as it is by sketchy information, deals individually with five major species (Sebastes flavidus, S. pinniger, S. brevispinis, S. reedi and S. paucispinis) whose annual harvests may already be at or beyond the level of MSY; three minor species S. proriger, S. entomelas, and S. aleutianus whose potential may go unrealized because of the likely management requirements for the major species; and a third group of species (S. babcocki, S. borealis, S. ruberrimus, and others) which, because of their relatively low growth rates and extensive mixing with faster growing species, are being or are likely to be overexploited regardless of the management regimes imposed on the major species. Finally, there is a group of species (S. crameri, S. diploproa, Sebastolobus alascanus) for which there is currently no market because of their small average size.

2.2 Sebastes flavidus (Yellowtail rockfish)

2.2.1 Summary of catch statistics

There has been a historical fishery by U.S. vessels in Canadian waters since the mid-1960's, however Canadian vessels did not land S. flavidus in quantity until after 1970, primarily due to marketing constraints. Unfortunately, we have poor resolution of species catches by area in U.S. data and must make some extrapolations and interpolations from the two data bases. Specifically, there is no breakdown of U.S. catches available for major or minor statistical areas; thus S. flavidus landings (for Areas 3C and 3D) have been interpolated from those reported for the INPFC Vancouver area which encompasses Areas 3B, 3C, and 3D; similarly for the 5A-5B areas and INPFC Charlotte area. The species composition of landings by INPFC areas (Wash. Dept. Fish. Tech. Rep. 34) are somewhat suspect, however, since the landings by species interpolated from these data are often at considerable odds with known Canadian catches (Table 2.1).

The fishery for Sebastes flavidus is divided into four general areas which are roughly encompassed by PMFC Areas 3C, 3D, 5A-5B and 5C-5D. Landings from other areas are minor and incidental in occurrence. The lack of significant landings of S. flavidus from between these four areas argues for individual area mangement. While no definite conclusions can be reached about genetically distinct stock units, there are sufficient geographic barriers (deep submarine canyons) between these exploited groups to justify some stock distinction, based upon the generally observed behaviour of shelf rockfish species. It is on this basis that the populations of S. flavidus in these four areas will be treated as separate stock units. In so doing, the inconclusive nature of available information is acknowledged and the current assignment of stock units may well be modified as better data are obtained.

2.2.1.1 Southwest coast of Vancouver Island (Area 3C)

Canadian landings of S. flavidus from Area 3C have traditionally been from north of the published median line between the Canadian and U.S. zones of extended jurisdiction. Only in 1977 were there significant Canadian landings from south of the line.

Total landings of S. flavidus underwent a substantial decline from 1969-75, and were accompanied by a similar decline in CPUE for U.S. vessels (which applied the majority of fishing pressure -- Table 2.1). In 1976, however, many of the U.S. vessels fishing in the Canadian zone began using a new, modified Norwegian trawl which had an increase in vertical opening of approximately 50% (up to ~31 ft) over conventional trawls. This net would be expected to have a considerably greater catching power for species such as S. flavidus, which tend to school vertically over the bottom. In fact, the U.S. catch of S. flavidus from Area 3C did increase considerably (600+ %) in 1976 and 1977, over that of previous years. This increased catch and CPUE did not appear to be derived from recruitment of a strong new year-class into the fishery since the size/age composition of sampled landings did not change. The data imply therefore, that either the availability or the vulnerability of the fish had increased. The former may be verified if CPUE for Canadian vessels which have fished consistently with the same gear, over the periods and areas in question, had increased commensurately with that of U.S. vessels. It is only in that area closest to the U.S.-Canada boundary that any increase in Canadian CPUE had taken place during 1975-76, but such evidence is based on only 10 hr fishing effort. In 1977, however, the CPUE of Canadian vessels fishing for S. flavidus on Swiftsure Bank well to the north of the boundary (Minor Area 21) was very high (1.02 m.t./hr) up until the time the fishery was closed, and this catch rate was associated with significant fishing effort (176 hr). The remainder of Area 3C showed no evident trend in catch rates for S. flavidus, as might be expected where no directed fishery occurs.

We have, then, two somewhat dichotomous trends evident in these data: (1) a decreasing catch and catch rate for S. flavidus by U.S. vessels up until 1976 after which these values increased, possibly as the consequence of gear improvement; and (2) a concomitant increase in the catch rate by Canadian vessels since 1975, in that area where directed fishing takes place. While the 1975 and 1976 values were associated with very low fishing effort, the 1977 catch rate was high and resulted from substantial fishing effort.

2.2.1.2 Condition of resource and assessment for 1978/79 (Area 3C)

The quantity of *S. flavidus* in the Canadian portion of Area 3C is evidently very small. The substantial increase in landings during 1977 was restricted to grounds south of the median line, where 78% of the catch originated. Unfortunately, we have little information, aside from CPUE data, upon which to assess the abundance of the species in this area, and even then the U.S. CPUE data involves nominal rather than species-specific effort.

There was a substantial decline in U.S. CPUE from 1969 through 1975 in the 3C-3B area. As noted in Section 2.2.1.1, many U.S. vessels switched to new gear sometime in 1976, which could well have resulted in the increased CPUE noted. It is difficult to provide objective assessment of the change in CPUE of the U.S. fishery since Canadian CPUE also increased in 1976, when one Canadian trawler began fishing in the traditional U.S. fishing areas. What is obvious, however, is that removals of up to 1,500 m.t./yr (1968-69) precipitated declines in CPUE despite subsequent decreases in effort. If a measure of instantaneous natural mortality (M) represents what might be the exploitable proportion of the population on a sustainable basis then:

1,500 m.t.> M × (Equilibrium biomass of exploitable stock)[4]

Since the best available estimate of M is 0.2, the biomass of standing stock in 1968-69 must have been less than 15,000 m.t. in the 3B-3C area (and smaller still in Area 3C alone).

There are two other estimates of the biomass of *S. flavidus* in the 3B-3C area. In 1977, the United States conducted a biomass survey of rockfishes in the California-Washington region using bottom trawls. For the U.S. segment of the 3B-3C area, the estimated biomass of *S. flavidus* was 11,480 m.t. ± 98%. Imposing the previous rationale with regard to sustainable yields, an estimated equilibrium yield (EY) from this biomass would be 2,296 m.t./yr. Canada has conducted hydroacoustic biomass estimates in Area 3C and part of Area 3B periodically from 1974-1976. The following table presents the estimated biomass of marketable *S. flavidus* obtained in these surveys:

Year/month	*S. flavidus* biomass
1974 Aug.	14,279 m.t.
Oct.	2,541 m.t.
1975 Sept.	2,666 m.t.
Nov.	42 m.t.
1976 Nov.	1,696 m.t.

The 1974 estimate is an obvious anomaly, but it was noted that 1974 biomass estimates for all species surveyed were exceptionally high. No explanation of these high values is available but the surveyors did state that while checks

[4] Equilibrium Biomass = (.5)(Virgin Biomass)(after Gulland, 1970)

had been performed, equipment malfunction could not be ruled out. The lack of other substantiating evidence of high abundance in 1974 (CPUE for the U.S. fleet was one of the lowest on record) would argue that the August, 1974 estimates were inaccurate. Mean estimate of S. flavidus biomass in the 1975-76 period would then be 1,736 m.t. for the 3C area, resulting in an EY of approximately 347 m.t.

A fourth estimator of population biomass and EY can be obtained through examination of the historical record of catch and CPUE using the Leslie-Davis method. In applying this method there are several conceptual assumptions which must be justified: (1) the data must apply to a unit stock in which there is equilibrium between annual recruitment and annual losses due to natural mortality; (2) the catchability of the stock, q, must be approximately constant over the time interval considered; and (3) the estimates of K_t must be reliable. Assumption (2) regarding catchability is suspect considering the aforementioned gear changes in 1976 and the fact that although landings of S. flavidus were recorded in 1967, the fishery by U.S. vessels did not begin in earnest until 1968. The catch data were, therefore, progressively resolved to take into consideration these constraints. In general, the errors noted would result in some over-estimation of N_0, the initial population. The results of these examinations are presented below:

Catch data[a]	CPUE data[b]	r	No	EY
1967-1977	1967-1977	-0.399	9,877 m.t.	990 m.t.
1967-1977	1968-1977	-0.774	6,685 m.t.	670 m.t.
1967-1975	1967-1975	-0.863	5,321 m.t.	530 m.t.
1967-1975	1968-1975	-0.863	5,443 m.t.	540 m.t.

[a]North American catch.
[b]U.S. nominal S. flavidus CPUE

Original population size is thus estimated to be in the range 9,877-5,321 m.t., although the low correlation coefficient for the highest value should be noted. One would intuitively have less confidence in this value since the poor correlation results from a single data point, generated prior to the development of the major fishery. The most probable values arising from this type of analysis then would yield N_0 in the range 6,685-5,443 m.t. and concomitant EY values of 530-670 m.t./yr.

In summary, the following information is available for S. flavidus in the 3B-3C areas.

Year	Biomass estimate	Source	EY estimate
1966	6,685-5321 m.t.	Regression	530-670 m.t./yr
1968-69	< 15,000	Trend analysis	< 1,500 m.t./yr
1974	2,541-[14,279][a]	Hydroacoustic survey	500-[2,860][a] m.t./yr
1975	42-2,666	Hydroacoustic survey	8-530 m.t./yr
1976	1,696	Hydroacoustic survey	340 m.t./yr
1977	11,480	Trawl survey	2,296 m.t./yr

[a]Questionable value.

For lack of secondary supporting evidence two figures of EY in these these data appear extremely high, the higher 1974 estimate and the 1977 trawl survey estimate. It is also significant to note that following removal of 1,072 m.t. of S. flavidus in 1976, U.S. CPUE fell 47% in 1977; a further indication that the sustainable yield from this stock at its current level of abundance is probably well below 1,000 m.t./yr. The 1975-1976 hydroacoustic surveys infer EY's of 400-500 m.t. (if the fishery had reduced virgin biomass by roughly one-half) and considering the 1976-1977 removals the lower figure is adopted as EY_{79} here, i.e. 400 m.t. for the 3B-3C area, of which only a small segment (possibly 20%) applies to water within Canadian jurisdiction.

2.2.1.3 Recommendation

A TAC of 100 m.t. is recommended for the Canadian portion of Area 3C. The probable transboundary nature of the stock implies close cooperation with the United States in its management of that part of the stock lying within the U.S. zone.

2.2.2.1 Northwest coast of Vancouver Island (Area 3D)

Landings of S. flavidus by Canadian vessels from this area have always been small (< 35 m.t. annually -- Table 2.1), the fishery being largely composed of landings of lingcod and S. pinniger. Similarily, U.S. landings of S. flavidus from 3D have been low (< 150 m.t./yr) however, their relative importance has increased in recent years possibly due to decreases in the catches of the predominant species S. pinniger.

The impact of the short-lived but large removals of S. flavidus and S. entomelas by the Polish trawl fleet in 1975 and 1976 is difficult to assess due to the effect of markets on domestic catches and the differences in fishing gears used by the domestic and foreign fleets. Species composition of the 1975 Polish catch was 6,700 m.t. of S. flavidus, 6,125 m.t. of S. entomelas and 48 m.t. of other rockfish; fishing effort was ~6,265 hr. In 1976, 2,339 m.t. of S. flavidus, 1,364 m.t. of S. entomelas, 211 m.t. of S. pinniger and 17 m.t. of other rockfish were caught by Polish vessels; fishing effort was 4,950 hr. Nominal CPUE of the Polish fleet thus fell some 59% in one year. While the North American catches of S. flavidus and S. pinniger did drop in 1976, following the large 1975 Polish fishery, the catch of S. flavidus increased again in 1977 (when fishery restrictions were in effect). The catches of S. flavidus obtained by Poland were made through the use of midwater nets, whereas the North American fleet relies almost exclusively on bottom trawls. It may thus be possible that the initial lack of evident effects of the Polish fishery on domestic catches is a result of the exploitation of different segments of the population by the two fleets. The long-term effects of the Polish fishery may only be discernible if more domestic vessels begin using midwater gear in this area; however, the large decreases in nominal CPUE experienced by the Polish fleet infers a decrease in the abundance of S. flavidus.

2.2.2.2 Condition of resource and assessment for 1978-79 (Area 3D)

The S. flavidus stock currently exploited by domestic vessels in Area 3D is evidently small (a 1976 hydroacoustic survey indicated a biomass of 315 m.t.) and catches are primarily incidental. Only 12% of the total effort expended during 1978 resulted in catches were S. flavidus was ≥25% of the total catch. Qualified (25%) CPUE for 1978 Canadian catches is essentially unchanged from 1977 (Table 2.2). Nominal CPUE has undergone no significant changes in recent years, rather has followed a somewhat erratic course. Given the incidental nature of the domestic fishery for the species in this area but also considering the Polish fishery of 1975-76, it would appear unwise to allow the catch to exceed 200 m.t. until more information on the state of the stock can be ascertained.

2.2.2.3 Recommendation

Given the incidental nature of the domestic fishery for the species in this area but also considering the 1975-76 Polish fishery, it is recommended that a provisional TAC of 200 m.t. be set and that any changes in the nature of the fishery be monitored closely.

2.2.3.1 Queen Charlotte Sound (Areas 5A-5B)

The two major areas into which Queen Charlotte Sound has been divided have been the traditional North American fishing areas for S. flavidus. Primary areas of catch are the southeast edge of Goose Island Bank and the Cape Scott Spit. Peak landings occurred in 1973 and have since declined substantially, although there was some improvement in 1977 (Table 2.1). U.S. landings have been the prime determinant in the trend of total North American landings in Queen Charlotte Sound and the substantial decline in total landings since 1973 is totally reflective of the U.S. landings. Nominal CPUE[5] of the U.S. fleet has decreased 67% between the peak year, 1973, and 1977.

Over the same period Canadian landings have undergone a decrease, followed by major increases in the past three years. CPUE of Canadian vessels fishing in Area 5B also peaked in 1973, although the 5A CPUE trend has been erratic. Again, marketing constraints confound the understanding of some of the observed trends in landings and CPUE of the Canadian fleet.

2.2.3.2 Condition of resource and assessment for 1978-79 (Area 5A-5B)

CPUE data from the Canadian fleet and nominal CPUE data for the U.S. fleet do not indicate any major stock abundance problems in Areas 5A-5B. Both fleets have shown an increase in CPUE in 1977 and 1978 despite increased effort. At least part of this increase may be due to the shift in fishing effort from S. alutus, which has undergone substantial reduction in recent years. The size composition of commercial samples of S. flavidus has not shifted to a smaller mean size as is evident in Area 3C. Indeed, the size structure (and presumably age structure) of the Queen Charlotte Sound fish has remained relatively constant in recent years. Age composition of the stock suggests that there may be a relatively stronger 1967 year-class entering the fishery, although this is associated with a slight decrease in the relative abundance of the dominant year-class and should be monitored closely.

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[5]Based upon effort for all shelf rockfish; species effort is not available.

A secondary consideration, as in the 3C area, is the use of new gear in the fishery. Domestic vessels are experimenting with midwater and high-opening nets to which S. flavidus is susceptible. The fishery will need to be monitored to determine if, for example, midwater fishing exploits juveniles before they enter a bottom trawl fishery.

The most recent data available from the Canadian fishery indicates that both unqualified and qualified (25%) CPUE for S. flavidus have increased in 1978 over that in 1977. While this is encouraging of itself, it should be noted that there has been no U.S. fishing effort since mid-June. A decrease in overall fishing effort might permit increases in school sizes of rockfish and concomitantly higher catch rates.

2.2.3.3 Recommendation

A TAC of 3,000 m.t. is recommended for the 5A-5B area.

2.2.4.1 Hecate Strait (Areas 5C-5D)

S. flavidus has only recently attained any significance in landings from Hecate Strait where it is now caught only by Canadian vessels (Table 2.1). Prior to 1976, landings averaged < 40 m.t./yr. While trawl effort for this species has increased considerably in the past two years, it has not yet developed into a truly directed fishery, but there is evidence that in 1978 Canadian fishermen are beginning to target on this species.

Gross estimates of CPUE suggest a decline in abundance since 1971-72, but the small size of the catch in the early years make this conclusion suspect.

2.2.4.2 Condition of resource and assessment for 1978-79 (Area 5C-5D)

The incidental nature of the fishery for S. flavidus in this area until 1976 was noted in Section 2.2.4.1. The species-specific S. flavidus CPUE declined 39% between 1976 and 1977 but has recovered 17% of that drop in 1978 despite increased trawling effort (Table 2.1). Qualified (25%) CPUE has declined slightly (13%) in 1978 but is associated with a 96% increase in qualified effort.

Size composition of the stock has remained relatively constant, although the number of samples is small. Size frequencies indicate the possible presence of a strong, incoming 1967 year-class, which was also noted for Queen Charlotte Sound.

In light of this limited evidence, controlled growth of the fishery would seem in order, but special attention should be given to Area 5D (Northern Hecate Strait) where indication of reduced CPUE is most pronounced.

2.2.4.3 Recommendation

A TAC of 450 m.t. is recommended for the 5C-5D area.

2.2.5.1 Foreign catches (coastwide)

Except as noted previously for the Polish fleet in Area 3D, the incidence of S. flavidus in foreign catches has been relatively minor. This has been largely a result of targetting on S. alutus in deep water; the overlap of depth range for these two species is very small. The incidence of S. flavidus in foreign catches is primarily an inferred conclusion because it was only subsequent to 1976 that accurate species composition data of rockfishes in foreign catches were obtained. The only significant quantities of S. flavidus landed in 1977 were from Sub-zone 5-2 (Area 3C) in the hake fishery. There were no records of S. flavidus catch by foreign (non-North American) vessels during 1977 in Sub-zones 5-5 or 5-4 (i.e. to seaward of Queen Charlotte Sound, Areas 5A and 5B, and off the Queen Charlotte Islands and Dixon Entrance, Area 5E).

2.2.6.1 Condition of resource and assessment for 1978-79 (Area 5E)

There is no significant fishery for S. flavidus in this area, however there are substantial concentrations of unidentified rockfishes in shallow water which are presently inaccessible to trawl fishing. In view of the rapidly evolving nature of the fishery, imposition of at least provisional catch limits might be a desirable safeguard.

2.2.6.2 Recommendation

A TAC of 100 m.t. is recommended for that part of Area 5E south of 54°00'N.

2.3 Sebastes pinniger (Canary rockfish)

2.3.1 Summary of catch statistics

The exploitation of S. pinniger has been almost exclusively undertaken by North American trawlers, mainly because the depth distribution of the species places it well within territorial waters. North American landings, effort (where known) and CPUE for this species are presented by major area in Table 2.3. In lieu of more detailed information, the same segregation of stocks as was proposed for S. flavidus will be adopted here i.e. 3C, 3D, 5A-5B, 5C-5D and 5E.

2.3.1.1 Southwest coast of Vancouver Island (Area 3C)

Landings of S. pinniger in this area by Canadian vessels have always been minor except in 1977 when 120 m.t. were recorded. Approximately one-half of this total was taken from south of the present Canada-U.S. boundary region, so that the landings from traditional Canadian fishing areas have not markedly changed. Lowered landings in the early 1970's may have been the result of market conditions rather than stock abundance changes, since increased CPUE in more recent years has resulted from increased effort, as well.

United States catches averaged approximately 450 m.t./yr from 1967-71 but decreased in the early 1970's. Landings recovered in 1975 and 1976; 1977 catches were obtained under fishery restrictions (early closure upon attainment of the TAC for all rockfishes) and may not accurately reflect stock conditions.

2.3.1.2 Condition of resource and assessment for 1978-79 (Area 3C)

As was the case with *S. flavidus*, the majority of the landings in Area 3C originate south of the median line and the largest proportion of the stock thus comes under U.S. management control. Nonetheless, a total stock examination is required before delimiting a Canadian zone TAC.

The 1977 U.S. trawl survey in the U.S. segment of the 3B-3C area estimated a biomass of 19,940 m.t. ± 168% of *S. pinniger*. The best estimate of M for the species is 0.2. Applying the rationale of EY = M × Equilibrium Biomass would then result in an estimated equilibrium yield of 2,000 m.t. (if the fishery had not significantly reduced N_0) for the U.S. part of 3B-3C area. In contrast to this estimate is the decreasing CPUE trend noted in the early years of the fishery at a catch level substantially below that suggested by the biomass survey. It would thus be prudent to heed evidence provided by the fishery when assessing the validity of the 2,000 m.t. TAC. These data infer that a catch level of ~600 m.t./yr may not be sustainable.

Catch data for the early years (1967-69) of the U.S. fishery for *S. pinniger* showed a decline in the nominal CPUE (Table 2.3). A trend analysis of this initial segment of the data suggests that the initial population may have been approximately 4,080 m.t. and that EY would be ~400 m.t./yr. While this value may be somewhat more realistic than that suggested by the 1977 trawl survey, it should be noted that the observed decreases in CPUE were: (a) restricted to three years, after which CPUE rose (although accompanied by decreased effort), and (b) associated with catches of only ~450 m.t./yr. The 400 m.t. EY suggested by the regression analysis might therefore be excessive.

There is an almost total lack of biological data for *S. pinniger* in Area 3C, as commercial landings were sampled only in 1967 and 1975. The size frequency data such as they are suggest that increased catches in 1975 may have resulted from the recruitment of a strong year-class to the fishery. However, this may merely be a reflection of bathymetric size-segregation, since the samples taken in 1967 and 1975 were from markedly different depths.

In summary, there are three suggested EY's for *S. pinniger* in the 3B-3C area; about 2,000 m.t. as estimated from the 1977 biomass survey, 400 m.t. from the partial regression analysis and 600 m.t. from the trend analysis. Decreases in CPUE observed in the early years of the fishery argue that the first EY estimate is excessive. It is concluded that EY estimated through examination of trends in catch statistics and partial regression analysis, while rather unsound mathematically, is the most probable level of EY for the stock. As was the case with *S. flavidus*, only a segment of this TAC would normally be obtained from Canadian waters.

2.3.1.3 Recommendation

A TAC of 100 m.t. is recommended for the Canadian segment of Area 3C.

2.3.2.1 Northwest coast of Vancouver Island

This area has traditionally produced the majority of landings by the North American fleet. Total landings peaked in 1970 and have declined erratically since then, with 1977 landings being the lowest on record, because of the aforementioned fishery restrictions. Canadian participation in this fishery has achieved significant levels only in the past two years (1976-77). The proportion of S. pinniger in U.S. landings from Area 3D has undergone a progressive and substantial reduction since 1974.

2.3.2.2 Condition of resource and assessment for 1978-79 (Area 3D)

In this area, which has consistently yielded a major portion of S. pinniger production from waters off B.C., changes have taken place in recent years which give rise to some concern about the health of the stock. In particular, the decline in the proportion of S. pinniger in U.S. landings of rockfish as well as the absolute decline in catch and nominal CPUE, concomitant with increased effort, indicates the possibility of a decline in stock abundance. Over the same period, however, Canadian catch has been increasing; effort, catch and CPUE decreased in 1977 while fishery restrictions were in effect. Biological data from the area are almost totally lacking; one size frequency sample each from the Esperanza and Topknot grounds for 1978 show approximately the same size composition as samples from the Queen Charlotte Sound stock with no evidence of stronger incoming year-class. No information is available from the Cape Cook ground, where the major North American fishery occurs.

A research cruise in the 3D area during September 1978 showed S. pinniger to be the dominant species caught in the 60-89 fm range around Cape Cook but not in other areas, except Esperanza. Catch rates in the traditional fishing areas were not at the level of the present Canadian fishery although they were similar to recent U.S. CPUE values. It should be noted that, in general, research cruises of this nature will produce lower CPUE values, due to survey design, than commercial fishing.

Catch and effort data for the U.S. fishery in Area 3D in 1978 are not yet available but the CPUE values for S. pinniger are thought by U.S. fishery biologists to be relatively higher than in past years. Although it is difficult to quantify this information, the U.S. fleet did catch ~600 m.t. of shelf rockfish in a relatively shorter period of time than in previous years. 1978 Canadian CPUE, however shows a decrease from 1977 in both qualified (25%) and unqualified CPUE.

Regression analysis of catches and U.S. CPUE data suggests an EY value of approximately 500 m.t./yr from the 3D area, for an initial (pre-1967) biomass of approximately 5,200 m.t. Landings of S. pinniger have never been this high and yet there have been indications of decreases in stock abundance. Recent reported increases in U.S. CPUE have yet to be confirmed.

2.3.2.3 Recommendation

A TAC of 500 m.t. of S. pinniger is recommended for the 3D area. While this figure is above recent catches, it will provide the opportunity to verify the reports of changes in CPUE for the area.

2.3.3.1 Queen Charlotte Sound (Areas 5A-5B)

Historical U.S.-Canada landings of S. pinniger from Queen Charlotte Sound reached a high of 944 m.t. in 1968 and have never approached this value in recent years, despite levels of effort well in excess of that expended in 1968. Canadian landings have been increasing steadily since 1975. Changes in U.S. landings of S. pinniger are, in part, inversely correlated with those of S. flavidus in the same area. It is possible that some substitution of species occurs so that catch levels may be maintained. While fishery restrictions were in effect during 1977, the actual TAC was slightly undersubscribed, i.e. the decreased U.S. catch of S. pinniger in 1977 was not a result of any restrictions on the U.S. fleet.

2.3.3.2 Condition of resource and assessment for 1978-79 (Area 5A-5B)

While catches of S. pinniger in Queen Charlotte Sound have never regained the peak level of 1968 (943 m.t.), there has been no indication of changes in the stock until 1977 when Canadian CPUE and U.S. nominal CPUE decreased. The decreases were moderate for the Canadian fleet but substantial (-84%) for the U.S. fleet. Qualified (25%) Canadian CPUE for 1978 showed a slight increase over 1977 (Table 2.3).

Biological data for S. pinniger in Queen Charlotte Sound are minimal and restricted to 1978. The three available size frequency samples show similar composition with major modes of the 51-53 cm range and no indication of young age groups being recruited to the fishery.

In summary, despite lowered catches of S. pinniger in Queen Charlotte Sound in 1977, there is no evidence of large reductions in stock biomass. However, it is acknowledged that substantiating data are few and that U.S. and Canadian CPUE in 1978 was essentially the same as it was in 1977, which supports the view that in the last several years the Canadian fishery has developed to the point where it is now providing a more reliable index of abundance of S. pinniger than its declining U.S. counterpart.

2.3.3.3 Recommendation

A TAC of 600 m.t. is recommended for the 5A-5B area.

2.3.4.1 Hecate Strait (Areas 5C and 5D)

Landings of S. pinniger from Hecate Strait are primarily incidental to other species. Pre-1978 landings never exceeded 25 m.t./yr, but the fishery in lower Hecate Strait (Area 5C) has shown evidence of considerable development in 1978, as over 130 m.t. have been landed to October 20, 1978. Directed fishing appears to be concentrated in the area of the Horseshoe ground. Further expansion may occur southeast of Banks Island.

2.3.4.2 Condition of resource and assessment for 1978-79 (Area 5C-5D

The incidental nature of the historical fishery for S. pinniger in Hecate Strait precludes any detailed analysis. In 1977-78 however, there was an increase in the amount of directed fishing for that species, as indicated by the increase in the amount of qualified catch and effort in 1978.

Again, biological data on S. pinniger are minimal however there are several size frequency samples. Three of four samples exhibit a striking contrast to samples from Queen Charlotte Sound and Area 3D in that a distinctly separate size composition is evident. Samples from other areas exhibit major size modes in the 51-53 cm range whereas three of the four samples from Area 5C show major size modes in the 41-43 cm range. The presence of smaller (younger) fish may indicate recruitment of new year-classes to the fishery. It must be emphsized, however, that in the present poor state of knowledge of the seasonal bathymetric distribution of S. pinniger by age and sex, any interpretation of scattered sampling data lies primarily in the realm of speculation.

Obviously much more information is required. In the meantime, a cautiously optimistic course should be taken in setting catch limits for the Hecate Strait area.

2.3.4.3 Recommendation

A TAC of 150 m.t. is recommended for Area 5C-5D.

2.3.5.1 West coast of Queen Charlotte Islands (Area 5E)

The catch of S. pinniger in this area is very small, incidental to directed fisheries for S. alutus and S. reedi. Catches are not expected to rise dramatically until the fishing fleet is able to target in shallow water areas of higher S. pinniger.

2.3.5.2 Condition of resource and assessment for 1978-79 (Area 5E)

The fishery for S. pinniger is primarily incidental to that for S. alutus and S. reedi. As noted earlier, increases in landings of S. pinniger may occur pending development of a shallow water (< 100 fm) fishery in the area. In the meantime, there does not seem to be any reason to discourage such a development.

2.3.5.3 Recommendation

A TAC of 100 m.t. is recommended for that segment of Area 5E south of 54°00'N.

2.3.6.1 Coastwide foreign catches

S. pinniger is a very minor component of foreign catches, largely because fishing has occurred at depths below the range where S. pinniger is most abundant. In 1977, only the hake fishery in mangement Sub-zone 5-2 (Area 3C) produced enough S. pinniger (incidentally caught) to make up even 0.1% of the total catch.

2.4 Sebastes brevispinis (Silvergray rockfish)

2.4.1 Summary of catch statistics

As is the case with most rockfish species in Canadian waters, a directed fishery for S. brevispinis was initiated by U.S. vessels in the mid-1960's. Significant Canadian participation did not occur until the early 1970's. While historical landings by North American vessels were substantial in some areas, it is only in the most recent years that major increases in landings have occurred in most areas. Catch statistics by major areas are presented for the North American fleet in Table 2.4.

2.4.1.1 Southwest coast of Vancouver Island (Area 3C)

Aggregate North American landings were minor (< 100 m.t./yr) until 1977 when 644 m.t. were landed; 626 m.t. by U.S. vessels operating in the 3B-3C areas as a whole. The majority of this catch was from south of the Canada-U.S. boundary region. Canadian catches of S. brevispinis in the 3C area has always been small and incidental to other species.

2.4.1.2 Condition of resource and assessment for 1978-79 (Area 3C)

It is extremely difficult to assess the condition of the stock of S. brevispinis in the 3B-3C area because there is essentially only one year of data for directed fishing and the majority of the landings came from waters under U.S. jurisdiction. Canadian landings in Canadian waters are very small and will probably remain so. The single year of U.S. data shows a relatively high CPUE value and stocks may well be healthy. No biological data for S. brevispinis in this area have been obtained.

2.4.1.3 Recommendation

A TAC of 100 m.t. for the Canadian segment of Area 3C is recommended.

2.4.2.1 Northwest coast of Vancouver Island (Area 3D)

U.S. landings of S. brevispinis from this area have been erratic and without evidence of trends. Peak landings occurred in 1969 (320.6 m.t.) and have since fluctuated around the 250 m.t./yr level (Table 2.4). The 1977 catch by the U.S. fleet was only 18.4 m.t. despite over 1,000 hr of nominal effort for shelf rockfish; the CPUE value of the U.S. fleet was also the lowest on record. While the U.S. data may show strong indications of stock changes the fishery restrictions in effect for part of 1977 (early closure upon attaining the TAC) may have had some effect on catches.

Canadian catches have always been incidental to other species and small (usually less than 10 m.t./yr). There was some increase in 1977 and 1978, but still below 20 m.t.

2.4.2.2 Condition of resource and assessment for 1978-79 (Area 3D)

Landings from Area 3D prior to 1977 show no sign of strong changes in stock biomass. There is, however, a strong, direct correlation between nominal effort and CPUE. Such situations suggest that the production system may be close to maximal exploitation. The problems of interpretation are somewhat complicated by the fact the species-specific effort is not available for U.S. catch statistics and the observed changes in CPUE may be in part an artifact of directed fishing for other shelf rockfish species. Unfortunately, this problem must remain largely unresolved until more details on the U.S. fishery are made available. The substantial drop in CPUE for S. brevispinis in the 3D area during 1977 is somewhat alarming. It is unlikely that restrictions had a major effect on this figure because the nominal effort reported is that for which shelf rockfish comprised a portion of the catch; since this was also the case in previous years, the figure probably is reflective of stock changes.

While Canadian CPUE increased markedly in 1977, the amount of effort expended is still small. The subsequent 1978 fishery was considerably larger with a concomitantly lower CPUE. Both qualified catch and CPUE were substantially reduced in 1978 relative to 1977. It would then appear that there are possible stock reductions of S. brevispinis in Area 3D.

The exploitation of S. brevispinis is of special concern because the growth rate of the species is extremely low relative to the other species it is caught with (S. flavidus, S. paucispinis); U.S. fishery biologists estimate the von Bertalanffy growth completion rate, K, as 0.04 for S. brevispinis (S. flavidus = 0.20; S. paucispinis = 0.15). The successful optimization of yields from this species is therefore critically dependent on its targettability. The changes in the CPUE noted in 1977-78 for this area merit attention but their significance is not entirely clear. For this reason a provisional catch limit which will allow the fishery to continue and provide more information on stock condition would seem advisable.

2.4.2.3 Recommendation

A TAC of 150 m.t. for the 3D area is recommended.

2.4.3.1 Queen Charlotte Sound (Areas 5A and 5B)

Queen Charlotte Sound has been the area of highest annual production of S. brevispinis by the North American fleet. The fishery was primarily conducted by U.S. vessels until 1976 when Canadian markets for this species became stronger. Peak U.S. landings of 1,164 m.t. occurred in 1969 and have never returned to that level, but rather, have fluctuated around 300 m.t./yr (Table 2.4). An increase occurred in 1976 which was not sustained through 1977.

Canadian landings have increased steadily since 1975 and are currently at their highest historical level. Qualified (25%) catch and effort have also increased in 1978 (Table 2.2), but the higher Canadian CPUE may merely reflect the suspension of the U.S. fishery in June.

2.4.3.2 Condition of resource and assessment for 1978-79 (Areas 5A-5B)

The stock of *S.brevispinis* in the Queen Charlotte Sound region has undergone heaviest exploitation. Data from the U.S. fishery indicates some inverse correlation between nominal fishing effort and CPUE. The peak landings of 1969 were followed by decreased CPUE, despite decreased effort in 1970. Thereafter, the CPUE fluctuated inversely with effort by the U.S. fleet.

Canadian CPUE has fluctuated around the level of 0.080 m.t./hr until 1978 when it rose to 0.175 m.t./hr. The 1978 increase may be in part owing to the decrease in total fishing pressure with the exclusion of the U.S. fleet in mid-June. Qualified (25%) catch and CPUE for Canadian vessels have also increased in 1978, over those of 1977.

Catch statistics indicate that the *S. brevispinis* stock in Queen Charlotte Sound may be close to maximum utilization. Biological data from this area are limited to size frequency samples from the Goose Island gully in 1978. The samples show approximately the same size distribution and major modes, although the sample from primarily deeper water exhibits a more balanced sex ratio.

If we assume the same rationale regarding EY as was previously used and if $M = 0.1$, then the average yield from 1967-1977 of 580 m.t./yr implies a virgin biomass of approximately 11,600 m.t. This may be a somewhat conservative estimate due to the effects of averaging yields however it is probably not excessively so since peak yields in this area were followed by descreases in nominal CPUE. Recent increases in CPUE need to be confirmed by a fishery applying similar effort as in previous years.

In summary, the stock of *S. brevispinis* in Queen Charlotte Sound may be maximally exploited. Average yield of past years has been approximately 580 m.t./ yr and a catch limit of about this magnitude would seem advisable.

2.4.3.3 Recommendation

A TAC of 600 m.t. from the 5A-5B areas is recommended for 1979.

2.4.4.1 Hecate Strait (Areas 5C and 5D)

Canadian landings from Hecate Strait were mainly incidental to other fisheries until 1976 when more directed fishing began to occur. Previous to 1976, landings averaged less than 30.0 m.t./yr. Although 1978 landings are currently less than the previous year, the qualified (25%) catch is almost equal with a substantial reduction in qualified effort.

2.4.4.2 Condition of resource and assessment for 1978-79 (Areas 5C-5D)

The fishery for *S. brevispinis* in Hecate Strait is a relatively recent one in terms of directed fishing effort. While 1971 and 1972 saw catch rates of about 0.20 m.t./hr, landings were still below 100 m.t./yr and subsequent years did not produce similar yields. In 1976, the fishery appeared to develop, with a seven-fold increase in species effort and an order of magnitude increase in

CPUE. Although the 1978 catch is not yet equal to that of 1977, CPUE has risen some 47% while effort has declined 53%. There is no indication as yet of any significant effect of the fishery on the stock. Qualified CPUE has risen for both the 5C and 5D areas (Table 2.7).

Hecate Strait is one of the very few areas where even small amounts of historical biological data are available for rockfishes. Two size frequency samples for the White Rocks ground in 1972 show similar frequency distributions with the major size mode at 55-57 cm. Both distributions are characterized by a relatively narrow range. A similar distribution is evident in samples taken in 1977 from the same areas although the data suggest that a slightly stronger year-class may be recruiting to the fishery. All samples appear to be multimodal with a single major mode. The 1978 samples, by contrast show a relatively stronger minor mode and in one case (White Rocks, 48-52 fm, July 27, 1978) show a major mode at 44 cm. Although this particular sample is from a shallower section of the range of the species, a new year-class or series of year-classes may be recruiting to the fishery. The progress of this group of fish should be monitored closely for signs of excessive exploitation; this mode may also provide more accurate information on growth and mortality.

In the absence of any indications of lowered stock abundance, a catch limit larger than the free-fishery catch of recent years would permit development of the fishery under somewhat controlled conditions.

2.4.4.3 Recommendation

A TAC of 300 m.t. for the 5C-5D areas is recommended

2.4.5.1 West coast of the Queen Charlottes (Area 5E)

S. brevispinis landings from the west coast of the Queen Charlotte Islands have only been incidental to directed fisheries for *S. alutus* and *S. reedi*. The 1977 landings were 20.4 m.t. and had no qualified component, while 1978 landings were 95.1 m.t. to October 20, of which 49.3 m.t. are above the 25% qualification level. There was a large increase in species effort in 1978.

2.4.5.2 Condition of resource and assessment for 1978-79 (Area 5E)

The limited amount of information available on *S. brevispinis* in Area 5E does not indicate any stock problems created by the currently developing fishery. Indeed, the major portion of the stock would be expected to be slightly shallower than the range of the current fishery. Biological samples taken in 1978 tend to support this, at least in terms of the size of fish encountered at various depths; although there may be some confounding effects of location.

The extrapolated data presented on foreign catches off the Queen Charlotte Islands (Table 2.5) indicate that a yield of ~276 m.t./yr was probably sustained from the northern segment of Area 5E. It is probable that a yield in excess of this value would be possible for the entire area, although developments of new fisheries would necessitate careful monitoring. In setting a catch limit, the low growth rate of *S. brevispinis* does counsel a certain caution.

2.4.5.3 Recommendation

A provisional TAC of 350 m.t. is recommended for that part of Area 5E south of 54°00'N.

2.4.6.1 Coastwide foreign catches

The catch of S. brevispinis by foreign vessels is very difficult to determine because of the inadequate species identification in reports by foreign nations. In 1977, the percentage of S. brevispinis in the Japanese trawl fishery in Area 5E (Management Sub-zone 5-5) was estimated to be 8.3% of the total rockfish catch, or approximately 166 m.t. Off Queen Charlotte Sound, the estimated catch was approximately 17 m.t. It is not entirely appropriate to apply these percentages to the historical reports of "Other rockfish" by foreign nations for two reasons: (a) the areas of fishing by foreign fleets are believed to have changed over time in response to depletions of target species in traditional areas of abundance; and (b) the species composition of the category "Other rockfish" is not consistent among or within nations. The only nation for which detailed area breakdown of catches where S. brevispinis would be caught is Japan. A suggested historical incidence of this species in Japanese catches off the Queen Charlotte Islands and Queen Charlotte Sound is contained in Tables 2.5 and 2.6, respectively. Catches of S. brevispinis might thus have averaged 275 m.t./yr in Sub-zone 5-5 and 87 m.t./yr in Sub-zone 5-4. This species is not normally encountered in the hake fishery off Vancouver Island and since no observations have been made of trawl fisheries for other species in this area, it is not possible to estimate S. brevispinis incidence.

2.5 Sebastes reedi (Yellowmouth rockfish)

2.5.1 Summary of catch statistics

The fishery for S. reedi in Canadian waters has always been a relatively minor component of total rockfish landings by North American trawlers, except for occasional large catches in Queen Charlotte Sound, until 1977. With the development of a rockfish fishery in Area 5E, more attention has been focused on this species. There are only two areas of significant catches of S. reedi (Areas 5A-5B and 5E).

2.5.1.1 Recommendation (Areas of minor importance)

A nominal TAC of 50 m.t. is recommended for each of Areas 3C, 3D and 5C-5D.

2.5.2.1 Queen Charlotte Sound (Areas 5A and 5B)

Landings of S. reedi from Queen Charlotte Sound have been erratic although catch rates have been generally high (Table 2.8). While a certain amount of the species is caught incidentally in the S. alutus fishery, the major portion of the stock appears to lie over rougher bottom areas than S. alutus, which accounts for the inconsistent directed effort for it. The area around Triangle Island at the mouth of Goose Island gully is the area where major catches have occurred, mainly with the use of midwater gear. There has also been some development of a S. reedi fishery in Mitchell's gully in 1978. While catches are lower in 1978, CPUE is relatively similar.

2.5.2.2 Condition of resource and assessment for 1978-79 (Area 5A-5B)

Landings of S. reedi from Queen Charlotte Sound by the Canadian fleet have been somewhat erratic. No estimates of U.S. landings are available by area, but they might logically be expected to average approximately 250 m.t./yr from 1973-1977. By far the major impact on the stock of S. reedi in and off Queen Charlotte Sound has been made by non-North American trawlers. Average removals of S. reedi from 1971-1977 by Japan were estimated to be over 1,800 m.t. /yr. Historical landings may have been as high as 2,700 m.t. although the fishery for S. alutus may not have encountered as much S. reedi when the target species was more abundant.

In view of the fact that both the North American nominal CPUE for S. reedi and the foreign CPUE for "ocean perch" have been decreasing relatively steadily, there is a strong possibility that stock biomass is also decreasing. In addition, there are other indications of lowered stock abundance in the 5A-5B area. All of the landings of S. reedi in Queen Charlotte Sound during 1977 came from Area 5A and 99% of these were included in the qualified catch (331.3 m.t.) and CPUE (1.46 m.t./hr). In 1978 there have been no landings from Area 5A. In contrast, there were no landings in Area 5B in 1977 while 1978 landings are 89.0 m.t., of which 94% of the catch (83.6 m.t.) and CPUE (1.85 m.t./hr) exceeded the qualification level (25%). Such data suggest that localized depletions may be occuring but this would require more information to confirm.

Biological samples from the area are limited to size frequency distributions and these samples indicate strong size segregation with depth (juveniles occur in shallower water than adults). It also appears that the fishery may be largely dependent upon a single year-class for the bulk of the standing stock. The all-nation decreases in CPUE recorded or implied for S. reedi in Area 5A-5B, taken with the inference of dislocation of fishing effort from areas of relatively high production, suggests that historical levels of catch (ca 1,800-2,700 m.t.) are not sustainable from the present biomass. Restriction of the catch to about one-tenth this level appears desirable, but subject to review as the 1979 season progresses.

2.5.2.3 Recommendation

A TAC of 250 m.t. for Areas 5A-5B is recommended, of which the limit is 200 m.t. for waters outside the fishery closing line.

2.5.3.1 West coast of the Queen Charlottes (Area 5E)

The fishery in the 5E area developed in very late 1976. Catches of S. reedi in 1977 were 1,256.7 m.t. and represented almost one-half of the rockfish landings from the area. Landings have dropped substantially in 1978 although qualified CPUE has increased. The fishery diversified considerably by area in 1978 and an analysis conducted in August of 1978 indicates that yields from this area cannot be sustained at present levels.

2.5.3.2 Condition of resource and assessment for 1978-79 (Area 5E)

In a previous analysis it was noted that the CPUE for S. reedi in Area 5E had fallen by 14% from 1977-78. The maintenance of CPUE was largely a result of diversification of the fishery to new fishing areas in 1978. The decrease in CPUE for the same fishing areas during the two years was 37%. In partial contrast to the foregoing are the data on qualified (25%) catch and fishing effort for the two years (Table 2.9). Qualified catch in 1978 is only 58% of the 1977 level but CPUE has increased 13%; this increase is rather modest, however, and may be entirely a function of the decrease in qualified effort from 458 to 236 hours. If CPUE is directly proportional to stock abundance, these data indicate that 1977 removals were somewhat in excess of what could be sustained by the standing stock. Thus it would seem advisable to limit the catch in 1979 to about the same level as 1978, and to monitor closely the progress of the fishery. However, in view of the fact that S. reedi is fished jointly with S. alutus, selection of a catch limit must take into consideration the conservation needs of the latter species as well.

2.5.3.3 Recommendation

A TAC of 750 m.t. for that segment of Area 5E south of 54°00'N is recommended.

2.5.4.1 Foreign fisheries off the north coast

Historical catches of S. reedi by foreign fleets are very difficult to estimate because of both the general problems of species segregation in foreign data and the very pragmatic problem of the inability of untrained people (including fishermen) to distinguish the species from S. alutus. Applying 1977 observer percentages to historical catches suggests an average yield of 332 m.t./yr from the Queen Charlotte Islands area and 1,859 m.t./yr from the Queen Charlotte Sound area, by Japan, over the period 1971-1977 (Tables 2.5 and 2.6 respectively). It is likely that there have always been substantial catches of S. reedi as it will have been identified as S. alutus in catches.

2.6 Sebastes paucispinis (Bocaccio)

2.6.1 Summary of catch statistics

Sebastes paucispinis has always been a minor species in the North American fishery, with landings normally being less than 550 m.t. for Canadian waters as a whole. Market acceptance of this species appears to be higher for the U.S. fleet since Canadian vessels are generally restricted by fish companies as to the quantity they may land per boat trip. The reason for this is apparently that the high incidence of nematode parasites in the flesh of the fish required additional processing and quality control. Most of the catch comes from Area 3D (off Vancouver Island) and Areas 5A-5B (Queen Charlotte Sound) (Table 2.10). Landings of this species by foreign nations have never been of great significance, if 1977 observer reports are representative.

2.6.1.1 Southwest coast of Vancouver Island and northern Washington (Areas 3B and 3C)

Landings of S. paucispinis are very small in this region, with maximum annual total being < 65 m.t. Catches are primarily incidental to other directed fisheries such as that for lingcod. Landings by U.S. vessels have decreased in recent years whereas those by Canadian vessels have increased.

2.6.1.2 Condition of the resource and assessment for 1978-79

The near total absence of directed fishing for S. paucispinis and the very low level of its incidence in other directed fisheries render assessment attempts almost futile. There are two biological samples available; one from Area 5E and one from Area 5A, both for 1978. Nonetheless, available information will be examined for evidence of any anomalous situations.

Nominal CPUE of U.S. catches has been remarkably constant over the 1967-77 period; not surprising when the incidental nature of the fishery is considered. Canadian catches increased up to 1977 but are minimal in 1978, probably because of the closure of the fishery in mid-June. Canadian CPUE has also been remarkably stable.

2.6.1.3 Recommendation

A TAC of 50 m.t. is recommended for the Canadian segment of Area 3C.

2.6.2.1 Northwest coast of Vancouver Island

There has been a traditional fishery by U.S. vessels for S. paucispinis in this area, although not a directed fishery. Landings averaged less than 100 m.t./yr over the 1967-76 period with peaks occurring in 1970 and 1976. Canadian landings remain very minor in the area, never exceeding 20 m.t./yr.

2.6.2.2 Condition of resource and assessment for 1978-79 (Area 3D)

While some fluctuations have occurred in recent years, the nominal CPUE of U.S. vessels in the 3D area has fluctuated about 0.40 m.t./hr. It is notable that the highest CPUE values are associated with the highest catches, typical of non-target fisheries. If a limit were to be placed on the catch of S. paucispinis for the 3D region, it should be at the level of highest historical catch.

2.6.2.3 Recommendation

A TAC of 200 m.t. is recommended for the 3D area.

2.6.3.1 Queen Charlotte Sound (Areas 5A and 5B)

Queen Charlotte Sound is the major area of production for this species by North American vessels. Peak landings by U.S. vessels occurred in 1969 (657 m.t.) and have approached that level only once in the succeeding decade. Prior to the onset of fishery restrictions in 1977, the U.S. catch of S. paucispinis averaged approximately 280 m.t.; over the same period the Canadian catch averaged about 32 m.t./yr, although it has been increasing steadily in the most recent 3 years. 1978 Canadian landings stood at 135 m.t., the highest on record, as of October 20, 1978.

2.6.3.2 Condition of resource and assessment for 1978-79 (Areas 5A-5B)

In spite of the wide variance in landings of S. paucispinis there are no strong indications of changes in stock biomass due to the fishery. While CPUE has varied it displays no strong, consistent correlations with fishing effort. The single sample from Area 5A shows a rather broad frequency distribution suggesting that the fishery may be based on several successive year-classes. Such a situation is generally felt to be a healthy one from a stock point of view because it infers relatively consistent recruitment and potential stability of the resource base. Catch limits if any should be at about the average level of removals in past years, and raised if the fishery continues to appear healthy in 1979.

2.6.3.3 Recomendation

A TAC of 300 m.t. for Areas 5A-5B is recommended.

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

The Hecate Strait region has produced minor quantities of S. paucispinis as incidental catches to other fisheries. The peak catch of 92 m.t. in 1974 is considerably above both recent and previous catches. 1978 landings are 27 m.t. and are unique in that the species effort is considerably above the species effort for historical catches.

2.6.4.2 Condition of resource and assessment for 1978-79 (Areas 5C-5D)

From what information is available there is no sign that the stock is in danger. If a catch limit is necessary, it should be at least as high as the best catch year on record.

2.6.4.3 Recommendation

A TAC of 100 m.t. for Areas 5C-5D is recommended.

2.6.5.1 West coast of the Queen Charlottes (Area 5E)

Landings of S. paucispinis in this area are an extremely small catch (0.1%), incidental to other directed rockfish fisheries.

2.6.5.2 Recommendation

A TAC of 50 m.t. for that segment of 5E south of 54°00'N is recommended.

2.7 Sebastes entomelas (Widow rockfish)

2.7.1 Summary of catch statistics

The North American fishery for S. entomelas is a rather recent development. Canadian landings had never risen above 10 m.t. for the coast as a whole until 1977 (Table 2.11), when there was a major increase in the landings from Areas 3C and 5A-5B as well as first records of landings from Hecate Strait and the west coast of the Queen Charlotte Islands. Landings have further increased in the latter area and in Queen Charlotte Sound during 1978. Complete information on the species composition of shelf rockfish catches by U.S. trawlers is not available but S. entomelas is normally ranked as a minor species in this group.

Fraidenburg et al. (1977) estimated that foreign catches of S. entomelas were extremely small in the INPFC Charlotte and Vancouver Areas, never exceeding 60 m.t./yr during 1967-75. It was in 1975 however, that the Polish trawl fleet reported 6,125 m.t. of S. entomelas in Area 3D.[6] The Polish fleet returned in 1976 and removed an additional 3,900 m.t., of which 1,364 m.t. was S. entomelas.

2.7.2 Condition of resource and assessment for 1978-79

The relatively recent origin of the fishery for S. entomelas in B.C. waters, except in Area 3D, and the fact that landings in 1977 and 1978 were quite small would indicate that there are no stock problems with this species. Unqualified CPUE rose over 1977 values in all areas where a fishery continued in 1978.

The fishery in Area 3C was curtailed by restrictions imposed in May 1978 and there was therefore very little Canadian effort in 1978. Landings of S. entomelas from Area 3D are notable by their absence. This is at once both logical and puzzling; the foremer because the large Polish removals may have severely depleted the resource and the latter because there are still catches of S. flavidus in the area despite the Polish fishery and the two species would normally be caught together. Available information suggests that the growth and mortality rates of the two species are not greatly different and therefore it would not be expected that one species would be exploited to the point of reduction while the other was not.

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[6] It should be noted that the identification of S. entomelas in Polish catches was never confirmed by North American scientists, although Polish biologists reportedly were aboard at least some of the 6 vessels which operated in Area 3D. They initially identified the species as S. ciliatus, but the identification was altered to S. entomelas by S. J. Westrheim, for reason that S. ciliatus is an inhabitant of northern waters with a southern limit of Hecate Strait.

For the time being there seem to be no stock problems and hence no foundation for restrictions on the fishery. However, should catch limits be deemed desirable they should be set at levels which at least will not discourage fishing and hence prevent the gathering of much needed additional information.

2.7.3 Recommendations

A summary of the recommended TAC's for S. entomelas is as follows:

Area	TAC
3C (Canadian)	100 m.t.
3D	50 m.t.
5A-5B	250 m.t.
5C-5D	50 m.t.
5E (S. of 54°N)	100 m.t.

2.8 Sebastes proriger (Redstripe rockfish)

2.8.1 Summary of catch statistics

Sebastes proriger has only recently become a marketable species in Canada and significant fisheries are restricted to Queen Charlotte Sound (mainly Area 5A) and the west coast of the Queen Charlotte Islands (Area 5E). There are minor landings off the west coast of Vancouver Island and in Hecate Strait (Table 2.12). Almost all of the S. proriger landed are taken incidentally to fisheries for S. alutus. As such, it would be difficult to establish a TAC unique to this species since it might seriously compromise the optimization of a more abundant resource. It is also apparent from an examination of available data, that little can be said about the condition of the resource.

The major component of the fishery for S. proriger is presumed to have been removals by foreign nations. Tables 2.5 and 2.6 present estimated removals by Japan from 1971-77 for Sub-zones 5-5 and 5-4, respectively, based upon an assumed species composition of total rockfish catches. Average removals from Sub-zone 5-5 (i.e. Area 5E) from 1971-77 were 432 m.t./yr while the comparable figure off Queen Charlotte Sound (Areas 5A and 5B) was 1,219 m.t./yr.

2.8.2.1 Condition of resource and assessment for 1978-79 (Areas 3C and 3D)

Hydroacoustic biomass estimates are available for S. proriger off the west coast of Vancouver Island for the period 1974-76. Using an M value of 0.1 to calculate EY, the following results are obtained, assuming no substantial reductions of No:

Area		Estimated biomass (m.t.)	Estimated EY (m.t./yr)
3C	1974 - Aug.	7,481	750
	- Oct.	10,099	1,010
	1975 - Sept.	791	80
	- Nov.	193	20
	1976 - Nov.	2,282	230
3D	1976 - Nov.	997	100

The 1974 estimate again appears anomalous relative to other years. The reservations about these 1974 data have been noted earlier (see Section 2.2). While the later biomass estimates may or may not be very accurate, there are certain pragmatic constraints regarding establishing catch limits at these levels. The stock of S. alutus off Vancouver Island is known to be in a depressed condition and since the catching of S. proriger could not be accomplished without an unacceptably high incidental catch of S. alutus, catch should either be prohibited or set at a very low level.

2.8.2.2 Recommendation

A TAC of 50 m.t. each is recommended for the Canadian segment of Area 3C and Area 3D.

2.8.3.1 Queen Charlotte Sound (Areas 5A and 5B)

Catch statistics from this area show a steadily declining CPUE for S. proriger landed by the Canadian fleet. This decline could be attributed, in large measure, to the removals by foreign fleets as estimated in Table 2.6. Regression analysis suggests that virgin biomass might have been as high as 9,700 m.t. If growth is as slow as it appears in this species, the natural mortality (M) may be as low as 0.1, in which case EY would be about 490 m.t. It is possible that biomass is now below 7,000 m.t. and current potential yield from the area as a whole would be 700 m.t./yr. However, the yield to a North American fishery would have to be less, since the regression analysis is based on Japanese catches, which, according to observers contain substantial numbers of small fish which would not be acceptable on the North American market. In any event, whatever the catch limit, it should be geared to provide optimal protection for the potentially more valuable resource of S. alutus which cohabits grounds frequented by S. proriger.

2.8.3.2 Recommendation

A TAC of 75 m.t. is recommended for Areas 5A-5B and an additional 150 m.t. outside the Fishery Closing Line. For Areas 5C-5D, a TAC of 50 m.t. is recommended.

2.8.4.1 West coast of the Queen Charlotte Islands (Area 5E)

The present fishery in Area 5E is distinct from the historical foreign fishery and should be allowed to proceed unimpeded, based on the 1977-78 catch statistics.

2.8.4.2 Recommendation

A TAC of 250 m.t. is recommended for that segment of Area 5E south of 54°00'N.

2.9 Sebastes aleutianus (Rougheye rockfish)

2.9.1 Summary of catch statistics

The fishery for S. aleutianus has always been a relatively minor one in Canadian waters. The only region of significant landings has been Area 5E, since the development of the rockfish fishery in this area (Table 2.13). Small annual landings (< 15 m.t.) have occurred in other areas as incidentals.

Landings of S. aleutianus by foreign fleets in Area 5E may have been well in excess of 200 m.t./yr if 1977 observer estimates are representative. Table 2.5 presents estimated Japanese landings in Area 5E from 1971-77. The estimated average yield of S. aleutianus thus obtained is 389 m.t./yr.

2.9.2 Condition of the resource and assessment for 1978-79

Assessment of the condition of the S. aleutianus stock off the west coast of the Queen Charlotte Islands can progress little beyond a narrative account. The present fishery is geographically distinct from the previous foreign fishery which accounted for the major removals from the area. Effective management of this species will not be possible in isolation since it is caught incidentally with S. alutus and S. reedi. It is difficult to determine whether the stock could maintain removals on the order of 389 m.t./yr because species-specific effort is not available for foreign catches. The CPUE of S. aleutianus in the Canadian fishery fell in 1978, but the incidental nature of the fishery for this species precludes effective control of its harvest without reducing yield from the major fishery. If catch limits must be identified, they should be set at a level no less than current removals.

2.9.3 Recommendation

A TAC of 150 m.t. is recommended for that segment of Area 5E south of 54°00'N.

2.10 Sebastes babcocki (Redbanded rockfish)

2.10.1 Summary of catch statistics

The Canadian fishery for Sebastes babcocki has always been a minor incidental fishery with S. alutus and also incidental in the line fishery for halibut two decades ago. U.S. trawlers also land the species as an incidental with slope rockfish catches, and it is usually designated as a trace or minor species. Individual species breakdown for U.S. slope rockfish catches are not available, however statistics of the Canadian fishery are presented in Table 2.14. U.S. vessels would be expected to obtain a similar percentage of S. babcocki in their S. alutus fishery.

There were no records of S. babcocki in the 1977 foreign trawl fishery. This may indicate that the species does not occur in the offshore deep water fishery.

2.10.2 Condition of resource and assessment for 1978-79

In almost all areas of capture, CPUE for S. babcocki increased in 1977 over 1978. Available biological samples (3) from Queen Charlotte Sound indicate a relatively broad size frequency base to the resource. Since there are no indications of stock problems with the species catch limits, if any, should be no less than present removals.

2.10.3 Recommendations

The following TAC are recommended for S. babcocki in 1979:

Area	TAC
3C (Canadian)	20 m.t.
3D	20 m.t.
5A-5B	200 m.t.
5C-5D	75 m.t.
5E	25 m.t.

2.11 Other rockfish species

There are several other rockfish species occurring in trawl catches from B.C. waters which will not be dealt with on an individual species basis at this time. In general, these species are either uncommon or are too small for a marketable product. For species which are low in abundance, such as S. borealis and S. elongatus, the basic problem is that their abundance in trawl catches is so low that it is almost impossible to gain any insight into their population dynamics through examination of catch statistics.[7] Data so produced

[7] S. ruberrimus is uncommon on trawling grounds but appears to be common in sheltered inshore inlets and channels, as well as untrawlable offshore areas. It is often taken on sportfish jigs and in the past at least was a common incidental species in the handline fishery for lingcod.

are not sufficiently precise, nor may they ever be, to detect population changes, and understanding of such changes will be gained only through research programs designed to estimate the vital parameters of their populations. The very low incidence of these species in trawl catches would indicate that their effective management is precluded. The most likely prognosis for these rather slow-growing species is that they will become reduced, if not eliminated, in those areas where they co-exist with more abundant and faster-growing species. A mechanism for the avoidance of this is not evident, given the current species focus of the trawl fishery.

There are several other rockfish species which are normally too small for market acceptance; among this group are S. crameri, S. diploproa, S. zacentrus and Sebastolobus alascanus. While some occur in abundance in particular areas, it is difficult to obtain information about them because they are normally discarded at sea and cannot be sampled from landings. Consequently, data on populations of these species and their dynamics can only be obtained via research vessel activities. Further, it is also difficult to assess the impact of a fishery on these species because fishing mortality rates cannot be realistically estimated without catch data and information on the quantity discarded.

ADDENDUM

The rockfish stocks in the area of Canadian waters adjacent to Queen Charlotte Sound, seaward of the fishery closing line from Cape St. James to Triangle Island, are presented here as an addendum for several reasons. Chief among these reasons is that the area represents a logical management unit and it merits attention as such. While some biological constraints to this approach do exist, they concern primarily one species and will be dealt with later.

The historical foreign fishery for rockfishes off Queen Charlotte Sound is thought to have severely reduced their biomass. The section of this document dealing with Sebastes alutus has chronicled this decline. Indeed, the 1977 discovery of the true species composition of rockfish catches on Japanese trawlers in the area implies declines in many other rockfishes beside S. alutus. The two species of major concern in this area are S. alutus and S. reedi; the yields from other species will be almost exclusively determined by those of these two major species, since they are caught concurrently.

It is believed that a deeper-water group of S. alutus exists off Queen Charlotte Sound and that this group does not take part in the observed seasonal bathymetric migration displayed by the main body of fish, exploited by domestic trawlers inside Queen Charlotte Sound. This deep-water group of fish is genetically indistinct (protein isozymes) from the main body of the stock. The S. alutus returns to the Japanese fishery when it was excluded from fishing the main body of the stock imply that the size of the deep-water group is not large. In view of this it is recommended that no more than 200 m.t. be removed from this deep-water group. In addition, it will be necessary to limit the time period over which this TAC may be fished to June-September, inclusive to avoid overlap with the main body of the stock.

For S. reedi, the 250 m.t. identified for Queen Charlotte Sound earlier in the document can be roughly partitioned into components inside and outside the fishery closing line, based on historical distribution of the fishery for it. The domestic fishery has been prosecuted as a directed fishery only off Triangle Island and almost exclusively outside the closing line. Approximately 200 m.t. of the 250 m.t. TAC previously recommended could be designated as available outside the closing line. The remaining 50 m.t. takes on a somewhat 'softer' character since landings from inside Queen Charlotte Sound have been erratic.

With regard to other rockfish species, the catch levels recommended are reflective of observed percentages in landings of the two previous species.

Recommendation

In summary, the following TACs are recommended for the area of Queen Charlotte Sound (Area 5A/B) seaward of the fishery closing line:

Species	TAC
Sebastes alutus	200 m.t.[a]
S. reedi	200 m.t.
S. proriger	150 m.t.
S. diploproa	15 m.t.
S. zacentrus	75 m.t.
S. crameri	20 m.t.
Sebastolobus alascanus	50 m.t.
	710 m.t.

[a] Fishing restricted to the period June-September, inclusive.

Table 2.1 Catch (m.t.), effort (hr) and CPUE (m.t./hr) of <u>Sebastes flavidus</u> by Canada and United States, 1967-78.

Year & Nation	Area											
	3B-3C			3D			5A-5B			5C-5D		
	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE
1967 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	121.7	4579	0.027	79.6	1344	0.059	872.5	9313	0.094	-	-	-
1968 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	1081.7	7551	0.143	16.0	1381	0.012	281.4	8488	0.033	-	-	-
1969 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	1575.8	8619	0.183	113.3	2172	0.052	2129.8	13557	0.157	-	-	-
1970 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	379.9	3637	0.104	142.1	2978	0.048	2568.0	9264	0.277	-	-	-
1971 Can.	9.7	100	0.097	4.8	38	0.126	209.8	966	0.217	50.5	201	0.251
U.S.	398.0	4934	0.081	91.2	1825	0.050	1805.6	7137	0.253	-	-	-
1972 Can.	11.3	437	0.026	-	-	-	678.2	2414	0.281	25.5	108	0.236
U.S.	416.3	4823	0.086	115.6	1691	0.068	2349.4	9224	0.254	-	-	-
1973 Can.	13.8	247	0.056	-	-	-	519.2	1387	0.374	0.5	42	0.012
U.S.	227.3	4182	0.054	17.3	1613	0.011	2837.7	9625	0.295	-	-	-
1974 Can.	16.8	631	0.027	0.3	11	0.027	153.4	1188	0.129	47.1	242	0.195
U.S.	123.5	5165	0.024	111.3	1849	0.060	924.1	8797	0.105	-	-	-
1975 Can.	5.6	217	0.026	0.6	14	0.043	383.4	1760	0.218	53.3	303	0.176
U.S.	124.9	10101	0.012	89.7	2034	0.044	379.3	5179	0.073	-	-	-
1976 Can.	47.7	931	0.051	25.4	141	0.180	627.6	4360	0.144	178.9	1002	0.179
U.S.	1024.3	12408	0.083	3.0	1550	0.002	341.5	4620	0.074	-	-	-
1977 Can.	238.6	1858	0.128	8.0	53	0.151	1012.1	4744	0.213	295.2	2713	0.109
U.S.	542.3	12464	0.044	99.4	1037	0.096	507.1	5165	0.098	-	-	-
1978 Can.	24.7	3009	0.008	23.2	213	0.109	1622.2	6469	0.251	353.8	2526	0.140

Table 2.2 Canadian qualified (25%) catch (m.t.), effort (hr) and CPUE (m.t./hr) of major rockfish species (other than Pacific ocean perch) from Areas 3C, 3D, 5A and 5B in 1977 and 1978.

	Area 3C					
	1978			1977		
Species	catch	effort	CPUE	catch	effort	CPUE
S. aleutianus	–	–	–	–	–	–
S. babcocki	–	–	–	–	–	–
S. brevispinis	–	–	–	7.75	5.00	1.55
S. entomelas	–	–	–	13.29	11.50	1.16
S. flavidus	6.80	23.75	0.29	188.89	82.50	2.29
S. paucispinis	–	–	–	–	–	–
S. pinniger	2.11	14.55	0.14	37.88	162.50	0.23
S. proriger	–	–	–	0.03	1.00	0.03
S. reedi	0.32	1.00	0.32	–	–	–

	Area 3D					
	1978			1977		
Species	catch	effort	CPUE	catch	effort	CPUE
S. aleutianus	–	–	–	–	–	–
S. babcocki	–	–	–	–	–	–
S. brevispinis	0.45	1.75	0.26	9.45	23.25	0.41
S. entomelas	–	–	–	–	–	–
S. flavidus	7.35	26.83	0.27	6.85	28.50	0.24
S. paucispinis	4.58	31.00	0.15	0.46	2.75	0.17
S. pinniger	34.80	47.33	0.74	89.59	66.75	1.34
S. proriger	–	–	–	–	–	–
S. reedi	–	–	–	–	–	–

Table 2.2. (Cont'd)

	Area 5A					
	1978			1977		
Species	catch	effort	CPUE	catch	effort	CPUE
S. aleutianus	-	-	-	-	-	-
S. babcocki	22.23	9.5	2.34	-	-	-
S. brevispinis	240.61	497.51	0.48	56.49	115.75	0.49
S. entomelas	-	-	-	10.20	7.00	1.46
S. flavidus	319.37	803.00	0.40	251.04	1114.50	0.23
S. paucispinis	33.83	59.60	0.57	10.41	31.00	0.34
S. pinniger	68.18	158.75	0.43	9.62	29.25	0.33
S. proriger	3.40	8.00	0.43	35.89	84.75	0.42
S. reedi	-	-	-	331.29	226.25	1.46

	Area 5B					
	1978			1977		
Species	catch	effort	CPUE	catch	effort	CPUE
S. aleutianus	-	-	-	-	-	-
S. babcocki	32.21	27.00	1.19	3.25	8.50	0.38
S. brevispinis	161.29	363.45	0.44	62.57	176.75	0.35
S. entomelas	119.43	136.50	0.87	26.38	53.00	0.50
S. flavidus	1109.28	1690.20	0.66	620.02	1557.75	0.40
S. paucispinis	8.39	37.00	0.23	5.15	22.50	0.23
S. pinniger	29.71	92.75	0.32	45.23	164.25	0.28
S. proriger	5.66	30.50	0.19	-	-	-
S. reedi	83.56	45.20	1.85	-	-	-

Table 2.3 Catch (m.t.), effort (hr) and CPUE (m.t./hr) of Sebastes pinniger by Canada and United States, 1967-78.

Year & Nation		Area											
		3B-3C			3D			5A-5B			5C-5D		
		catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE
1967	Can.	-	-	-	-	-	-	-	-	-	-	-	-
	U.S.	342.1	4579	0.075	352.0	1344	0.262	226.4	9313	0.024	-	-	-
1968	Can.	-	-	-	-	-	-	-	-	-	-	-	-
	U.S.	472.8	7551	0.063	494.9	1381	0.358	943.5	8488	0.111	-	-	-
1969	Can.	-	-	-	-	-	-	-	-	-	-	-	-
	U.S.	495.8	8619	0.058	557.3	2172	0.257	455.6	13557	0.034	-	-	-
1970	Can.	-	-	-	-	-	-	-	-	-	-	-	-
	U.S.	511.8	3637	0.141	727.9	2978	0.244	171.8	9264	0.019	-	-	-
1971	Can.	51.7	355	0.146	13.6	48	0.283	18.0	365	0.049	24.7	310	0.080
	U.S.	466.0	4934	0.094	573.3	1825	0.314	167.0	7137	0.023	-	-	-
1972	Can.	0.2	38	0.005	-	-	-	0.4	48	0.008	1.9	77	0.025
	U.S.	168.8	4823	0.035	198.5	1691	0.117	45.9	9224	0.005	-	-	-
1973	Can.	-	-	-	-	-	-	29.1	116	0.251	8.1	50	0.162
	U.S.	179.0	4182	0.043	473.7	1613	0.294	267.8	9625	0.028	-	-	-
1974	Can.	9.9	333	0.030	3.8	59	0.064	2.5	78	0.032	-	1	-
	U.S.	169.5	5165	0.033	586.0	1849	0.317	466.2	8797	0.053	-	-	-
1975	Can.	6.7	178	0.038	7.0	10	0.700	21.9	390	0.056	3.2	102	0.031
	U.S.	549.8	10101	0.054	442.3	2034	0.217	279.9	5179	0.054	-	-	-
1976	Can.	51.8	627	0.083	137.6	157	0.876	102.6	1538	0.067	7.5	273	0.027
	U.S.	644.2	12408	0.052	170.4	1550	0.110	459.4	4620	0.099	-	-	-
1977	Can.	119.8	1766	0.068	97.0	135	0.719	123.4	2358	0.052	15.4	412	0.037
	U.S.	302.8	12464	0.024	85.4	1037	0.082	84.1	5165	0.016	-	-	-
1978	Can.	9.2	1617	0.006	44.0	133	0.331	242.6	2552	0.095	61.7	1533	0.040

Table 2.4 Catch (m.t.), effort (hr) and CPUE (m.t./hr) of <u>Sebastes brevispinis</u> by Canada and United States, 1967-78.

Year & Nation	Area											
	3B-3C			3D			5A-5B			5C-5D		
	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE
1967 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	43.1	4579	0.009	148.5	1344	0.110	348.5	9313	0.037	-	-	-
1968 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	24.7	7551	0.003	161.4	1381	0.117	799.9	8488	0.094	-	-	-
1969 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	5.8	8619	0.001	320.6	2172	0.148	1164.1	13557	0.086	-	-	-
1970 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	38.5	3637	0.011	297.9	2978	0.100	269.4	9264	0.029	-	-	-
1971 Can.	2.0	3	0.667	2.6	46	0.057	17.9	322	0.056	34.5	229	0.151
U.S.	50.6	4934	0.010	133.9	1825	0.073	689.0	7137	0.097	-	-	-
1972 Can.	-	-	-	0.3	38	0.008	53.0	629	0.084	61.0	232	0.263
U.S.	12.8	4823	0.003	371.3	1691	0.220	350.7	9224	0.038	-	-	-
1973 Can.	0.2	38	0.005	-	-	-	37.5	293	0.128	9.9	147	0.067
U.S.	-	4182	-	205.9	1613	0.128	198.4	9625	0.021	-	-	-
1974 Can.	-	-	-	1.4	12	0.117	45.0	414	0.109	12.9	64	0.202
U.S.	-	5165	-	217.9	1849	0.118	336.2	8797	0.038	-	-	-
1975 Can.	0.5	35	0.014	3.2	9	0.356	30.7	480	0.064	11.2	191	0.059
U.S.	98.1	10101	0.010	65.9	2034	0.032	286.2	5179	0.055	-	-	-
1976 Can.	4.6	9	0.511	0.1	4	0.025	164.4	1606	0.102	121.3	1429	0.085
U.S.	52.5	12408	0.004	254.1	1550	0.164	496.6	4620	0.107	-	-	-
1977 Can.	18.0	476	0.038	10.3	40	0.258	197.7	2463	0.080	233.8	2059	0.114
U.S.	626.4	12464	0.050	18.4	1037	0.018	209.7	5165	0.041	-	-	-
1978 Can.	1.0	48	0.021	16.3	237	0.069	652.6	3736	0.175	162.8	971	0.168

Table 2.5. Estimates of Japanese catches (m.t.) of selected rockfish species, 52°N-54°30'N, (Area 5E or Management Sub-zone 5-5).

Year	Total rockfish	*S. brevispinis*[a]	*S. reedi*[a]	*S. proriger*[a]	*S. aleutainus*[a]
1971	3113	258	311	405	364
1972	4559	378	456	593	533
1973	4208	349	421	547	492
1974	2883	239	288	375	337
1975	2954	245	295	384	346
1976	3538	294	354	460	414
1977	~2000	166	200	260	234

[a]Extrapolated using observed % in 1977 rockfish catch.

Table 2.6. Estimates of Japanese catches (m.t.) of selected rockfish species, 50°30'N-52°N, (Areas 5A and 5B or Management Sub-zone 5-4).

Year	Total rockfish	*S. brevispinis*[a]	*S. reedi*[a]	*S. proriger*[a]
1971	349	6	135	92
1972	2,643	48	1,020	700
1973	5,653	102	2,182	1,498
1974	14,240	256	5,497	3,374
1975	6,490	117	2,505	1,720
1976	3,364	61	1,299	891
1977	~970	17	374	257

[a]Extrapolated using observed % in 1977 rockfish catch.

Table 2.7 Canadian qualified (25%) catch (m.t.), effort (hr) and CPUE (m.t./hr) of major rockfish species (other than Pacific ocean perch) from Areas 5C, 5D in 1977 and 1978.

	Area 5C					
	1978			1977		
Species	catch	effort	CPUE	catch	effort	CPUE
S. aleutianus	-	-	-	-	-	-
S. babcocki	2.27	11.00	0.21	-	-	-
S. brevispinis	19.19	41.40	0.46	23.54	69.20	0.34
S. entomelas	-	-	-	-	-	-
S. flavidus	13.61	17.70	0.77	-	-	-
S. paucispinis	3.63	17.00	0.21	0.23	2.00	0.11
S. pinniger	36.29	37.20	0.98	3.42	2.00	1.71
S. proriger	0.68	4.00	0.17	-	-	-
S. reedi	-	-	-	-	-	-

	Area 5D					
	1978			1977		
Species	catch	effort	CPUE	catch	effort	CPUE
S. aleutianus	-	-	-	-	-	-
S. babcocki	5.81	5.70	1.02	1.09	6.00	0.18
S. brevispinis	103.83	171.90	0.60	112.14	377.70	0.30
S. entomelas	-	-	-	1.72	2.00	0.86
S. flavidus	150.39	433.60	0.35	89.37	220.75	0.40
S. paucispinis	7.94	50.00	0.16	19.04	33.50	0.57
S. pinniger	2.72	5.50	0.49	2.38	8.00	0.30
S. proriger	-	-	-	-	-	-
S. reedi	-	-	-	3.75	2.50	1.50

Table 2.8 Canadian catch (m.t.), effort (hr), and CPUE (m.t./hr) of <u>Sebastes reedi</u>, 1971-78.

	Area											
	3C			5A-5B			5C-5D			5E		
Year	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE
1971	-	-	-	5.4	32	0.169	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	176.7	38	4.650	-	-	-	-	-	-
1974	-	-	-	78.9	23	3.430	-	-	-	-	-	-
1975	0.5	3	0.167	1.1	35	0.031	-	-	-	-	-	-
1976	-	-	-	12.3	10	1.230	-	-	-	-	-	-
1977	-	-	-	335.9	466	0.721	3.8	3	1.267	1256.7	583	2.156
1978	0.3	1	0.300	89.0	140	0.636	-	-	-	851.7	459	1.856

Table 2.9 Canadian qualified (25%) catch (m.t.), effort (hr) and CPUE (m.t./hr) of major rockfish species (other than Pacific ocean perch) from Area 5E in 1977 and 1978.

	Area 5E					
	1978			1977		
Species	catch	effort	CPUE	catch	effort	CPUE
S. aleutianus	98.92	118.30	0.84	74.69	66.00	1.13
S. babcocki	-	-	-	-	-	-
S. brevispinis	49.37	102.80	0.48	-	-	-
S. entomelas	1.28	6.70	0.19	-	-	-
S. flavidus	-	-	-	1.38	10.00	0.14
S. paucispinis	0.08	14.60	0.01	-	-	-
S. pinniger	9.07	1.00	9.07	0.18	1.00	0.18
S. proriger	67.11	28.70	2.34	58.04	79.33	0.73
S. reedi	720.43	236.26	3.05	1243.30	458.20	2.71

Table 2.10 Catch (m.t., effort (hr) and CPUE (m.t./hr) of <u>Sebastes paucispinis</u> by Canada and United States, 1967-78.

Year & Nation	Area 3B-3C catch	3B-3C effort	3B-3C CPUE	3D catch	3D effort	3D CPUE	5A-5B catch	5A-5B effort	5A-5B CPUE	5C-5D catch	5C-5D effort	5C-5D CPUE
1967 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	3.2	4579	0.001	51.8	1344	0.039	170.9	9313	0.018	-	-	-
1968 Can.	-	-	-	-	-	-	-	-	-	-	-	-
U.S.	15.9	7551	0.002	34.2	1381	0.025	52.7	8488	0.006	-	-	-
1969 Can.	--	-	-	-	-	-	-	-	-	-	-	-
U.S.	8.7	8619	0.001	96.5	2172	0.044	657.4	13557	0.048	-	-	-
1970 Can.	-	-	-	-	-	-	--	-	-	-	-	-
U.S.	63.1	3637	0.017	117.7	2978	0.040	78.4	9264	0.008	-	-	-
1971 Can.	0.5	38	0.013	11.6	291	0.040	23.8	637	0.037	2.2	245	0.009
U.S.	19.5	4934	0.004	18.1	1825	0.010	119.9	7137	0.017	-	-	-
1972 Can.	1.3	32	0.041	5.8	172	0.034	17.9	126	0.142	26.0	128	0.203
U.S.	19.6	4823	0.004	72.7	1691	0.043	287.5	9224	0.031	-	-	-
1973 Can.	2.9	80	0.036	13.2	115	0.115	38.8	347	0.112	19.0	222	0.086
U.S.	15.2	4182	0.004	69.9	1613	0.043	582.3	9625	0.060	-	-	-
1974 Can.	4.4	115	0.038	9.5	91	0.104	81.3	719	0.113	92.0	673	0.137
U.S.	-	5165	-	25.7	1849	0.014	378.7	8797	0.043	-	-	-
1975 Can.	0.7	14	0.050	0.5	4	0.125	4.6	81	0.057	10.1	208	0.049
U.S.	-	10101	-	18.7	2034	0.009	303.4	5179	0.059	-	-	-
1976 Can.	3.9	45	0.087	8.4	109	0.077	28.3	741	0.038	25.5	525	0.049
U.S.	18.6	12408	0.001	165.1	1550	0.107	201.7	4620	0.044	-	-	-
1977 Can.	29.0	712	0.041	10.1	118	0.086	41.9	1161	0.036	59.7	858	0.070
U.S.	8.9	12464	0.001	4.9	1037	0.005	119.6	5165	0.023	-	-	-
1978 Can.	2.1	169	0.012	13.8	221	0.062	134.8	6253	0.022	26.5	2779	0.010

Table 2.11 Catch (m.t.), effort (hr) and CPUE (m.t./hr) of <u>Sebastes entomelas</u> by Canada and United States, 1967-78.

	Area											
	3C			5A-5B			5C-5D			5E		
Year	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE
1972	0.1	11	0.009	-	-	-	-	-	-	-	-	-
1973	1.5	27	0.057	0.3	11	0.025	-	-	-	-	-	-
1974	2.3	68	0.034	2.7	13	0.210	-	-	-	-	-	-
1975	0.1	16	0.009	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-
1977	52.9	167	0.317	86.3	869	0.099	3.5	26	0.135	12.3	136	0.090
1978	-	-	-	143.2	691	0.207	-	-	-	32.0	263	0.122

Table 2.12 Canadian catch (m.t.), effort (hr) and CPUE (m.t./hr) of *Sebastes proriger*, 1975-78.

	Area														
	3C			3D			5A-5B			5C-5D			5E		
Year	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE	catch	effort	CPUE
1975	-	-	-	-	-	-	12.9	35	0.369	-	-	-	-	-	-
1976	-	-	-	-	-	-	11.6	46	0.253	-	-	-	-	-	-
1977	0.7	53	0.013	-	-	-	49.4	356	0.139	0.9	25	0.036	156.0	454	0.344
1978	0.2	1	0.230	5.1	41	0.124	20.2	1877	0.011	0.9	15	0.060	180.1	293	0.615

Table 2.13 Canadian catch (m.t.), effort (hr), and CPUE (m.t./hr) of Sebastes aleutianus, 1971-78.

	Area														
	3B-3C			3D			5A-5B			5C-5D			5E		
Year	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
1971	4.8	134	0.036	3.7	21	0.176	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	8.2	48	0.170	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	14.4	63	0.229	-	-	-	-	-	-
1977	-	-	-	-	-	-	0.3	29	0.012	0.4	56	0.007	76.3	135	0.565
1978	-	-	-	-	-	-	-	-	-	-	-	-	125.6	262	0.479

Table 2.14. Canadian catch (m.t.), effort (hr) and CPUE (m.t./hr) of *Sebastes babcocki*, 1971-78.

	Area											
	3B-3C			5A-5B			5C-5D			5E		
Year	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
1971	-	-	-	13.5	179	0.075	11.9	195	0.061	-	-	-
1972	-	-	-	-	-	-	4.2	118	0.036	-	-	-
1973	-	-	-	3.8	51	0.075	2.7	60	0.045	-	-	-
1974	-	-	-	5.3	68	0.078	0.8	55	0.015	-	-	-
1975	-	-	-	29.4	205	0.143	3.6	112	0.032	-	-	-
1976	1.0	6	0.167	64.1	563	0.114	14.4	568	0.025	-	-	-
1977	0.3	60	0.005	20.2	602	0.034	12.8	498	0.026	2.3	32	0.072
1978	0.5	40	0.013	85.9	438	0.196	28.0	327	0.086	5.0	170	0.029

3. SABLEFISH (BLACKCOD) STOCK ASSESSMENT

3.1 History of the fishery

The sablefish (*Anoplopoma fimbria*) fishery off British Columbia has a history which dates from the early years of the century. The domestic fishery has been erratic and never of great magnitude. Indeed within the past two decades it has been so small (average 586 m.t./yr) that insufficient information could be obtained to determine the state of stocks (Table 3.1).

A Japanese longline fishery began in 1968 with a significant production of 1,454 m.t. (Table 3.2). It peaked in 1970 at 4,900 m.t., and since that time has varied narrowly between 2,700 and 4,400 m.t. The USSR and the Republic of Korea also entered the fishery off Canada but to a smaller extent, in 1973 and 1974, respectively (Table 3.1).

3.1.1 Trends in catch and CPUE

The assessment of the state of the sablefish resource in the Canadian zone is, for the reason noted above, dependent entirely on the catch and effort statistics for the Japanese fishery. However, before attempting an evaluation, a few words should be said about the definition of stocks. With the present state of knowledge obtained from tagging, it is likely that sablefish occurring in the Canadian zone constitute one or several stocks. Preliminary tagging analysis suggests that the majority are relatively non-migratory for most recaptures are made in the general area of tagging.

For present purposes two possibilities will be considered:

(1) that a single stock ranges freely along the entire length of the British Columbia coast, and

(2) that separate stocks exist in Zone 5-5 (Queen Charlotte Islands and Dixon Entrance or PMFC Area 5E), Zone 5-4 (Queen Charlotte Sound or PMFC Area 5A and 5B), and 5-1, 5-2, and 5-3 (west coast of Vancouver Island or PMFC Area 3C and 3D).

3.1.1.1 Canadian zone as a whole

Table 3.2 and Fig. 3.1 show that after an initial 4-yr decline in CPUE to 0.162 m.t. per 10 hachi, CPUE remained remarkably steady from 1972-1976 ranging from 0.194 to 0.210 m.t. per 10 hachi. However, during 1977, CPUE dropped by 24% to 0.147 m.t. per 10 hachi. CPUE expressed as catch-per-boat-day (Table 3.6) shows a similar trend but the decline since 1972 is somewhat more pronounced.

3.1.1.2 Sub-areas of the Canadian zone

Tables 3.3, 3.4, and 3.5, and Fig. 3.2 show that when the Japanese catch statistics are broken into three sub-areas of the coast, the CPUE follows essentially the same trend as that exhibited for the coast as a whole, namely that for practical purposes the apparent abundance was relatively stable up to 1976. Most of the fishing in the Queen Charlotte Islands Area, Zone 5-5 (Table 3.5) has occurred consistently in one statistical block (033540).[8] In the Queen Charlotte Sound Area, Zone 5-4 (Table 3.4), production has been more variable yet CPUE shows no significant trend. Statistical block 030513 has been the most important block since 1971 (with the exception of 1973) and has contributed, on average, 41% of the catch in Zone 5-4 during this period. In the Vancouver Island Area (Table 3.3), production has fluctuated moderately and there has been some variability in the productivity of particular statistical blocks. CPUE, however, has remained notably stable.

3.2 Longline CPUE as an index of abundance

The lack of trend in longline CPUE data between 1969 and 1976 has been regarded with suspicion and several alternative interpretations have been advanced to explain how CPUE statistics based on catch-per-hachi might be masking the true trend in abundance.

These include:

(i) Saturation effects resulting from a situation where sablefish are so abundant that all hooks are occupied or without bait. Thus, CPUE will not reflect changes in abundance until the stock is reduced to a level at which there is no longer competition for bait;

(ii) increased efficiency of Japanese vessels;

(iii) exploitation of new areas as production rate decreases on previously fished grounds;

(iv) utilization of a greater percentage of small fish to achieve production goals.

Canadian observers have monitored catch rates and catch composition of foreign vessels throughout the year since January 1977. These records have been useful in considering the interpretations given above and have provided a means of evaluating the usefulness of longline CPUE as an index of abundance.

Observers reported that an average of 15% of all hooks set captured sablefish and that an average of 20% of hooks were retrieved without fish but still baited. Moreover, there is little correlation between the percentage of hooks capturing sablefish and the percentage baited but without fish ($r = 0.17$) or with the percentage of hooks catching other species ($r = 0.28$) which suggests

[8] Statistical reference system where the figure indicates longitude-latitude of the southeast corner of each block.

that the number of hooks actually fishing is not a limiting factor at present catch rates. CPUE dropped 24% from 0.194 m.t. per 10 hachi during 1975 and 1976 to 0.147 m.t. per 10 hachi in 1977. Assuming that the average weight has not changed over this period (i.e. that the drop in CPUE can be attributed entirely to a decline in abundance), it would be expected that approximately 25% more sablefish had been caught per hachi during 1975-76 so that 20% of all hooks caught sablefish. By further assuming that the catch rate of incidental species was not higher in previous years, there must still have been 15% of hooks available to fish in 1975-76 and similarly, 10% in 1978. Therefore, it seems doubtful that the steady trend in CPUE until 1976 followed by the sharp decline in 1977 can be attributed to a saturation effect masking true trends in abundance.

U. S. scientists (Low et al. 1976) claim that the efficiency of Japanese vessels has increased through increased 'soak-times' (i.e. the length of time gear is left in the water). Indeed, trends in CPUE expressed in terms of catch-per-boat-day for the Bering Sea and Gulf of Alaska indicate a markedly greater decline in abundance (Low et al. 1976; Anon. 1978). And to some extent, the downward trend in CPUE expressed in catch-per-boat-day for Canadian waters is more pronounced than for CPUE expressed in catch-per-hachi (Fig. 3.1). Both indices have been considered in the analyses of section 3.3.

In addition to changes in soak-times, variation in the number of hooks per hachi will be reflected in catch-per-hachi statistics. Although little information has been obtained regarding previous years, observers found that the average number of hooks per hachi during 1977-78 was 37 but that the variability was large (± 30% with 95% confidence). Presumably, if large numbers of hachi are considered in CPUE calculations, values will be consistent from year to year. However, because CPUE is a quotient of catch and fishing effort, this variability may significantly affect CPUE estimates when fishing effort is low.

As mentioned in Section 3.1.1.2, certain statistical blocks, particularly in Zones 5-5 and 5-4, have consistently provided the greatest yield. This would seem to indicate that the Japanese fleet has not found it necessary to move from area to area to maintain a high CPUE. Hence, it appears that the same stock(s) of sablefish have been exploited since the beginning of the Japanese longline fishery.

It is difficult to assess the possibility that the average size of sablefish in Japanese catches has decreased over the years. Certainly no such changes have been evident since 1977 and the size composition of Japanese catches during 1977 and 1978 is similar to that of trap catches made in the same general areas during 1977-78, and in a previous survey in 1972.

Canadian observers have reported a discrepancy between total catch estimates (and hence CPUE) recorded in Japanese fishing log books and estimates calculated from processed weight using recovery rates obtained during sampling of the catch. It appears that the conversion factor used by the Japanese fleet to calculate total weight from processed weight is generally 1.33 which represents a recovery rate of 75%, 17% higher than the average recovery rate (64%) determined by observers. Of course, if these conversion factors have not changed since the beginning of the fishery, CPUE data will at least be consistent. Yet under a quota system which restricts total catch such as imposed in 1977, the discrepancy becomes important because use of the higher recovery rate means that a larger processed weight will be taken before the estimated total catch exceeds the quota.

Should this have occurred in 1977, CPUE for that year would be underestimated. The effect of this possibility has been investigated in Section 3.3 using a corrected CPUE figure of 0.172 m.t. per 10 hachi (= nominal CPUE × 1.17) in addition to the nominal CPUE for 1977.

In conclusion, longline CPUE appears to be a satisfactory index of stock abundance. However, where soak-times have increased over the years, catch-per-boat-day should better reflect trends in availability. Also, inconsistent calculations of total catch is a potentially serious problem that demands careful attention in the future, as it not only results in an underestimation of CPUE but allows catch quotas to be exceeded without account in the catch records.

3.3 CPUE analyses

Parameters of the Schaefer stock production model and maximum sustainable yield have been estimated from longline CPUE and fishing effort data in Canadian waters using two methods. The first involves a regression of CPUE on the average fishing effort over a number of preceding years (K) which ideally, should be equal to the average length of time an individual of a year-class is vulnerable to the fishery (Gulland 1961); the second is a dynamic, stochastic version of the Schaefer model (Schnute 1977).

Table 3.6 and Fig. 3.3 and 3.4 present the results of Gulland's (1961) linear regression model with K = 4 and K = 5 and CPUE expressed in both catch-per-10 hachi and catch-per-boat-day. The best fit to the data (as determined by the correlation coefficient) is obtained with K = 5 and CPUE expressed in catch-per-boat-day (r = 0.898) and the resulting estimate of MSY is 4100 m.t./yr. However, all estimates of MSY using nominal CPUE data range between 3400 and 4100 m.t. per year. The use of the corrected 1977 CPUE figure does nothing to improve the fit in this approach.

Results generated by the modified Schaefer model are presented in Table 3.7 and Fig. 3.5. The best fit in this case was achieved using only data from 1968 to 1976 and MSY was predicted to be 6200 m.t./yr ($\sigma = 0.177$). In fact, no solution could be found using nominal CPUE for 1977. A reasonable estimate (MSY = 5300 m.t./yr) with the lowest variance ($\sigma = 0.174$) was obtained using the corrected CPUE for 1977. However, the failure rate index in this case was higher (closer to 1.0) indicating that past and present effort levels predict catches less well.

In a document entitled "Re-calculations of the longline effort and stock assessment of blackcod in the North Pacific" provided by Japanese scientists in May 1978, the Gulland (1961) linear model was used to relate estimated total effort (= total catch/longline CPUE) to longline CPUE in terms of catch-per-hachi and resulted in an estimate of MSY = 26,000 m.t./yr for Canadian waters. However, the source of statistics for total catch was not given and the data used are very different from either the total Japanese catch (i.e. longline and incidental trawl catches) or the all-nation catches listed in Table 3.1. Moreover in the Japanese analysis, longline CPUE for 1968 was used to derive total effort figures for 1966 and 1967 when no Japanese longline fishery existed off Canada. This approach is very questionable and seems particularly unwise in view of the fact that the total Japanese catch during 1966 and 1967 was only 6% and 42%, respectively, of the total all-nation catch in 1968. Since Gulland's model assumes that fishing effort during previous years is the major factor determining present abundance, the relatively small removals during 1966 and 1967 do not merit consideration.

The use of estimated total effort has advantage in that it considers total removals but it is only appropriate if all effort is directed toward the same stock. In this case, the assumption is perhaps acceptable since most longline and trawl catches (which represent over 95% of total removals since 1968) are taken from the same geographic areas although trawl catches are generally taken from shallower water and include a greater percentage of small sablefish. Japanese longline catches have comprised an average of 69% of total removals since 1968; thus longline CPUE should provide an adequate index of availability given the assumption that all effort is directed towards a single stock. The results of the Gulland analysis with total effort are given in Table 3.8 and Fig. 3.6. Again the best fit is obtained with $K = 5$ ($r = 0.754$) and MSY is estimated at 4800 m.t./yr. A marginally better fit ($r = 0.819$) is obtained using the corrected 1977 CPUE figure but the estimate of MSY is similar at 5200 m.t./yr.

3.4 Recruitment considerations

Yield-per-recruit analysis indicates that a cohort of sablefish will attain its greatest biomass at about age 5 or 55 cm fork length (Low et al. 1976). The minimum size regulation of 4 lb (1.8 kg) round weight presently in effect in British Columbia concurs well with this prediction. However, it is possible that due to the relatively long period (about 2 yr) between the time at which a cohort reaches its greatest biomass and the time at which it reaches maturity, yield-per-recruit analysis is inappropriate and misleading because it does not consider recruitment.

Approximately one-third of female sablefish in Japanese longline catches off Vancouver Island are immature. Although the proportion is less (5%) off the Queen Charlotte Islands, the situation warrants investigation. Another aspect of this problem involves discard rates of small sablefish incidental to Canadian trawl and seine catches throughout Canadian waters. During 1978, the incidental catch of one-year-old sablefish averaging 35 cm in length was unusually high. Between January 1 and August 31, 113 m.t. were discarded from trawl catches alone. Assuming that these fish would have reached a marketable size, 60 cm, in four years' time (an instantaneous rate of increase in weight, G, of roughly 0.4) and that they would have experienced a natural mortality rate of $M = 0.22$ (Low et al. 1976) the cohort would be expected, at least, to double its biomass. Hence, trawl discards during the first half of 1978 represent a potential harvest of roughly 230 m.t. in four years' time.

Clearly, catches of immature and juvenile sablefish must be monitored closely and further regulation may be required. However, no specific recommendations can be made until the consequences of these removals on recruitment are better understood.

3.5 Summary of stock condition

During the period 1973-77 the average annual landing of sablefish from the Canadian zone was 5200 m.t., and 4150 m.t. in 1977, the first year of extended jurisdiction. Estimates of MSY from stock production models based on Japanese longline CPUE and fishing effort in Canadian waters range from 3400-6200 m.t./yr.

3.6 Recommendations

In light of the recent decline in CPUE and concerns about recruitment, it is advisable to hold the total allowable catch at its present level of 3500 m.t./yr until the downward trend in CPUE has stabilized and a preliminary investigation of recruitment based on age composition data collected during 1977-78 has been completed.

It is also recommended that the present minimum size limit of 4 lbs (1.8 kg) round weight, which is equivalent to a fork length of 55 cm, or a dressed length (origin of first dorsal fin to fork of tail) of 39 cm, be enforced with regard to Japanese catches.

Finally, total catch estimates from processed catch weights should be closely monitored to ensure accurate catch data.

Table 3.1. Sablefish catch by nation (all fishing gears) in British Columbia waters 1964-1977 (metric tons).

Calendar year	Canada[a]	USA[b]	Japan[c]	USSR[b]	R.O.K.[b]	Total
1964	398	83	-	-	-	481
1965	455	92	-	-	-	547
1966	635	95	174	-	-	904
1967	393	65	1189	-	-	1647
1968	465	65	2271	-	-	2801
1969	312	43	4712	-	-	5067
1970	257	104	5119	-	-	5480
1971	314	161	3012	-	-	3487
1972	1086	582	4172	-	-	5840
1973	938	82	2950	6	-	3976
1974	482	70	3866	65	129	4612
1975	892	126	4460	0	1263	6741
1976	771	217	3379	0	2335	6702
1977	898	86[e]	3001[d]	0	168[d]	4153

Sources: [a]Can. Dept. Fish., B. C. Catch Statistics (1965-77) and Fish. Res. Board Canada, Catch and effort statistics of the B. C. trawl fishery, 1967-1977).
[b]Ketchen (1977b)
[c]INPFC statistical bulletins including unpublished data for 1975 and 1976.
[d]Fishing log books from foreign vessels.
[e]Personal comment, Mark Pedersen, Wash. State Dept. Fisheries.

Table 3.2. Sablefish catch and effort statistics for Japanese longline fishery in Canadian waters (48°00-54°30'N Lat.) 1968-1977.

Calendar year	Catch (m.t.)	Effort (× 10 hachi)	CPUE (m.t./10 hachi)
1968[a]	1,454	5,573	0.261
1969	4,224	20,412	0.207
1970	4,919	22,886	0.215
1971	2,721	16,774	0.162
1972	3,491	16,831	0.207
1973	2,585	12,367	0.209
1974	3,527	16,765	0.210
1975	4,433	22,807	0.194
1976	3,209	16,519	0.194
1977[b]	2,982	20,260	0.147
1968-77 average	3,354	17,119	0.201

[a]1968-1976 statistics from U.S. National Marine Fisheries Service computer printouts (SM 762).
[b]1977 statistics from fishing log books.

Table 3.3. Sablefish catch and effort statistics for Japanese longline fishery in the Vancouver Island Area, Zones 5-1, 5-2 and 5-3 (48°00-52°30'N. lat.)

	Total for Zone			Most important block[b]						
				Catch (m.t.)						
Year[a]	Catch (m.t.)	Effort (10 Hachi)	CPUE	028500	027493	027490	026483	025480	Effort (10 Hachi)	CPUE
1968[c]	239	1,153	.207	-	102	-	-	-	466	.219
1969	1,969	10,062	.196	-	796	-	-	-	4,367	.182
1970	1,060	4,901	.216	455	-	-	-	-	1,858	.245
1971	594	4,152	.143	-	-	-	200	-	1,264	.158
1972	826	4,044	.204	-	191	-	-	-	826	.231
1973	798	3,622	.220	-	-	-	211	-	943	.224
1974	1,556	7,135	.218	-	-	-	-	411	1,893	.217
1975	1,379	7,126	.194	-	-	371	-	-	1,903	.195
1976	824	4,342	.190	267	-	-	-	-	1,295	.206
1977[d]	1,164	7,672	.152	-	-	-	308	-	1,942	.158

[a] Calendar year.
[b] INPFC block bounded by 1° longitude and ½° latitude.
[c] 1968-1976 data from U.S. Nat. Marine Fish. Serv. computer printouts (SM762).
[d] 1977 data from Japanese log books.

Table 3.4. Sablefish catch and effort statistics for Japanese longline fishery adjacent to Queen Charlotte Sound, Zone 5-4 (50°30'-52°00'N lat.)

	Total for zone			Most important block[b]					
				Catch (m.t.)					
Year[a]	Catch (m.t.)	Effort (10 Hachi)	CPUE	029510	029503	030510	030513	Effort (10 Hachi)	CPUE
1968[c]	73	466	.157	22	-	-	-	189	.116
1969	765	3,700	.207	-	-	246	-	1,051	.234
1970	2,310	10,756	.215	-	-	886		3,988	.222
1971	655	4,458	.147	-	-	-	338	1,843	.183
1972	585	2,503	.234	-	-	-	295	1,140	.259
1973	460	2,156	.213	-	178	-	-	872	.204
1974	820	3,755	.218	-	-	-	268	1,172	.229
1975	1,444	7,397	.195	-	-	-	405	2,051	.197
1976	1,126	5,327	.211	-	-	-	741	3,382	.219
1977[d]	1,081	7,342	.147	-	-	-	423	2,761	.153

[a]Calendar year.
[b]INPFC block bounded by 1° longitude and ½° latitude.
[c]1968-1976 data from U.S. Nat. Marine Fish. Serv. computer printouts (SM 762).
[d]1977 data from Japanese log books.

Table 3.5. Sablefish catch and effort statistics for Japanese longline fishery in the Queen Charlotte Islands-Dixon Entrance Area, Zone 5-5 (52°00-54°30'N lat.)

	Total for zone			Most important block[b] (033540)		
Year[a]	Catch (m.t.)	Effort (10 Hachi)	CPUE	Catch (m.t.)	Effort (10 Hachi)	CPUE
1968[c]	1,142	3,954	.289	478	1,532	.312
1969	1,490	6,650	.224	580	2,128	.273
1970	1,549	7,229	.214	708	2,971	.238
1971	1,472	8,164	.180	786	4,484	.175
1972	2,080	10,284	.202	1,221	5,996	.204
1973	1,327	6,589	.201	752	3,731	.202
1974	1,151	5,875	.196	694	3,559	.195
1975	1,610	8,284	.194	935	4,759	.196
1976	1,259	6,850	.184	717	4,098	.175
1977[d]	737	5,246	.140	377	2,743	.138

[a] Calendar year.

[b] INPFC block bounded by 1° longitude and ½° latitude.

[c] 1968-1976 data from U.S. Nat. Marine Fish. Serv. computer printouts (SM762)

[d] 1977 data from Japanese log books.

Table 3.6. Sablefish catch-per-unit-effort and average fishing effort data expressed in 10 Hachi units and boat-days, for Japanese longline fishery in Canadian waters.

Calendar year	10 Hachi units[a] CPUE (m.t./10 Hachi)	10 Hachi units[a] Effort[c] K=4	10 Hachi units[a] Effort[c] K=5	Boat-days[b] CPUE (m.t./boat-day)	Boat-days[b] Effort K=4	Boat-days[b] Effort K=5
1971	0.162	16,411	-	7.42	390	-
1972	0.207	19,226	16,495	9.29	447	387
1973	0.211	17,214	17,854	9.07	393	415
1974	0.210	15,684	17,124	7.94	374	408
1975	0.194	17,192	17,108	7.42	433	419
1976	0.194	17,114	17,057	7.48	447	433
1977	0.147(.172)[e]	19,088	17,744	5.74	500	457

Parameter estimates from Gullands's (1961) linear regression model[d]

	10 Hachi units K=4	10 Hachi units K=5		Boat-days K=4	Boat-days K=5
a	0.281(0.214)[e]	0.536(.387)[e]		13.9	28.4
b	5.25×10^{-6}(1.19×10^{-6})	1.98×10^{-5}(1.09×10^{-5})		1.44×10^{-2}	4.90×10^{-2}
r	-0.274(-0.08)	-0.410(-0.369)		-0.532	-0.898
MSY (m.t./yr)	3800(9600)	3600(3400)		3400	4100
f opt. (×10 Hachi)	26,800(89,700)	13,500(17,700)	f opt (boat-days/yr)	480	290

[a]Source: Compiled for Canadian waters (48°00'-54°30') from U.S. NMFS computer printout SM 762.
[b]Source: data for INPFC Areas Charlotte and Vancouver (47°30'-54°30') presented by Japanese delegation at Nanaimo, B.C., May 1978. Anon.
[c]Effort averaged over previous K years.
[d]$Y/f = a - b\bar{f}$ where Y/f = CPUE, $\bar{f}$ = average effort over previous K yr.
MSY = $a^2/4b$ f opt = optimum fishing effort = a/2b
[e]Figures in parentheses refer to calculations made using 1977 CPUE corrected for discrepancy between observed recovery rates and recovery rate used by Japanese to calculate total catch weight from processed weight (see text).

Table 3.7. Results obtained by fitting a dynamic stochastic stock production model (Schnute 1977) to sablefish catch statistics for Japanese longline fishery in Canadian waters (48°00'-54°30'N lat.).

Parameters estimated	1968-1977	1968-1976	1969-1976	1968-1977[a] (corr.)
Biological parameters				
Natural growth rate (r)	negative	1.230	0.565	0.753
Carrying capacity (K) (m.t.)		20,000	25,800	28,100
Fishing parameters				
Catchability coefficient (q)($\times$10 Hachi^{-1})	-[b]	1.80×10^{-5}	1.89×10^{-5}	8.27×10^{-6}
MSY (m.t./yr)	-	6,200	3,600	5,300
Biomass at MSY (m.t.)	-	10,000	12,900	14,100
Optimum fishing effort (f opt.) ($\times$10 Hachi)	-	55,900	14,900	45,500
CPUE at f opt. (m.t./10 Hachi)	-	0.118	0.244	0.116
Variance parameters				
σ	0.201	0.177	0.181	0.174
Failure Index[c]	1.000	0.824	0.889	0.917
S1	-	0.157	0.131	0.181
S	-	0.186	0.133	0.192

[a]1977 CPUE corrected for discrepancy between observed recovery rates and recovery rate used by Japanese to calculate total catch weight from processed weight.

[b]no solution.

[c]The failure index is a rough gauge of the model's overall success in predicting present catches from past year's data. Although a value of 1.0 indicates a very poor fit, values less than 0.9 are reasonable.

Table 3.8 Sablefish CPUE for Japanese longline fishery, and all-nation catch and effort in Canadian waters (48°00'-54°30'N lat.), 1964-1977.

Calendar year	All-nation catch (m.t.)[a]	Japanese longline CPUE (m.t./10 Hachi)[b]	Total effort[c] (x 10 Hachi) averaged over K years		
			K=1	K=4	K=5
1964	481	-	-	-	-
1965	547	-	-	-	-
1966	904	-	-	-	-
1967	1,647	-	-	-	-
1968	2,801	0.261	10,732	-	-
1969	5,067	0.207	24,478	-	-
1970	5,480	0.215	25,488	-	-
1971	3,487	0.162	21,525	20,556	-
1972	5,840	0.207	28,213	24,926	22,087
1973	3,976	0.209	19,024	23,562	23,746
1974	4,612	0.210	21,962	22,681	23,242
1975	6,741	0.194	34,747	25,986	25,094
1976	6,702	0.194	34,546	27,570	27,698
1977	4,153	0.147	28,252	29,877	27,706
	(4,660)[e]	(0.172)	(27,093)	(29,587)	(27,474)

Parameter estimates from Gulland's (1961) linear regression model[d]

	K=4	K=5
a	0.251 (0.201)	0.384 (0.326)
b	2.49×10^{-8} (3.31×10^{-7})	7.65×10^{-6} (5.17×10^{-8})
r	-0.313 (-0.054)	-0.754 (-0.819)
MSY (m.t./yr)	6,300 (30,400)	4,800 (5,200)
f opt. (× 10 Hachi)	50,500 (303,000)	25,100 (31,600)

[a]Source: Table 1

[b]Source: Compiled for Canadian waters (48°00'-54°30') from U.S. Nat. Marine Fish. Serv. computer printout SM 762.

[c]Total effort (× 10 Hachi) = all-nation catch/Japanese longline CPUE.

[d]$Y/f=a-b\bar{f}$ where Y/f=CPUE, $\bar{f}$=average effort over previous K yr; $MSY=a^2/4b$; f opt.=optimum fishing effort=a/2b.

[e]Figures in parentheses refer to calculations made using 1977 Japanese longline catch and CPUE corrected for discrepancy between observed recovery rates and recovery rate used by Japanese to calculate total catch weight from processed weight (see text).

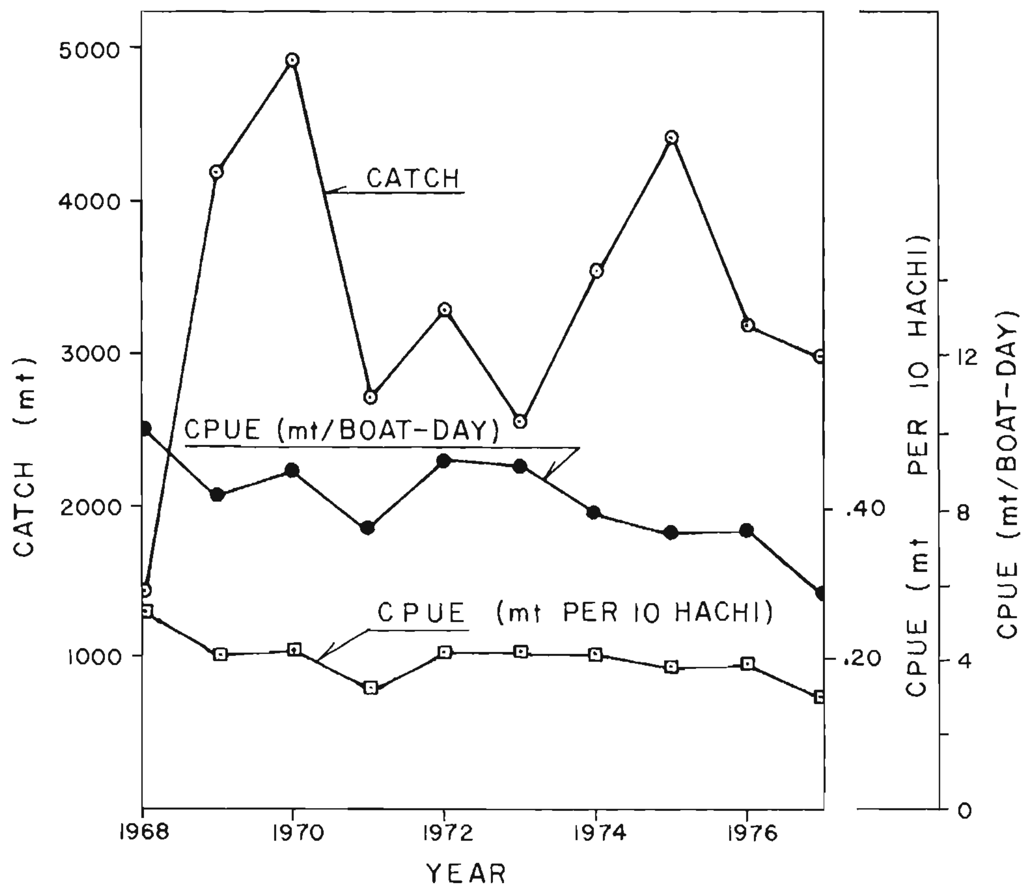

Fig. 3.1. Trends in catch and CPUE for Japanese longline fishery for sablefish in Canadian waters (48°00'-54°30'N Lat.) 1968-1977.

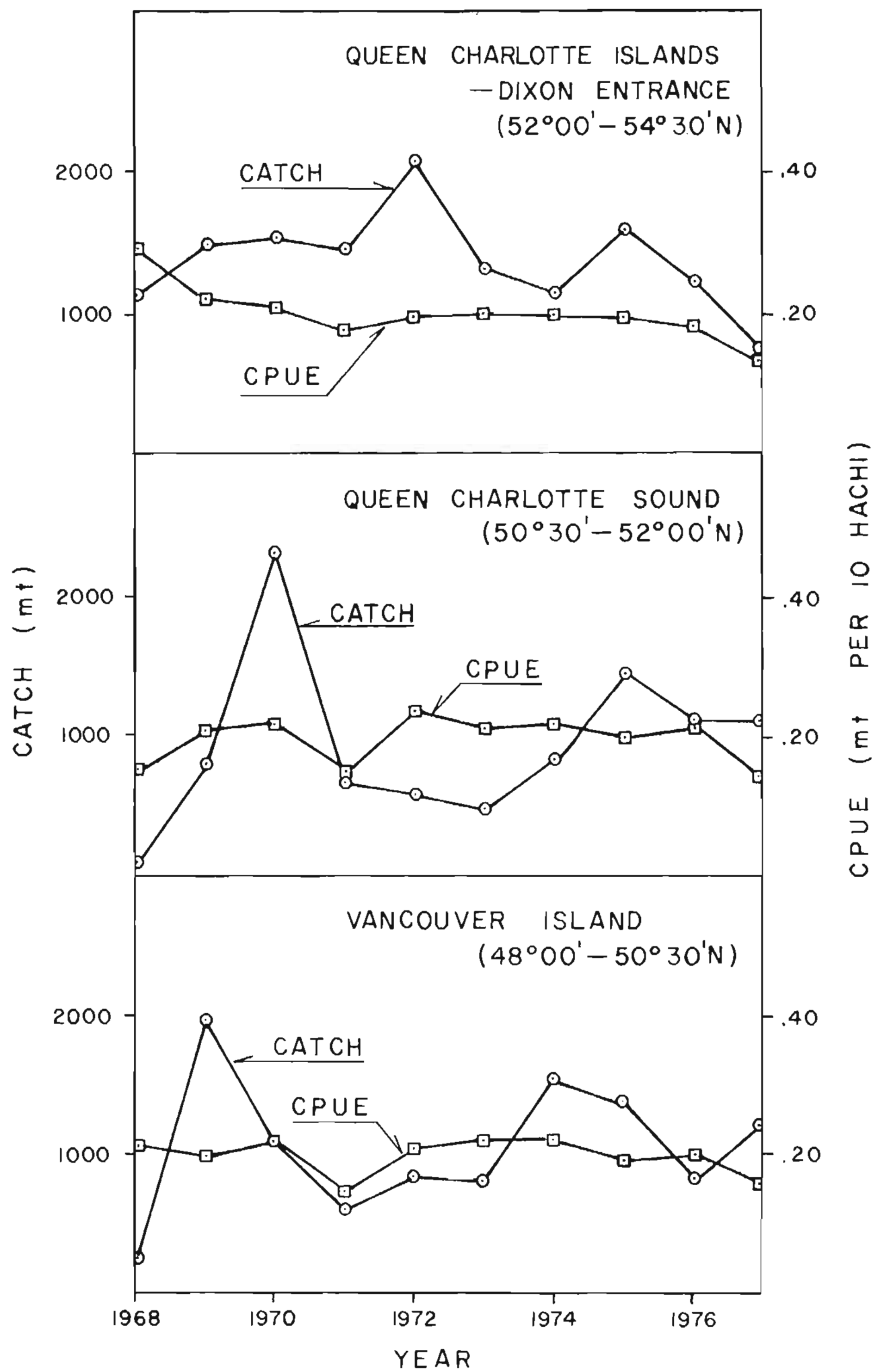

Fig. 3.2. Trends in catch and CPUE for Japanese longline fishery for sablefish by zone, 1968-1977.

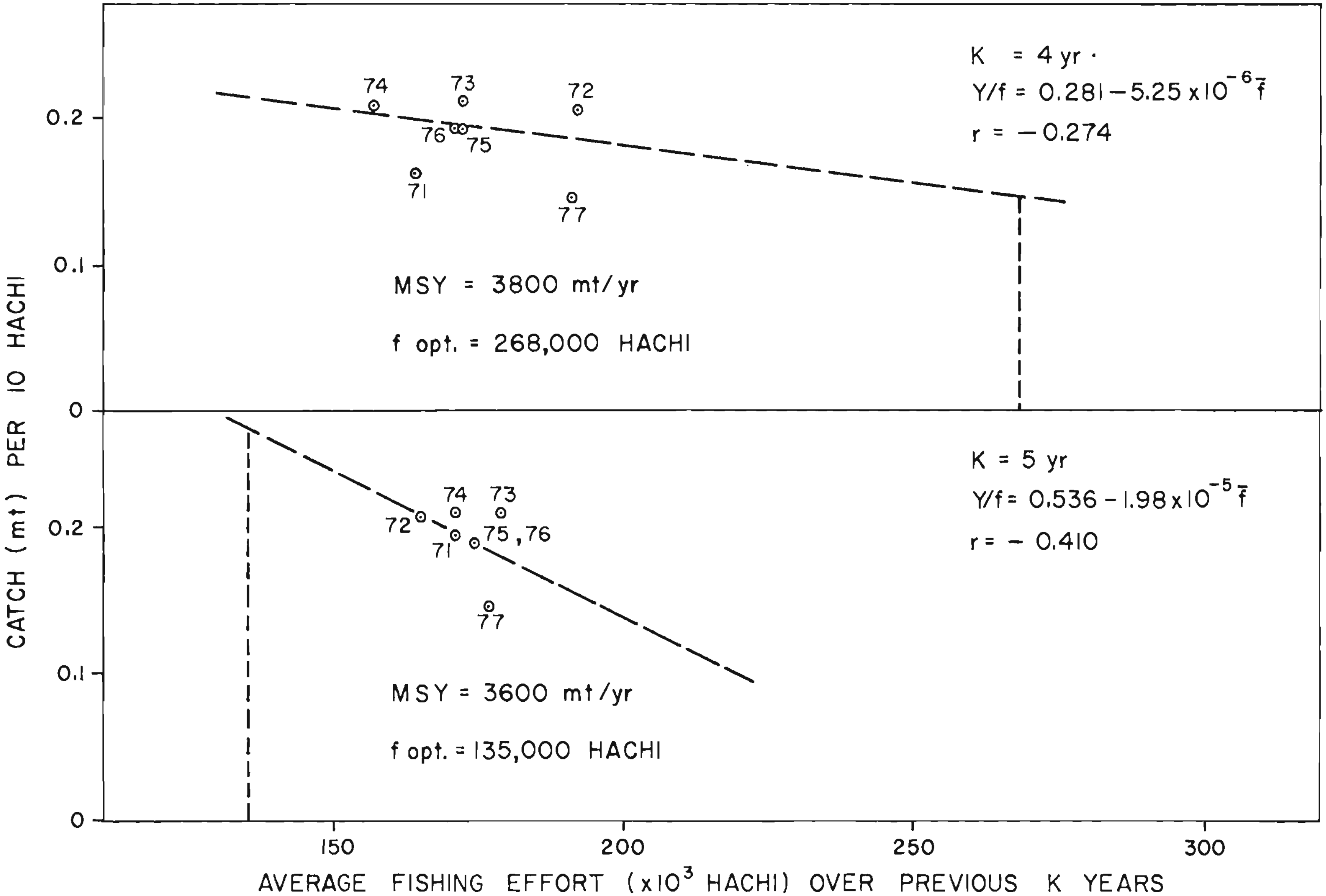

Fig. 3.3 Relationship between sablefish CPUE and fishing effort expressed in Hachi averaged over previous 4 and 5 years respectively for Japanese longline fishery in Canadian waters (48°00'-54°30'N Lat.) -- Gulland's (1961) linear regression model.

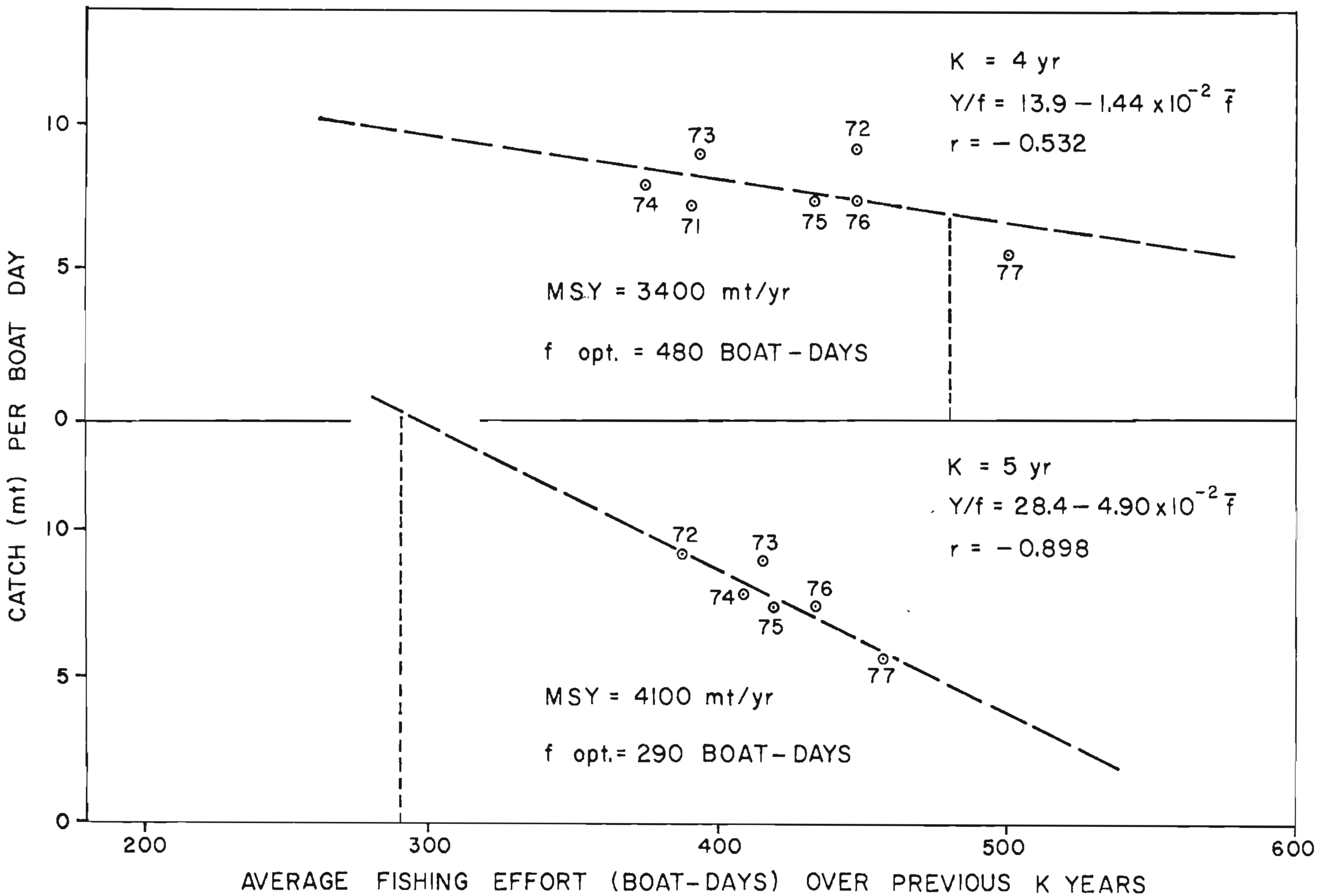

Fig. 3.4 Relationship between sablefish CPUE and fishing effort expressed in boat-days averaged over previous 4 and 5 years respectively for Japanese longline fishery in the Charlotte and Vancouver INPFC areas (47° 30'-54° 30'N Lat.) -- Gulland's (1961) linear regression model.

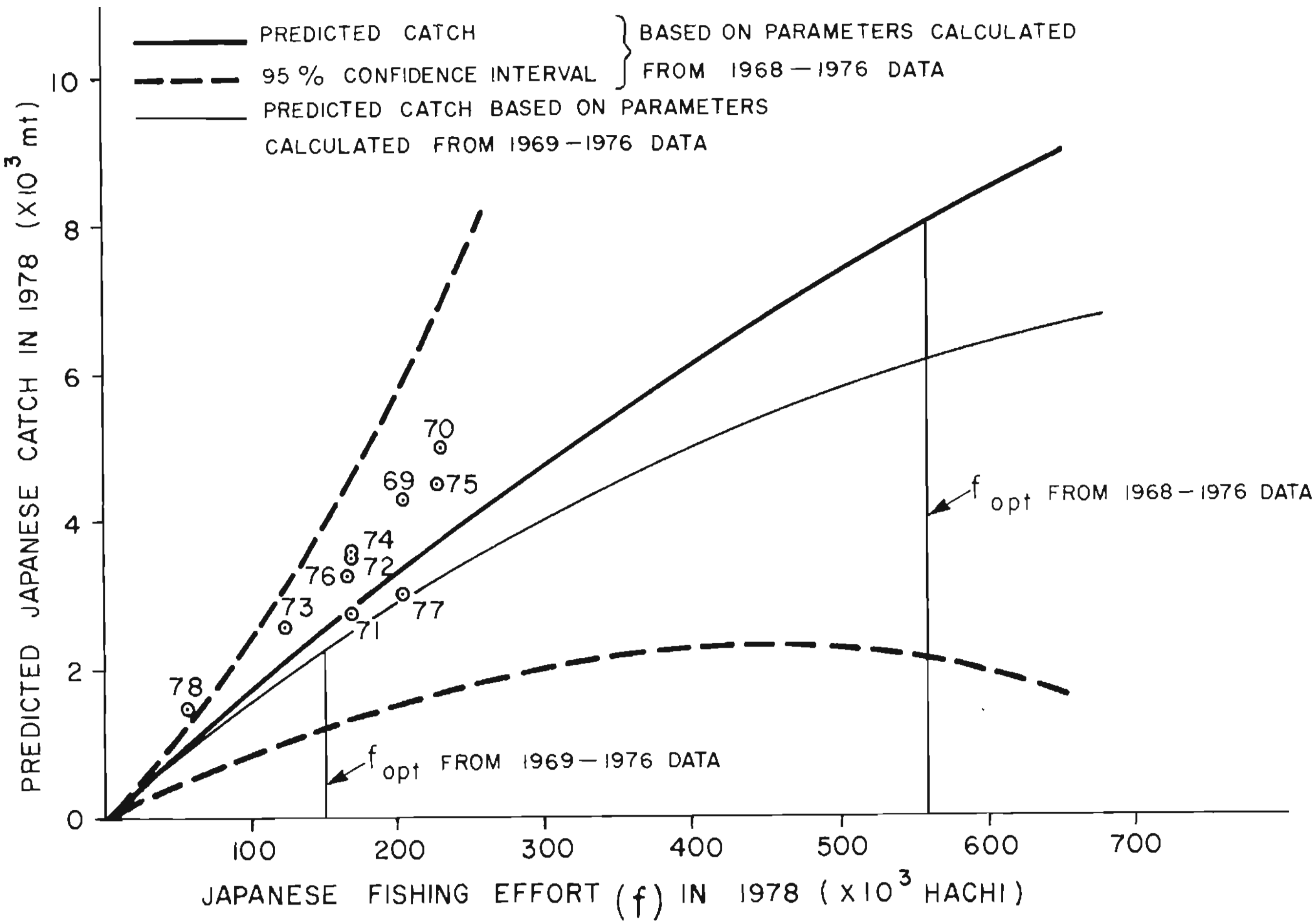

Fig. 3.5A. Projected 1978 sablefish catch for given levels of effort by the Japanese longline fleet in Canadian waters based on nominal 1977 catch data and estimates of population parameters from the dynamic stochastic stock production model (Schnute, 1977.)

Note- Although no solutions were possible from catch data streams using nominal 1977 data (Table 3.7) estimates of population parameters for 1976 based on two data streams, (1968-1976 and 1969-1976) were used as the estimates for 1977. This assumption is reasonable for the 1969-76 data stream since the estimates for 1974 through 1976 did not change appreciably, and could be expected to remain much the same as the 1977 catch is similar to the 1976 catch. However, the assumption is questionable in the case of the 1969-1976 data stream where estimates of population parameters for 1974 through 1976 show a slight trend.

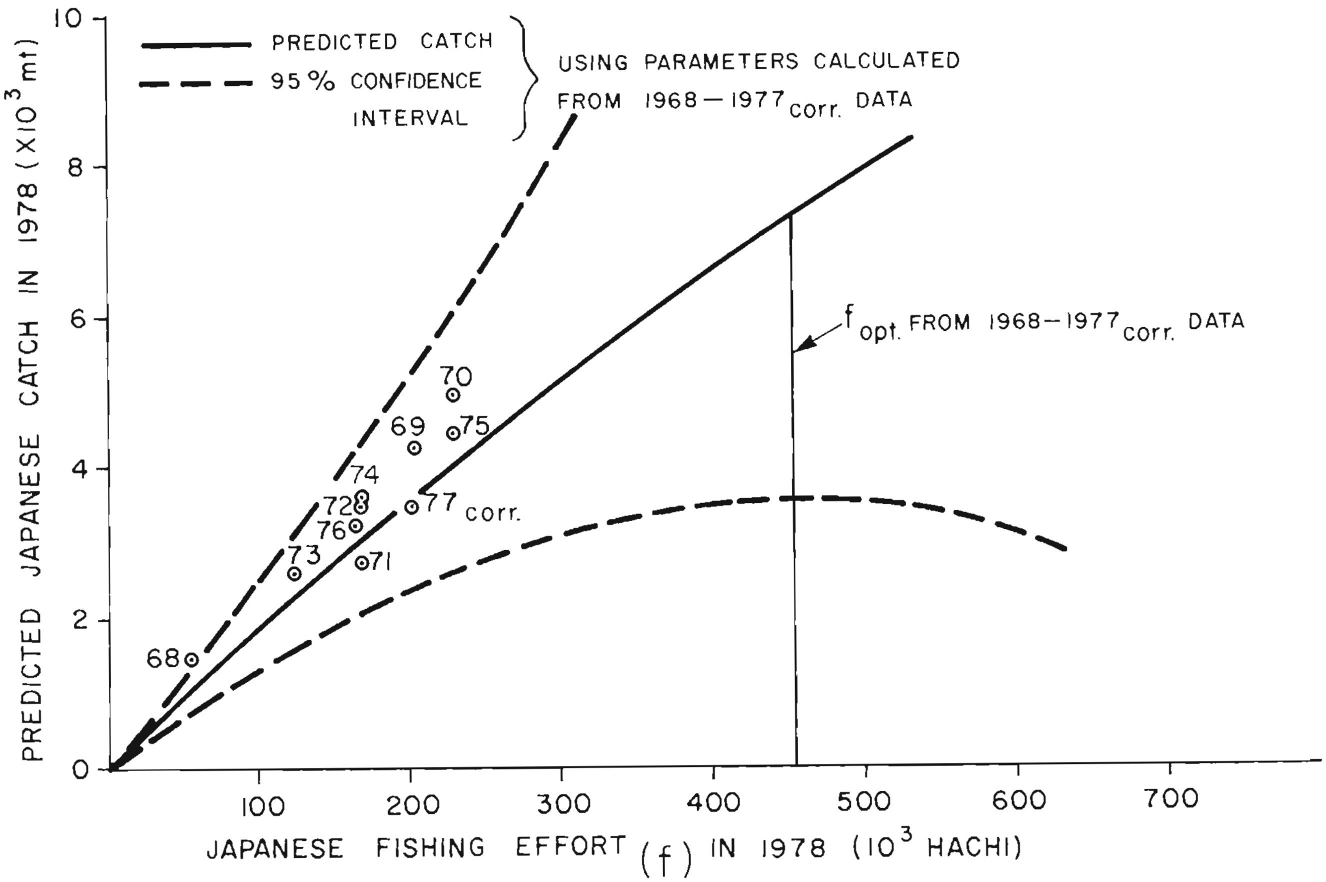

Fig. 3.5B. Projected 1978 sablefish catch for given levels of effort by the Japanese longline fleet in Canadian waters based on CORRECTED 1977 catch data and estimates of population parameters from the dynamic, stochastic stock production model (Schnute, 1977).

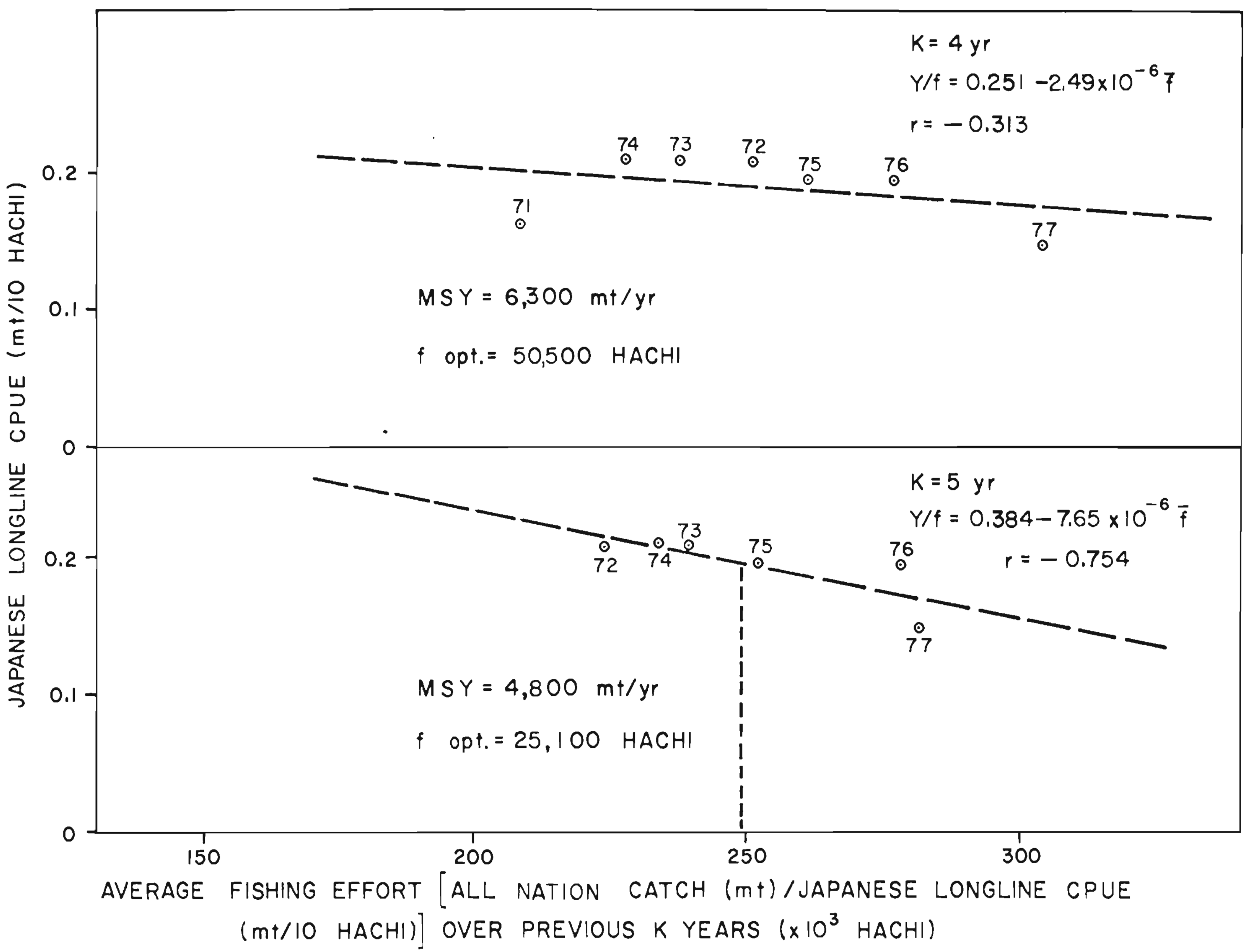

Fig. 3.6 Relationship between sablefish CPUE for Japanese longline fishery and estimated fishing effort by all nations in Canadian waters (48° 00'-54° 30'N Lat.) averaged over 4 and 5 years respectively -- Gulland's (1961) linear regression model.

4. PACIFIC COD STOCK ASSESSMENT

4.1 Introduction

Pacific cod (Gadus macrocephalus) is the most important species, based on quantities landed, in the Canada-United States trawl fishery off British Columbia. No other foreign nation participates in this fishery. Trawl fisheries exist in all regions of British Columbia except the west coast of Queen Charlotte Islands (Area 5E) (Fig. 4.1). Principal production regions are Hecate Strait (Areas 5C and 5D) and West Vancouver Island (Areas 3C and 3D), where annual Canada-U.S. landings during 1950-76 ranged from 1,814 to 9,072, and 907 to 5,443 m.t., respectively (Fig. 4.2). Secondary production regions are Queen Charlotte Sound (Areas 5A and 5B) and Georgia Strait (Area 4B) where 1950-76 landings ranged from 454 to 2,722, and 907 to 1,168 m.t., respectively. In all regions, landings fluctuated substantially, and somewhat cyclically.

Pacific cod in British Columbia waters exhibit rapid growth and a short life (Ketchen 1967). They recruit to the fishery at age 2+ and cease to be commercially abundant at age 5+ or less. The individual regional fisheries largely depend upon one or two year-classes in any one year. Hence, the large fluctuations in landings reflect the highly variable abundance of individual year-classes. Total mortality rate is high, and natural mortality rate comprises a large proportion, possibly of the order of 55-65% per annum (Ketchen 1964). To date, no evidence is available to demonstrate that the fishery is a major factor in determining year-class abundance.

Regional stock delineation has been roughly achieved by tagging studies conducted by Canadian and United States scientists in water of Hecate Strait, Georgia Strait, Puget Sound, southwest Vancouver Island, and northwest Washington State. Migration of cod among regions has been negligible in most cases. Percentages of recaptures reported from outside the tagging region were: 0.3% for Area 5C and 5D; 9.2% for Area 4B; 2.3% for Area 4A; 2.1% (Canadian) and 14.3% (U.S.) for Area 3C; 11.9% for Area 3B; and 42.9% for Area 3A.

The purpose of this report is to review the available statistical and biological information on Pacific cod in British Columbia waters, and to assess the condition and yield of the regional stocks off Southwest Vancouver Island (Area 3C), Georgia Strait (Area 4B), Queen Charlotte Sound (Area 5A and 5B), and in Hecate Strait (Area 5C and 5D).

4.2 Georgia Strait and vicinity (Area 4B)

Pacific cod is the most important species in the foodfish trawl landings from the Canadian portion of Georgia Strait and vicinity (Area 4B) (Fig. 4.1) -- accounting for 37% of the total groundfish production during 1960-72 (Forrester and Smith 1974). In second place was English sole (13%). For Area 4B, October-September has been established as the fishing year because of numerous time-area closures in effect throughout most of the area, and traditional tendency for the fleet to concentrate its efforts during October-March when the fish congregate for spawning (Forrester and Ketchen 1963).

Localized stocks of Pacific cod have been delineated by tagging experiments conducted during 1954-62 in the important production locations -- Northwest Gulf (Minor Statistical Area 14), Nanoose Bay (MSA 17N), Gulf Islands (MSA 17S and 18), and Juan de Fuca Strait (MSA 19 and 20) (Fig. 4.1). Little inter-MSA migration was noted for tagged cod, except those tagged at Nanoose Bay. For the Northwest Gulf, Gulf Islands, and Juan de Fuca Strait experiments, 81-93% of the recaptured cod were reported from the tagging area (Table 4.2). Cod only appear on the Nanoose Bay Ground during the spawning season (and the fishing season is restricted to January 31-March 20), and hence their widespread dispersion is not surprising. Only 45% of the recaptures were reported from the tagging area, while 26% were reported from Southeast Georgia Strait and North Puget Sound; 13% were reported from the Gulf Islands; and 7% were reported from Northwest Gulf.

4.2.1 Statistics and mortality rates

During 1960-77, October-September trawl landings of Pacific cod from Area 4B ranged from 318 to 1,089 m.t., with peak landings in 1963-64, 1966-67, 1970-71, and 1975-76 (Table 4.3). Mean annual landing was 585 m.t., of which 77% (449 m.t.) was landed during October-March. Principal production locations were minor statistical areas 18 (36%), 17 (21%), and 19 (17%). In all minor statistical areas annual landings fluctuated substantially, and among MSA's, non-synchronously. Only in 1975-76 did peak landings occur simultaneously for MSA 17, 18, and 19.

Estimates of instantaneous total mortality rates (Z) for 1955-58 were 1.27-1.77, based on growth parameters and length-frequency data, and tag returns (Ketchen 1961). Instantaneous natural mortality rate (M) for the same period, was estimated to be 1.39. Thus, instantaneous fishing mortality rate was apparently relatively low -- ca 0.29.

4.2.2 Stock assessment

Previous assessments of the Pacific cod stock(s) in Georgia Strait and vicinity have all concluded that the fishery was not a major factor in the substantial fluctuations in abundance (Forrester and Ketchen 1963; Forrester and Smith 1974; Ketchen 1967). Production, though variable and quasi-cyclical, shows no trend (Fig. 4.2), and no evidence is currently available to refute the conclusions of past stock assessments.

4.2.3 Recommendation

A TAC of 600 m.t. is recommended for Strait of Georgia (Area 4B) in 1979. Estimated 1978 landings is 600 m.t.

4.3 West Vancouver Island (Areas 3C and 3D)

Pacific cod is currently the most important species in the Canada-U.S. trawl landings from off West Vancouver Island -- 33% during 1965-74 (Westrheim 1977). Other important species are lingcod (21%), "Other" rockfish (17%), and Pacific ocean perch (12%). Canadian share of the landings has exceeded 60% (Fig. 4.2). Identifiable fishing grounds are Lennard Island (MSA 24), Amphitrite

Bank[9], Big Bank[10], Clo-oose, Swiftsure, and Cape Flattery Spit (Fig. 4.3). For analytical purposes, Area 3D has been excluded from further discussion.

Age composition of landings was essentially age-2+ fish during April-September, and age-3 fish during January-March (Fig. 4.4). Thus, the fishery generally depends upon the abundance of one year-class in each April-March period. Passage through the fishery of weak or strong year-classes can alter this relationship.

Stock delineation is difficult with the limited information available. Results of past tagging experiments suggest some migration of cod between Area 3C and Areas 4A, 4B, 3A, and 3B (Table 4.1), but no quantification is possible. It is possible there are one or more stocks which reside within Area 3C.

4.3.1 Statistics and mortality rates

During 1956-76, Canada-U.S. trawl landings of Pacific cod from Area 3C averaged 1,996 m.t. and ranged from 408 to 5,488 m.t. -- with peaks in 1957, 1963, 1966, 1972, and 1977 (Table 4.3). Seasonal distribution of landings has changed during 1956-76 -- 81% April-September during 1956-64; 79% January-June during 1965-76. During April-September the fishery harvests maturing, feeding cod; and during January-March, spawning cod.

Major fishing grounds in Area 3C, based on proportion of 1960-76 landings, were Amphitrite Bank (51%) and Big Bank (21%) (Table 4.5). Minor fishing grounds were Clo-oose (14%), Swiftsure (8%), Lennard Island (3%), and Cape Flattery Spit (3%). For the minor grounds, principal time of landing was January-June for Clo-oose, and April-September for Lennard Island, Swiftsure, and Cape Flattery Spit.

4.3.1.1 Amphitrite Bank

During 1960-76 annual production from Amphitrite Bank ranged from 181 to 2,540 m.t., and has been increasing -- 181-363 m.t. during 1960-64; 544-1,134 m.t. during 1965-70; and 1,406-2,540 m.t. during 1971-76 (Table 4.6). Principal season of landings has gradually changed from April-June (49-85%) during 1960-64 to January-March (80-96%) during 1973-76.

Conventional analysis of catch, effort, and CPUE is virtually precluded by the variable nature of the fishery, which has evolved from a spring fishery (1960-64) on maturing and mature feeding fish to a winter fishery (1972-76) on spawning fish. Furthermore, during 1972-78 the fishery further evolved from interception on the bank's periphery, of cod moving onto and off the spawning grounds, to trawling on schools concentrated for spawning on the bank itself. This latter development began about 1974. Nevertheless, the January-March catch statistics for Amphitrite Bank are shown in Table 4.7. The relatively large

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[9] Includes Firing Range and Cabbage Patch Ground.
[10] Includes S.E. Corner, S.W. Corner, Gunsight, and Finger Bank Grounds.

landings and catch rates during 1972-76 reflect: (1) heavier (older) individual fish; (2) denser concentrations of spawning fish (than feeding fish), and probably relatively more abundant year-classes. However, the sustained production was in part caused by the new method of targetting on spawning fish. Unfortunately, data are not available for standardizing effort.

Instantaneous rates of total mortality (Z) were estimated for year-classes 1967-71, by regressing catch rate (no/hr) on age (Table 4.8). Estimates ranged from 1.00 (1971) to 1.38 (1970), and varied directly with the relative strength of the year-class, as measured by catch rate at age 3.0.

4.3.1.2 Big Bank

During 1960-76, annual production from Big Bank ranged from 45 to 1,724 m.t., with peak production periods in 1965-66 and 1971-76 (Table 4.6). Principal season of landings has been April-September (79% of mean annual landings) throughout 1960-76.

Conventional analysis of catch, effort, and CPUE is warranted, providing that two constraints are acknowledged. First, the Canadian fleet has increased its efficiency (new, larger vessels) during the 1970's, although apparently no new fishing techniques have been developed. Second, during the same period, dogfish has become so abundant that they sometimes represent a hazard to trawling on Big Bank during April-September. Neither of these constraints has been quantified.

Analysis of landing statistics was restricted to April-September when annual proportions landed were greatest (79%) and most consistent (Table 4.6). Canada-U.S. landings and calculated fishing effort have generally fluctuated directly with one another (Table 4.7), with peaks in 1963, 1966, 1972, and 1976. Canadian vessels' catch rate likewise fluctuated, but not consistently with landings and effort. Catch rate peaks occurred in 1964, 1966, 1968, and 1972. Absence of a peak in 1976, and the relatively low values during 1974-1977 (234-266 kg/hr), suggest that the Pacific cod stock on the Big Bank is now at a relatively low level of abundance, and CPUE may not be correctly reflecting abundance.

Instantaneous rates of total mortality (Z) were estimated for year-classes 1968-72 by regressing catch rate (no/hr) on age (Table 4.8). Estimates averaged 1.11 and ranged from 0.66 to 1.52. They varied directly with year-class abundance, as measured by catch rate of age 2.5 cod.

4.3.2 Stock assessment

Currently, abundance of Pacific cod in Area 3C appears to be at a relatively low level, based on catch statistics and age composition data, and no new strong year-classes have been detected. Historically, cod abundance has fluctuated regularly, and substantially; and independently of the fishery. However, the Canadian fleet has increased its efficiency with new, larger vessels, and improved fishing techniques (on spawning fish). Thus, for the first time, recruitment overfishing is a distinct possibility, during the January-March fishery on spawning fish. Projected Canadian catch during January-March 1979, based on the Canadian catch during April-June 1978, is 842 m.t., and 432 m.t. based on the July-September landings (See Appendix I for details).

4.3.3 Recommendations

A TAC of 900 m.t. is recommended for Areas 3C and 3D in 1979 together with a prohibition of target fishing for Pacific cod during the months of January, February and March. Estimated Canada-U.S. landings in 1978 is 1,600 m.t.

4.4 Queen Charlotte Sound (Areas 5A and 5B)

Pacific cod is relatively unimportant in the Canada-U.S. trawl landings from Queen Charlotte Sound. Westrheim (1977) reported that during 1965-74 Pacific cod ranked third (12%) behind Pacific ocean perch (43%) and Other rockfish (26%). Canadian share of these cod landings has rarely exceeded 30% over the long-term but the proportion has risen markedly during the last several years (Fig. 4.2). Size and age composition data from commercial landings are intermittent and too sparse for analysis.

Principal fishing grounds are Goose Island Bank (Area 5B) and the grounds lying off the north coast of Vancouver Island (Area 5A) (Fig. 4.1).

No tagging experiments have been undertaken for Pacific cod in Queen Charlotte Sound, nor any other studies which would provide evidence for inter- or intra - regional stock delineation. Indirect evidence of regional isolation is the near-absence of cod recaptured in Queen Charlotte Sound which had been tagged elsewhere (Table 4.1). It is possible that cod in Area 5A are to a large degree separate from those in Area 5B.

4.4.1 Statistics and mortality rates

During 1956-76 Canada-U.S. landings of Pacific cod averaged 1,406 m.t. but ranged from 227 to 2,722 m.t., with peaks in 1957, 1965, 1972, and 1975 (Table 4.9). Principal time of landings was April-September in Areas 5A (77%) and 5B (90%). In Area 5A, landings ranged from 91 to 2,223 m.t., with peaks in 1957, 1966, 1972, and 1974. Trend is downward, based on landings in peak years. In Area 5B, landings ranged from 136 to 1,769 m.t., with peaks in 1960, 1965, 1972, and 1975. Trend is upward, based on landings in peak years.

Mortality rates have not been established for Pacific cod in Queen Charlotte Sound, primarily due to the paucity of available age-length data.

4.4.2 Stock assessment

On the basis of the limited data available, there is no indication that the fishery is a major factor in the fluctuating abundance of Pacific cod in Queen Charlotte Sound. No explanation is available for the opposing production trends in Areas 5A and 5B.

4.4.3 Recommendation

A TAC of 1,600 m.t. is recommended for the Queen Charlotte Sound (Area 5A & 5B) for 1979. Estimated Canada-U.S. landings for 1978 is 1,600 m.t.

4.5 Hecate Strait and Dixon Entrance (Areas 5C and 5D)

Pacific cod is currently the most important species in the trawl landings from Hecate Strait and Dixon Entrance (Areas 5C and 5D). Westrheim (1977) reported that during 1965-74, Pacific cod accounted for 56% of the Canada-U.S. trawl landings from this region (rock sole was second at 18%). Canadian share of the cod landings has exceeded 70% since 1960, and has been 100% since 1971 (Fig. 4.2). Landings are currently reported from seven fishing grounds -- Tow Hill; Two Peaks-Butterworth (hereafter referred to as Two Peaks); Freemans Pass-White Rocks-Bonilla (hereafter referred to as White Rocks); Shell (Potholes); Ole Spot; Horseshoe; and Reef Island (Fig. 4.5).

Tagging studies have demonstrated a migration of cod between winter spawning grounds at White Rocks and spring-summer feeding grounds at Two Peaks (Table 4.10), but the relationship has not been quantified. A similar relationship appears to hold between Bonilla and Ole Spot-Horseshoe. Intra-regional stock delineation is not well understood at this time.

Age composition of Pacific cod landings is generally 2+ and 3+ fish during April-September, and 3+ and 4+ during October-March (Fig. 4.6). Thus the fishery relies primarily on the abundance of 2 year-classes during each year.

4.5.1 Statistics and mortality rates

During 1956-77 annual Canada-U.S. landings ranged from 1,361 to 9,525 m.t., with peaks in 1958, 1966, and 1976 (Table 4.11). No trend in production is evident. Principal time of landing was in the period January-September (91%). Mean percentages were 28-31 for each of Quarters I-III, and 9% for Quarter IV. Quarter I landings have become relatively less important since 1971 (8-25%).

Major fishing grounds, based on percentage contribution of landings during the 1956-77 period, are Two Peaks (35%), White Rocks (20%), and Horseshoe (19%) (Table 4.12). Minor fishing grounds are Ole Spot (7%), Shell (5%), Reef Island (4%), and Tow Hill (1%). Shell and Reef Island grounds did not come into continuous production until the late 1960's and their 1968-77 mean percentages are 11 and 8, respectively, compared to 76% for the three major grounds combined. Winter fisheries on spawning cod predominate at White Rocks and Reef Island, while spring-summer fisheries for feeding cod prevail elsewhere in Hecate Strait.

4.5.1.1 Two Peaks ground

During 1956-77, annual landings of Pacific cod from Two Peaks ground ranged from 499 to 3,175 m.t., with peaks in 1959, 1965, and 1975 (Table 4.13).

No trend is evident. Principal time of landings is April-September (78%).[11] Quarters II and III were of more consistent importance than Quarters I and IV. Catch statistics for Quarters II and III have been used to assess this stock.

Catch statistics for Pacific cod landed from Two Peaks Grounds indicate substantial fluctuations in abundance, but no long-term trend upward or downward. Canada-U.S. landings have ranged from 384 m.t. in 1956 to 2,473 m.t. in 1966, with peaks in 1959, 1966 and 1975 (Table 4.14). In 1977, landings totalling 1,882 m.t. CPUE likewise has fluctuated without trend, with values ranging from 376 kg/hr in 1972 to 1,808 kg/hr in 1964. Peak values occurred in 1954, 1959, 1967, and 1974. In 1977, CPUE was 644 kg/hr.

Estimates of total instantaneous mortality rate (Z) were obtained from three time periods and methods -- years 1954-63, with growth parameters and length-frequency data (Ketchen, 1964); year-classes 1968-72 (Qtrs II & III), by scales; and year-classes 1957-72, (Qtr III), by length-frequency analysis (Foucher, personal communication). Values of Z from the three sources were 1.11-1.27 (1954-63), 0.02-1.16[12] (year-classes 1968-72, Table 4.15); and 0.76-2.57 (year-classes 1957-72, Table 4.15).

For the 1957-72 year-classes, an interesting relationship was noted between strong year-classes and the next following year-class, with respect to estimates of Z, as follows:

Year class	Z (Ages 3.8-5.8)
1962	2.57
1963	1.15
1965	2.26
1966	1.26
1957	1.90
1958	1.83

The relationship of Z values between a strong year-class and the adjacent, following year-class suggests that natural mortality rate is age-specific (directly proportional to year-class abundance), or the trawl fishery can target on a particularly stong year-class.

4.5.1.2 White Rocks ground

During 1958-77[13], annual landings of Pacific cod from White Rocks

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[11] High percentages for Quarter I in 1956 and 1957 are considered to be erroneous. Probable origin was White Rocks.

[12] Results questionable. Further studies on age determination are underway.

[13] 1956-57 values are deemed inaccurate. See footnote in preceding Two Peaks Section.

Ground ranged from 318 m.t. to 2,359 m.t., with peaks in 1959, 1965, 1967, 1972, and 1976 (Table 4.16). No trend is evident. Principal time of landings is October-March -- 1956-77 mean proportions were 56% for Quarter I and 27% for Quarter IV. Proportions landed during Quarter I were more consistent than for Quarter II, III and IV, but for analytical purposes, catch statistics were assembled which combined Quarter IV with Quarter I in the following year.

Catch statistics for Quarters IV and I of Pacific cod landed from White Rocks Ground show a generally close relationship between landings, effort, and CPUE, with peaks in 1962-63, 1964-65, 1967-68, 1972-73, and 1975-76 (Table 4.17). Only in 1958-59 did CPUE fail to peak with landings and effort. No trend is evident in landings, effort, or CPUE, but a downward trend in CPUE might well be concealed because effort has not been standardized.

Estimates of instantaneous total mortality rate (Z) were calculated only for the 1968 and 1972 year-classes[14]-- 1.17 for 1968 and 1.11 for 1972 (Table 4.18).

4.5.1.3 Horseshoe ground

During 1956-77, annual landings of Pacific cod from Horseshoe Ground ranged from 18 m.t. to 3,130 m.t. (Table 4.19). Landings peaked in 1958, 1966, 1968, 1973, and 1976. No trend is evident. Principal time of production was in Quarters II and III, and catch statistics for these Quarters have been combined for assessment of the cod stock on Horseshoe Ground.

Quarter II and III catch statistics did not display the close relationship between landings, effort, and CPUE noted for cod from Two Peaks and White Rocks Grounds. Landings peaked in 1958, 1966, 1973, and 1976 (Table 4.20). Peaks in effort occurred in 1960, 1965, 1968, and 1974 while CPUE peaks occurred in 1958, 1964, 1966, 1973, and 1976. Only in 1976 did the three factors peak simultaneously. No trend is evident in landings, effort, or CPUE.

Estimates of instantaneous total mortality rate (Z) were calculated on the basis of scale readings, for year-classes 1969-72, the only ones for which a continuous series of scale samples was available (Table 4.18). Values of Z ranged from 0.94 to 2.12 with an average of 1.29. Based on abundance (no/hr) of age-3.2 fish, Z values varied directly with year-class abundance. Earlier estimates of Z, 1950-52 and 1.05-1.53 for 1954-63 (Ketchen 1964).

4.5.1.4 Minor grounds

Minor grounds in Hecate Strait are Cle Spot, Shell Ground, and Reef Island -- the latter two are relatively new discoveries.

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[14]Data from the 1969-71 year-classes were not usable because no scale samples were collected in Quarters IV and I of 1972-73.

Ole Spot. Landings have been reported from Ole Spot since prior to 1956. During 1956-77, landings ranged from nil to 1,588 m.t. (Table 4.21). Landings peaked in 1958, 1966, and 1973. No trend is evident. Principal time of landings is April-June. Age composition data are intermittent and too sparse for analysis.

Shell Ground. Landings have been reported from this ground since 1966 on a regular basis. During 1966-77, landings ranged from 91 to 1,134 m.t. without trend (Table 4.13). Peak landings occurred in 1968 and 1975. Principal time of landings was January-June (82%). Age composition data are intermittent and too sparse for analysis.

Reef Island. Landings have been reported from Reef Island Ground since 1968 on a regular basis. During 1968-77 landings ranged from 91 to 590 m.t., with peaks in 1969, 1971, 1973, and 1976, without evident trend (Table 4.13). Principal time of landings was January-March (71%) when cod are spawning. Age composition data are intermittent and too sparse for analysis.

4.5.2 Stock assessment

During 1956-77 Pacific cod landings, and presumably abundance, exhibited substantial, quasi-cyclic fluctuations which were, for the most part non-synchronous among grounds. No trend in landings of CPUE was evident for any fishing ground. On the basis of the available evidence, the Pacific cod stock(s) in Hecate Strait is (are) in satisfactory condition, despite the fluctuations in annual landings.

4.5.3 Recommendations

A TAC of 2,000 m.t. is recommended for Hecate Strait (Areas 5C and 5D) in 1979.

Table 4.1 Distribution (%) of recaptured Pacific cod from Canadian and United States tagging experiments by location of tagging and recapture, 1954-68. (U.S. data from Gosho, 1976).

Tagging area[a]	Country[b]	No. tagged	Usable recaptures	Recapture area[a]							
				3A	3B	3C	3D	4A	4B	5A & 5B	5C & 5D
3A	U	63	7	57.1	14.3	28.6	-	-	-	-	-
3B	U	1,716	109	-	88.1	5.5	0.9	4.6	-	0.9	-
3C	C	1,686	283	-	0.1	97.9	-	-	1.8	-	-
	U	92	7	-	-	85.7	-	-	14.3	-	-
4A	U	10,749	2,570	-	0.2	0.4	-	97.7	1.9	0.03	0.2
4B	C	6,859	1,017	-	0.2	0.6	-	8.5	90.8	-	-
5C & 5D	C	13,036	3,585	-	-	-	0.1	-	-	0.2	99.7

[a] 3A & 3B = Washington State coast; 3C & 3D = West Vancouver Island; 4A = Puget Sound and U.S. portions of Georgia and Juan de Fuca Strait; 4B = Canadian waters off East and South Vancouver Island; 5A & 5B = Queen Charlotte Sound; 5C & 5D = Hecate Strait and Dixon Entrance.
[b] C = Canada; U = United States.
Recapture location known.

Table 4.2. Distribution (%) of Pacific cod tagged in Georgia Strait and vicinity (Area 4B), by location of tagging and recapture, 1954-62.

Recapture location	North of Nanoose (14)	Nanoose Bay (17N)	Gulf Islands (17S+18)	Juan de Fuca (19+20)
14 North of Nanoose	93	7	1	-
17N Nanoose Bay	5	45	1	-
17S+18 Gulf Islands	-	13	92	4
19+20+86[a] Juan de Fuca Strait	-	5	2	81
29+80+82+83[b] S.E. Strait	2	26	4	2
3B N.W. Washington	-	2	-	-
3C S.W. Vancouver Island	-	2	T	13
Total	100	100	100	101
Usable recaptures (N= 928)	61	193	626	48

[a] 86 = U.S. Sub-Area in 4A.

[b] 80, 82 + 83 = U.S. Sub-Areas in 4A.

Recapture location known.

Table 4.3. Trawl landings (m.t.) of Pacific cod from Georgia Strait and vicinity (Area 4B), and important Minor Areas, October-September 1960-77.

Year	Area 4B	Minor Statistical Area 18	17	19	14	20	12+ 13+ 15+ 16	29
1960-61	486	156	100	103	78	29	12	8
1961-62	434	161	69	49	55	78	10	12
1962-63	561	227	151	37	48	71	14	12
1963-64	772	349	138	74	111	54	16	28
1964-65	502	214	45	81	37	88	18	20
1965-66	326	77	16	117	18	76	13	8
1966-67	464	154	151	22	28	52	52	4
1967-68	381	96	126	49	22	58	16	13
1968-69	326	124	59	20	17	82	16	7
1969-70	509	192	93	80	25	95	11	12
1970-71	743	178	340	48	81	86	8	4
1971-72	665	169	302	20	69	98	3	2
1972-73	513	188	133	12	150	11	11	8
1973-74	526	247	144	51	58	8	16	TR
1974-75	740	218	75	258	74	83	26	6
1975-76	1096	418	89	467	83	14	25	2
1976-77	895	385	60	244	98	55	53	TR
Oct.-Sept. Mean	585	209	123	102	62	61	19	9
Oct.-Mar. Mean	447	169	112	73	52	21	16	4
% Oct.-Mar.	76	81	92	71	84	35	85	47
% Oct.-Sept. Mean	99	36	21	17	11	10	3	1

Table 4.4. Distribution (%), by Quarter-year, of annual Canada-U.S. landings of Pacific cod from Southwest Vancouver Island (Area 3C), 1956-76.

Year	Quarter I	II	III	IV	T	Total landings (m.t.)
1956	2	64	15	20	101	1,147
1957	3	68	25	5	101	1,582
1958	7	54	22	17	100	763
1959	2	56	22	20	100	673
1960	3	54	28	14	99	590
1961	T	62	26	11	99+	390
1962	17	50	28	5	100	567
1963	25	59	14	2	100	1,196
1964	21	61	15	4	101	1,143
1965	37	37	22	4	100	2,535
1966	31	35	32	2	100	2,644
1967	56	30	10	5	101	1,653
1968	68	22	4	6	100	1,173
1969	54	31	9	6	100	960
1970	37	32	25	7	101	965
1971	27	48	17	8	100	3,077
1972	43	40	13	4	100	5,487
1973	68	18	11	3	100	3,597
1974	54	24	18	8	100	3,365
1975	48	23	21	8	100	4,467
1976	44	38	16	3	101	3,916
1956-64 Mean	9	59	22	11	101	
C.V.	106	10	26	66		
1965-76 Mean	47	32	17	5	101	
C.V.	28	28	47	39		

Table 4.5. Distribution (%), by ground, of annual Canada-U.S.A. Pacific cod landings from Area 3C, 1960-76.

	Ground							
Year	Lennard Island	Amphitrite Bank	Big Bank	Clo-oose	Swiftsure	Cape Flattery Spit	Total	Annual Landing (m.t.)
1960	10	43	25	10	10	3	101	590
1961	3	44	12	29	10	3	99	390
1962	2	49	19	20	5	5	100	567
1963	1	31	21	33	12	2	100	1,196
1964	1	34	22	23	19	1	100	1,143
1965	2	45	29	18	5	1	100	2,535
1966	2	39	30	22	5	1	99	2,644
1967	8	49	11	30	1	1	100	1,653
1968	1	78	9	9	3	1	101	1,173
1969	2	75	15	3	4	1	100	960
1970	2	57	26	11	2	2	100	965
1971	4	45	37	11	3	1	101	3,077
1972	4	47	32	7	8	1	101	5,487
1973	1	69	14	5	10	1	100	3,597
1974	3	57	19	1	18	2	100	3,365
1975	4	49	14	1	16	16	100	4,467
1976	3	54	21	T	13	9	100	3,916
1960-76 Mean	3	51	21	14	8	3		
C.V. (%)	82	26	38	79	67	131		
r		0.448	0.011					
b		1.164	0.017					
a		-28.28	+19.77					

Table 4.6. Distribution (%), by Quarter-year, of Canada-U.S.A. landings of Pacific cod from Amphitrite Bank and Big Bank, 1960-76.

Year	Amphitrite Bank I	II	III	IV	Total	Total Landings (m.t.)	Big Bank I	II	III	IV	Total	Total Landings (m.t.)
1960	5	85	6	4	100	251	-	16	47	37	100	146
1961	1	81	14	5	101	170	-	30	40	30	100	48
1962	35	53	12	T	100	276	T	43	43	13	99	107
1963	48	49	3	T	100	368	2	46	50	2	100	253
1964	12	70	18	1	101	383	T	62	26	12	100	256
1965	54	33	11	1	99	1,144	26	24	38	12	100	739
1966	40	33	26	T	99	1,039	23	25	52	1	101	803
1967	65	32	1	1	99	816	1	44	21	34	100	178
1968	80	19	T	1	100	913	1	36	35	29	101	103
1969	71	28	1	T	100	720	-	33	51	17	101	145
1970	54	31	14	T	99	547	1	25	62	13	101	254
1971	58	40	3	T	101	1,389	-	41	37	22	100	1,137
1972	77	21	2	T	100	2,558	10	51	32	8	101	1,729
1973	90	9	T	T	99	2,489	23	34	33	10	100	494
1974	95	5	T	T	100	1,902	-	35	44	21	100	651
1975	96	2	2	T	100	2,187	T	51	31	18	100	630
1976	80	18	2	T	100	2,113	1	43	47	9	100	824
1960-76 Mean	57	36	7	1			5	38	41	17	101	
C.V.	53	69	114	194			180	31	26	63		

Table 4.7. Pacific cod landings (m.t.), calculated effort (hr), and catch rate (m.t./hr) from Amphitrite Bank, (January-March) and Big Bank (April-September), by Canadian and United States vessels, 1960-76.

	Amphitrite Bank (Jan.-Mar.)			Big Bank (Apr.-Sept.)		
Year	Canada-U.S. landings (m.t.)	Calculated[c] effort (hr)	Canada catch rate (m.t./hr)	Canada-U.S. landings (m.t.)	Calculated[c] effort (hr)	Canada catch rate (m.t./hr)
1960	12	838	.014	91	463	.197
1961	1	-	-	34	440	.076
1962	95	321	.297	93	622	.149
1963	178	875	.204	241	1,330	.181
1964	45	120	.374	225	476	.473
1965	621	5,189	.120[a]	460	1,200	.384
1966	418	1,382	.303	616	1,485	.415
1967	528	1,882	.281	117	386	.302
1968	729	2,302	.317	73	159	.459
1969	513	1,425	.360	121	376	.321
1970	297	1,030	.288	218	891	.245
1971	799	1,676	.477	889	1,617	.550
1972	1,963	2,467	.796	1,422	2,115	.672
1973	2,232	1,856	1,202	331	1,020	.324
1974	1,801	2,181	.826	517	1,991	.259
1975	2,098	3,115	.674	518	1,947	.266
1976	1,695	2,210	.767	740	2,984	.248
1977	-[d]	-	.721	-	-	.234[b]

[a]Doubtful, based on only 27,000 kg landed.
[b]Provisional
[c]Calculated effort equals Canada-U.S. landings divided by Canadian CPUE at 25% of qualification.
[d]U.S. data not available.

Table 4.8. Year-class abundance (no/hr), for selected age groups, and estimated instantaneous total mortality rate (Z), for Pacific cod landed from Amphitrite Bank during January-March and Big Bank during April-September, 1970-76.

Age (yr)	Year-class					
	1967	1968	1969	1970	1971	1972
			Amphitrite Bank (Jan.-Mar.)			
2.0	-	6	36	43	26	19
3.0	43	118	165	259	117	114
4.0	68	66	98	76	53	92
5.0	21	10	23	27	16	?
6.0	2	7	9	4	-	?
Z[a]	1.02	1.04	1.00	1.38	1.00	?
			Big Bank (Apr.-Sept.)			
2.5	-	56	192	196	62	82
3.5	-	76	148	66	29	56
4.5	-	28	19	8	13	22
5.5	-	9	3	3	5	?
Z[b]		1.08	1.45	1.52	0.85	0.67

[a]Based upon regression of ages 3.0-6.0, except year-class 1967 (4.0-6.0).

[b]Based upon regression of ages 2.5-5.5, except year-class 1968 (3.5-5.5).

Table 4.9. Distribution (%), by quarter-year, of Canada-U.S. landings of Pacific cod from Queen Charlotte Sound, by area, 1956-76.

Year	Area 5A I	Area 5A II	Area 5A III	Area 5A IV	Area 5A Total	5A landings (m.t.)	Area 5B I	Area 5B II	Area 5B III	Area 5B IV	Area 5B Total	5B landings (m.t.)	5A&5B landings (m.t.)
1956	14	28	33	25	100	1,159	19	32	43	6	100	594	1,754
1957	9	37	35	19	100	2,244	8	46	13	33	100	499	2,744
1958	16	49	27	8	100	681	2	68	22	9	101	497	1,178
1959	9	58	26	7	100	599	3	72	24	2	101	347	946
1960	4	60	26	11	101	233	12	41	46	1	100	386	619
1961	13	65	10	12	100	98	9	80	9	1	99	142	239
1962	21	26	46	7	100	174	4	44	50	3	101	248	422
1963	5	23	64	8	100	287	T	58	39	2	99	390	677
1964	3	41	29	27	100	513	3	39	49	9	100	762	1,275
1965	1	35	26	39	101	797	1	66	32	1	100	1,143	1,940
1966	6	33	37	25	101	1,066	T	59	34	7	100	745	1,811
1967	8	31	32	28	99	761	T	65	34	1	100	740	1,501
1968	7	59	27	7	100	626	1	56	35	8	100	334	960
1969	11	40	31	18	100	389	8	41	45	6	100	310	699
1970	8	42	30	20	100	185	6	50	38	5	99	114	299
1971	T	46	39	15	100	461	-	51	44	5	100	467	928
1972	1	56	30	12	99	756	T	55	39	6	100	1,564	2,320
1973	13	53	25	9	100	623	2	64	32	1	99	1,336	1,914
1974	5	53	35	8	101	868	1	60	35	3	99	1,424	2,292
1975	1	59	29	12	101	712	T	37	50	13	100	1,751	2,463
1976	2	27	54	7	100	1,142	T	24	56	20	100	1,129	2,271
1960-76 Mean	7	44	33	15	99		4	53	37	7	101		
C.V.	75	29	34	58			133	27	33	113			

Table 4.10. Distribution (%) of Pacific cod tagged from major experiments in Hecate Strait (Area 5C &5D), **by location** and time of tagging, and location of recapture, 1960-68.

Recapture Location	Tagging location: Two Peaks[a] May/64	Two Peaks[a] May/65	White Rocks[b] May/65	White Rocks[b] Feb/60	White Rocks[b] Jan-Feb/61	Bonilla Feb/68 (5C)	Bonilla Feb/68 (5D)
Tow Hill	0.2	0.4	0.4	-	1.0	-	-
Two Peaks[a]	81.0	93.0	10.0	10.0	21.0	19.0	17.0
White Rocks[b]	14.0	1.0	81.0	88.0	77.0	44.0	28.0
Shell	-	-	-	-	-	1.0	1.0
Ole Spot	2.0	2.0	4.0	-	-	20.0	39.0
Horseshoe	2.0	4.0	4.0	1.0	-	15.0	9.0
Reef Island	-	-	0.1	-	-	2.0	4.0
Ramsay Island	-	-	-	0.4	-	-	-
Queen Charlotte Sound (5A&5B)	0.2	-	0.5	0.4	-	-	-
W. Vancouver Island (3C&3D)	-	-	-	-	1.0	-	-
Total	99.0	100.0	99.0	99.0	100.0	101.0	99.0
Usable recaptures	852	252	856	257	220	124	246

[a]Includes Butterworth Edge.
[b]Includes Freemans Pass and Bonilla Grounds.

Table 4.11. Distribution (%), by quarter-year, of Canada-U.S. Pacific cod landings from Hecate Strait and Dixon Entrance (Area 5C & 5D), 1956-77.

Year	Quarter					Total landings (m.t.)
	I	II	III	IV	T	
1956	34	51	12	3	100	1,483
1957	45	28	6	21	100	2,319
1958	38	38	10	14	100	5,202
1959	48	17	23	12	100	5,125
1960	37	23	32	8	100	2,360
1961	56	24	14	7	101	1,616
1962	48	11	33	8	100	1,689
1963	40	31	21	8	100	2,927
1964	17	39	29	14	99	5,228
1965	22	31	39	8	99	9,059
1966	19	54	22	5	100	9,520
1967	25	27	27	21	100	5,081
1968	44	40	14	2	100	5,185
1969	35	39	23	2	99	2,959
1970	49	23	21	8	101	1,339
1971	34	38	25	3	100	1,476
1972	13	26	45	16	100	2,688
1973	14	39	39	9	101	4,002
1974	8	37	48	8	101	4,764
1975	17	42	31	9	99	4,963
1976	25	28	37	10	100	4,986
1977[a]	12	25	25	8	100	3,510
1956-77 Mean	31	32	28	9		
C.V.	46	32	46	57		

[a]Provisional.

Table 4.12. Distribution (%) of annual Canada-U.S. landings of Pacific cod from Hecate Strait and Dixon Entrance, by ground, 1956-77.

Year	Tow Hill	Two Peaks Butterworth	White Rocks Bonilla	Shell	Ole Spot	Horseshoe	Reef Island	Total	Total landings (m.t.)
1956	-	65	-	-	24	11	-	100	1,483
1957	-	66	26	-	1	6	-	99	2,319
1958	-	32	33	-	11	24	-	100	5,202
1959	-	39	46	-	6	10	-	101	5,125
1960	-	37	43	T	-	21	-	101	2,360
1961	1	45	52	1	-	1	-	100	1,616
1962	T	36	53	-	4	7	-	100	1,689
1963	-	32	38	-	4	26	-	100	2,927
1964	-	42	21	-	11	26	-	100	5,228
1965	-	35	24	-	12	29	-	100	9,059
1966	7	30	12	2	17	33	T	101	9,520
1967	2	23	29	6	19	21	-	100	5,081
1968	9	22	23	7	10	27	3	101	5,185
1969	4	25	21	10	12	18	9	99	2,959
1970	T	43	30	6	8	5	7	99	1,339
1971	T	34	22	9	6	13	16	100	1,476
1972	T	47	17	4	T	26	6	100	2,688
1973	T	30	9	9	2	39	10	99	4,002
1974	1	34	10	17	T	31	7	100	4,764
1975	T	35	19	22	T	16	7	100	4,963
1976	T	26	30	12	T	19	12	99	4,986
1977	T	56	17	10	-	11	6	100	3,510
1956-1977 Mean	1	38	26	5	7	19	4		
C.V.	224	32	53	120	106	53	129		
1968-1977 Mean	1	35	20	11	4	21	8		
C.V.	211	30	36	50	125	50	12		

Table 4.13. Distribution (%) of annual Canada-U.S. landings of Pacific cod from Two Peaks Ground, by quarter-year, 1956-77.

Year	Quarter					Total landings (m.t.)
	I	II	III	IV	T	
1956	53	42	-	5	100	957
1957	58	36	6	T	100	1,442
1958	27	46	7	20	100	1,582
1959	28	19	48	4	99	1,988
1960	8	14	64	14	100	870
1961	21	48	30	1	100	723
1962	19	19	62	T	100	610
1963	28	22	41	8	99	927
1964	17	18	62	4	101	2,199
1965	24	6	66	4	100	3,194
1966	12	62	26	1	101	2,817
1967	11	26	47	16	100	1,188
1968	27	45	26	2	100	1,153
1969	14	38	42	6	100	746
1970	12	35	40	12	99	577
1971	2	24	70	4	100	505
1972	2	22	69	8	101	1,251
1973	1	17	78	4	100	1,202
1974	-	6	89	5	100	1,600
1975	1	23	74	2	100	1,749
1976	1	24	72	3	100	1,305
1977	3	13	83	1	100	1,959
1956-77 Mean	17	28	50	6		
C.V.	95	53	52	96		

Table 4.14. Canada-U.S. landings (m.t.) calculated effort (hr), and Canadian CPUE (m.t./hr) for Pacific cod landed from Two Peaks Ground during April-September, 1956-77

Year	Canada-U.S. landing (m.t.)	Calculated effort[a] (hr)	Canada CPUE (m.t./hr)
1956	406	670	.600
1957	606	1,138	.533
1958	837	1,215	.689
1959	1,348	1,633	.826
1960	680	916	.743
1961	565	1,135	.498
1962	496	644	.770
1963	591	723	.817
1964	1,753	970	1,808
1965	2,281	1,324	1,723
1966	2,473	2,041	1.212
1967	863	666	1.296
1968	816	1,667	.489
1969	596	1,202	.496
1970	437	1,162	.376
1971	473	1,167	.405
1972	1,128	1,913	.590
1973	1,147	1,065	1.077
1974	1,516	1,040	1.458
1975	1,704	1,695	1.006
1976	1,261	2,052	.614
1977	1,882	2,923	.644

[a]Calculated effort equals Canada-U.S. landings divided by Canadian CPUE, based on 25% level of qualification.

Table 4. 15. Abundance (nos/hr) by age and estimated value of Z for Pacific cod landed from Two Peaks-Butterworth Ground during July-September, for the 1957-72 year-classes. (Age frequencies obtained from length-frequency analysis.)

Age (yr)	Year-class 1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
2.8	321	110	50	158	221	849	48	253	592	85	108	32	62	300	159	362
3.8	266	194	350	141	86	685	141	82	183	99	139	46	68	304	251	140
4.8	93	51	52	10	11	35	32	30	51	6	22	8	30	44	99	25
5.8	6	5	9	2	14	4	14	5	2	8	3	10	6	37	15	5
Z [a]	1.90	1.83	1.83	2.13	0.91	2.57	1.15	1.40	2.26	1.26	1.92	0.76	1.21	1.05	1.41	1.67
												(0.75) [b]	(0.02) [b]	(0.74) [b]	(1.16) [b]	(0.40) [b]

[a] Calcuated by regressing l_n nos/hr age 3.8-5.8 on l_n age.

[b] Values in parentheses calculated from age-frequencies based on scale readings

Table 4.16. Distribution (%) of annual Canada-U.S. landings of Pacific cod from White Rocks Ground, by quarter-year, 1956-77.

Year	Quarter I	Quarter II	Quarter III	Quarter IV	T	Total landings (m.t.)
1956	-	-	-	-	-	-
1957	31	T	-	69	100	614
1958	77	2	-	21	100	1,713
1959	82	-	3	16	101	2,341
1960	79	14	T	7	100	1,004
1961	87	1	T	12	100	845
1962	78	T	7	15	100	889
1963	82	-	5	13	100	1,109
1964	43	2	5	50	100	1,108
1965	48	9	17	27	101	2,189
1966	59	6	2	32	99	1,136
1967	35	T	15	50	100	1,467
1968	74	8	11	8	101	1,176
1969	52	13	31	4	100	608
1970	95	2	3	T	100	398
1971	78	21	1	1	101	319
1972	29	-	2	70	101	454
1973	45	1	6	48	100	358
1974	35	18	7	40	100	474
1975	59	2	2	38	101	951
1976	44	11	15	31	101	1,520
1977	25	17	24	33	99	605
1956-77 Mean	56	6	7	27		
C.V.	44	120	119	80		

Table 4.17. Canada-U.S. landings (m.t.), calculated effort (hr), and CPUE (mt/hr) for Pacific cod landed from White Rocks Ground during October-March 1957-77.

Year	Canada-U.S. landing (m.t.)	Calculated effort[a] (hr)	Canada CPUE (m.t./hr)
1957-58	1,734	2,737	.633
1958-59	2,268	4,529	.501
1959-60	1,158	4,035	.287
1960-61	810	2,329	.347
1961-62	790	2,945	.268
1962-63	1,040	3,021	.344
1963-64	629	2,031	.309
1964-65	1,593	2,854	.558
1965-66	1,267	2,786	.455
1966-67	857	2,179	.393
1967-68	1,424	3,026	.470
1968-69	298	1,527	.195
1969-70	404	817	.494
1970-71	248	792	.313
1971-72	132	481	.274
1972-73	476	877	.542
1973-74	337	780	.431
1974-75	748	1,213	.616
1975-76	1,015	2,166	.469
1976-77	617	1,799	.334

[a]Calculated effort equals Canada-U.S. landings divided by Canada CPUE at 25% level of qualification.

Table 4.18. Abundance (no/hr) by age, and estimated values of Z for Pacific cod landed from White Rocks-Bonilla Ground during October-March, and Horseshoe Ground during April-June, for selected year-classes. (Age frequencies obtained from scale readings.)

Age (yr)	Year-class 1968	Year-class 1972	Age (yr)	Year-class 1969	Year-class 1970	Year-class 1971	Year-class 1972
	White Rocks-Bonilla (Oct.-Mar.)			Horseshoe (Apr.-June)			
2.0	5	8	2.2	28	221	316	472
3.0	46	142	3.2	136	189	345	175
4.0	26	58	4.2	79	122	35	70
5.0	-	16	5.2	21	15	5	-
6.0	2	-	6.2	5	-	-	-
Z	1.17	1.11		1.12	0.94	2.12	1.00
Age range	3-6	3-5		3.2-6.2	3.2-5.2	3.2-5.2	2.2-4.2

Table 4.19. Distribution (%) of annual Canada-U.S. landings of Pacific cod from Horseshoe Ground, by quarter-year, 1956-77.

Year	Quarter					Total Landing (m.t.)
	I	II	III	IV	T	
1956	-	85	15	--		170
1957	-	33	28	38		151
1958	-	68	32	-		1,251
1959	-	72	28	-		499
1960	-	59	40	T		484
1961	-	56	35	9		20
1962	-	8	92	-		124
1963	-	75	25	-		775
1964	-	82	9	9		1,345
1965	T	59	41	-		2,624
1966	-	65	34	1		3,110
1967	T	56	44	-		1,059
1968	53	35	11	-		1,403
1969	30	55	15	1		541
1970	3	8	44	45		69
1971	5	79	4	12		188
1972	3	50	47	T		697
1973	1	57	37	5		1,578
1974	-	48	50	2		1,494
1975	5	69	25	1		774
1976	-	45	54	1		954
1977[a]	-	48	35	17		403
1956-77 Mean	5	55	34	6		
C.V.	277	37	56	192		

[a] Provisional.

Table 4.20. Canada-U.S. landings (m.t.) calculated effort (hr), and CPUE (m.t./hr) Pacific cod landed from Horseshoe Ground during April-September, 1956-77.

Year	Canada-U.S. landing (m.t.)	Calculated effort[a] (hr)	Canada CPUE (m.t./hr)
1956	170	87	1.950
1957	93	98	.949
1958	1,251	537	2.331
1959	499	703	.710
1960	483	1,017	.475
1961	18	61	.290
1962	124	223	.555
1963	775	603	1.285
1964	1,229	845	1.454
1965	2,620	2,359	1.110
1966	3,084	2,006	1.538
1967	1,054	1,024	1.030
1968	654	1,274	.513
1969	376	1,263	.298
1970	36	100	.358
1971	156	416	.375
1972	676	819	.825
1973	1,486	1,053	1.411
1974	1,466	1,202	1.220
1975	725	1,088	.666
1976	943	1,187	.795
1977	334	562	.595

[a]Calculated effort equals Canada-U.S. landings divided by Canada CPUE at 25% level of qualification.

Table 4.21. Distribution (%) of annual Canada-U.S. landings of Pacific cod from Ole Spot, Shell Ground and Reef Island Grounds, by quarter-year, 1956-77

Year	Quarter I	II	III	IV	T	Total landings (m.t.)
			Ole Spot			
1956	-	57	43	-	100	352
1957	-	100	-	-	100	17
1958	37	62	1	-	100	571
1959	4	45	-	51	100	297
1960	-	-	-	-	-	-
1961	-	-	-	-	-	-
1962	-	100	-	-	100	65
1963	-	100	-	-	100	116
1964	9	91	-	-	100	577
1965	17	82	1	-	100	1,053
1966	31	51	14	4	100	1,580
1967	56	36	8	-	100	961
1968	3	86	11	-	100	511
1969	51	48	-	-	99	357
1970	37	60	2	-	99	113
1971	47	53	-	-	100	93
1972	-	100	-	-	100	3
1973	-	100	-	-	100	88
1974	2	98	-	-	100	17
1975	15	52	-	33	100	24
1976	-	-	100	-	100	Tr
1977	-	-	-	-	-	-
19-year mean*	16	70	9	5	100	
C.V.	123	41	255	292		
			Shell Ground			
1966	36	64	-	-	100	207
1967	18	33	19	30	100	329
1968	32	47	21	-	100	352
1969	27	69	4	-	100	300
1970	82	18	1	-	101	78
1971	66	34	-	-	100	127
1972	4	73	22	-	99	112
1973	39	61	-	-	100	352
1974	-	-	100	-	100	808
1975	11	86	3	-	100	1,113
1976	30	50	20	1	100	622
1977	13	86	1	-	100	344
1966-77 Mean	30	52	16	3	101	
C.V.	81	52	176	346		

Table 4.21 (Cont'd)

Year	Quarter I	II	III	IV	T	Total landings (m.t.)
			Reef Island Ground			
1968	99	-	-	-	99	151
1969	74	25	1	-	100	276
1970	100	-	-	-	100	100
1971	46	54	-	-	100	243
1972	98	2	-	-	100	167
1973	55	33	-	12	100	420
1974	55	31	1	14	101	327
1975	30	51	1	17	99	338
1976	70	26	3	1	100	580
1977	85	8	6	-	99	199
1968-77 Mean	71	23	1	4	99	
C.V.	34	88	161	158		

[a]Excluding 1960-61 and 1977.

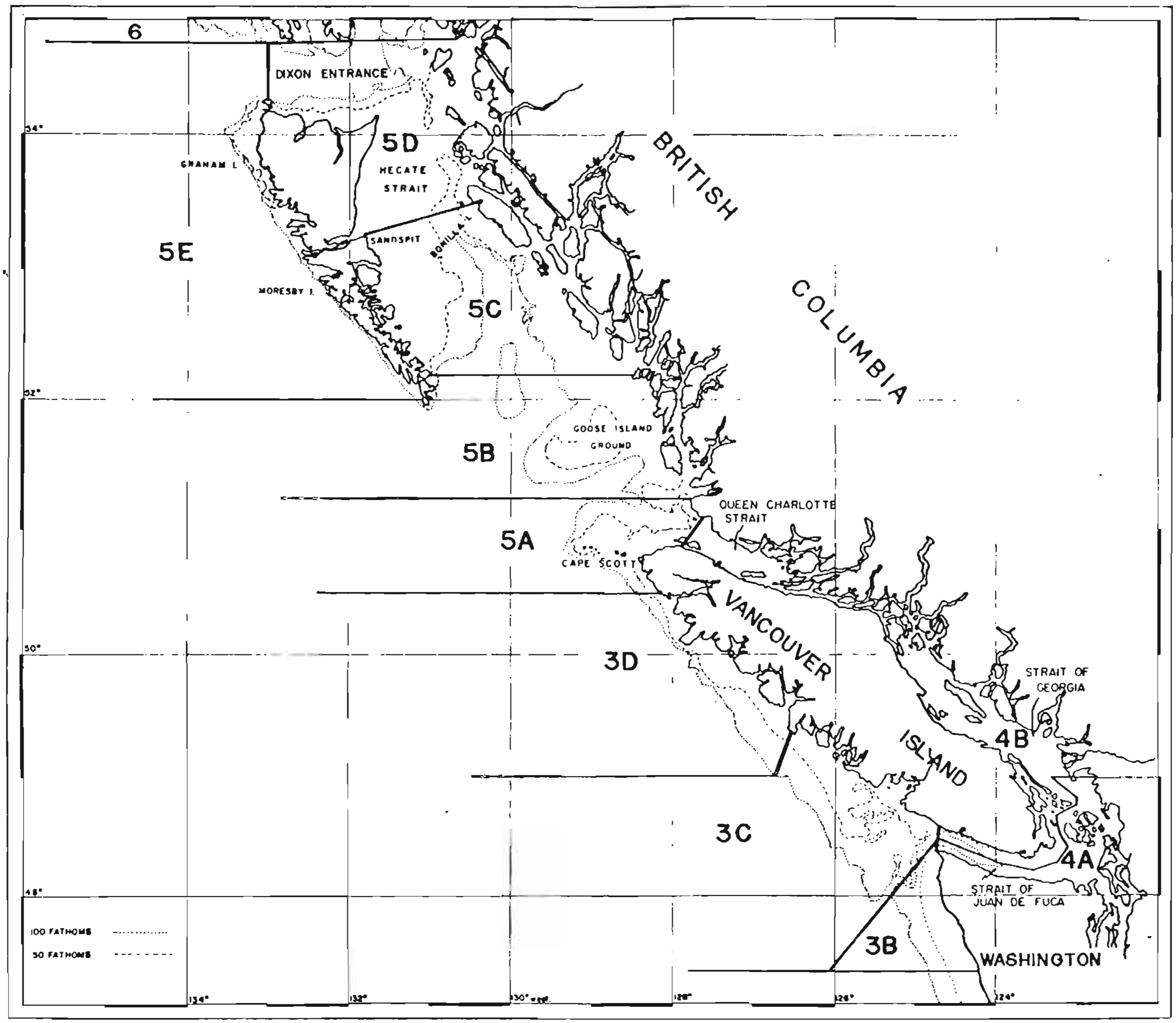

Fig. 4.1. International (Pacific Marine Fisheries Commission) Statistical Areas along the British Columbia coast.

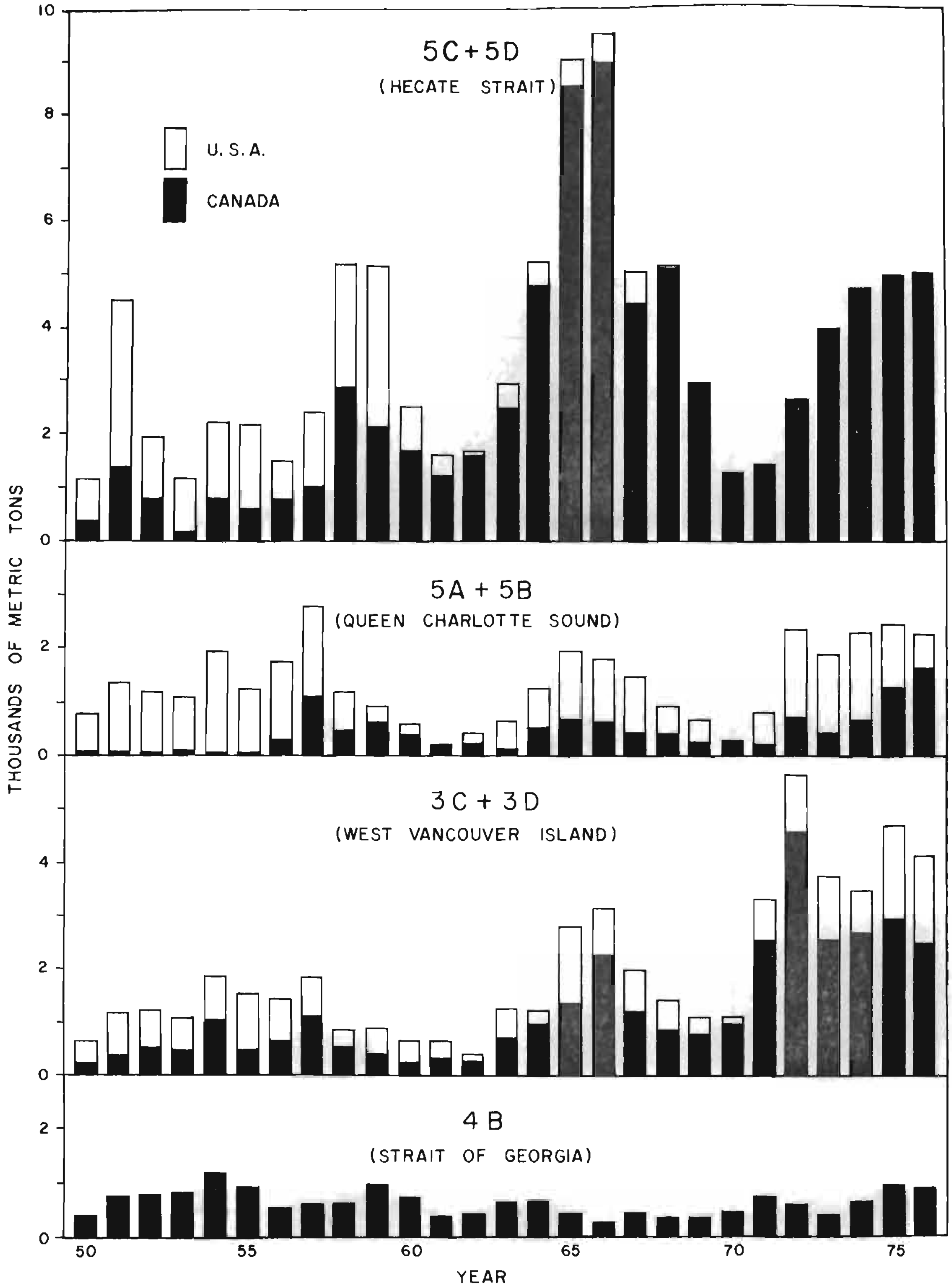

Fig. 4.2. Trawl landings of Pacific cod by major statistical area, combined Canada-U.S. versus Canadian only (solid bars), 1950-1976.

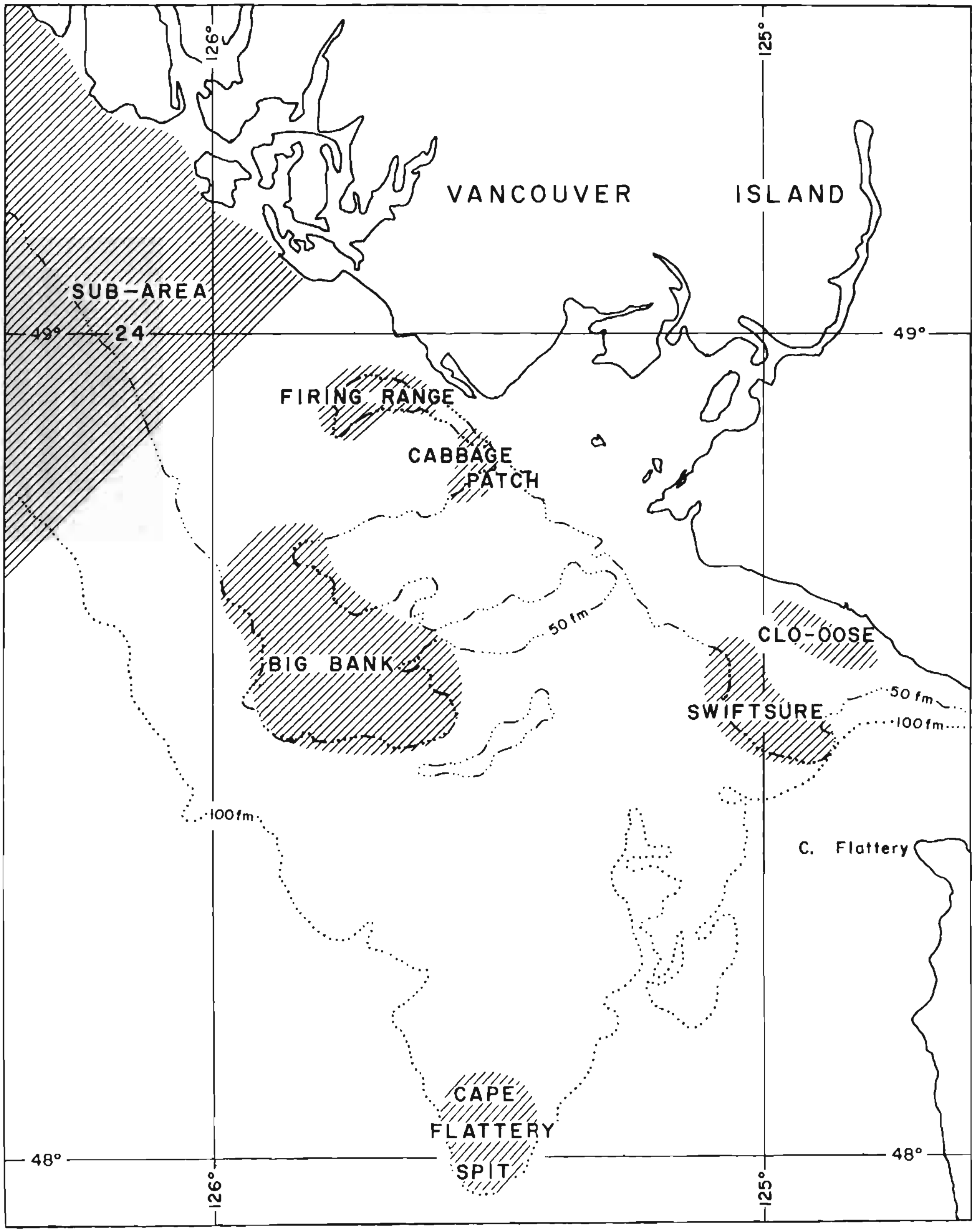

Fig. 4.3. Trawling grounds off Southwest Vancouver Island.

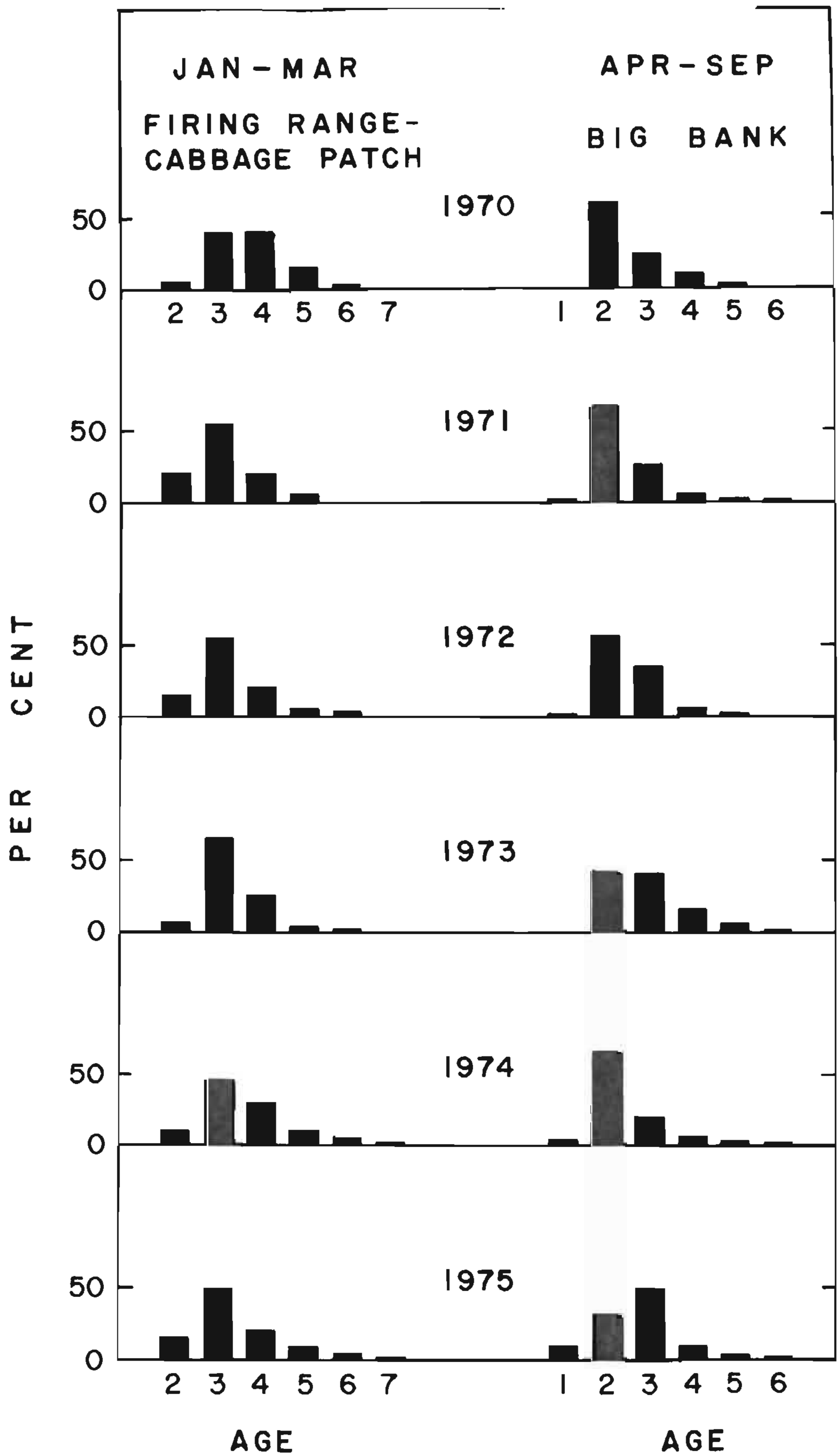

Fig. 4.4. Age composition of Pacific cod in Canadian landings from major grounds in Area 3C, 1970-75.

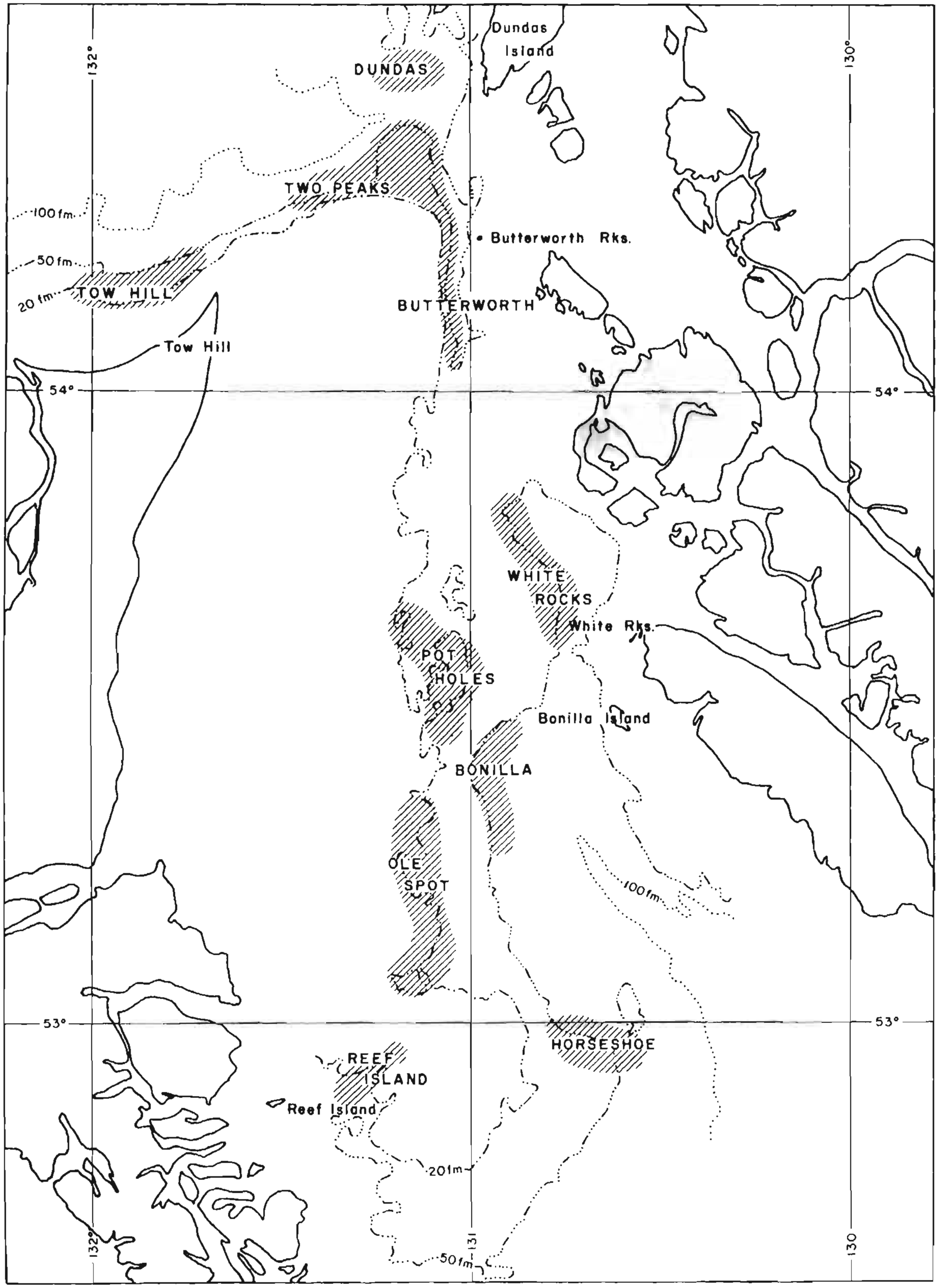

Fig. 4.5. Trawling grounds in Hecate Strait.

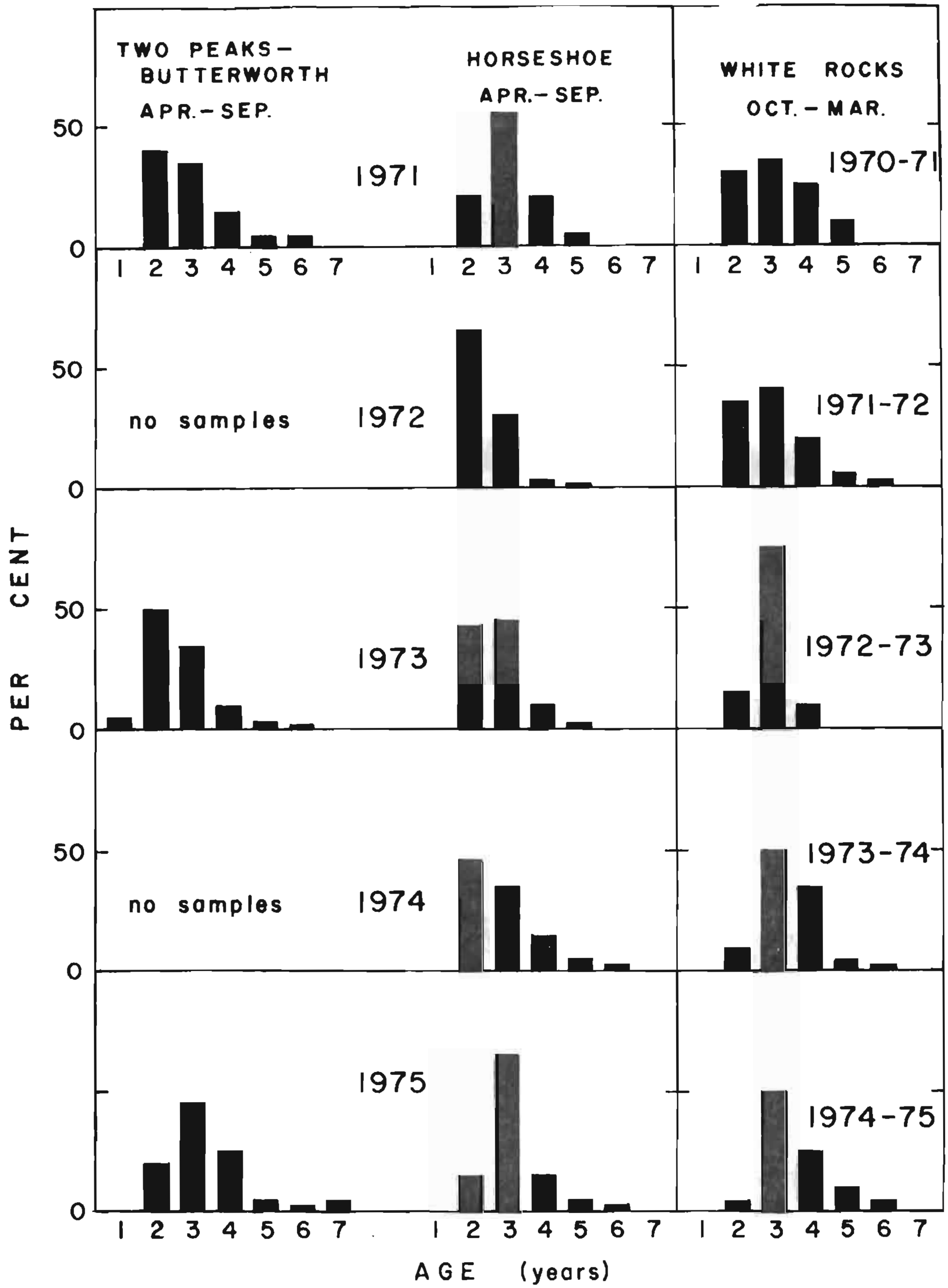

Fig. 4.6. Age composition (%) of Pacific cod in Canadian trawl landings from major grounds in Hecate Strait, 1971-74.

5. LINGCOD STOCK ASSESSMENTS

5.1 Introduction

Lingcod are fished commercially in waters off Canada's west coast by fish bottom trawl, handline, troll, longline, shrimp trawl and, to a lesser extent, by sunken gill-nets, traps, beach seines and spear fishing methods. Historically, both Canadian and U.S. fishermen have participated in the trawl fishery, but unknown and presumably insignificant quantities have also been caught by distant water trawlers since 1965. Other commercial fisheries for lingcod have been solely Canadian except for incidental catches by the U.S. halibut fleet and foreign longliners fishing for blackcod. As well as being of commercial interests, lingcod are landed by sports fishermen using troll, jig and spear fishing gear.

Over its long history dating from the early years of this century, the commercial fishery for lingcod has evolved from a traditional line fishery to a trawl-oriented fishery in most areas. However, the bulk of lingcod landed from the relatively sheltered inside waters of Vancouver Island is still caught by line gear.

Delineation of lingcod stocks is not clearly understood, since taggings have been conducted in only a few areas. Results, such as they are, suggest that the lingcod do not migrate extensively and probably exist as a large number of local stocks along the Canadian coast. For present purposes, the state of the lingcod resource will be examined in terms of major statistical areas, on the assumption that negligible intermingling occurs among these areas (Fig. 5.1).

5.2 Abundance indices

One method used as an index of lingcod abundance was selected in order to cover as much of the fishery as possible, namely the United States and Canadian trawl fisheries. The index is obtained by dividing the total Canada-U.S. catch of lingcod by the total fishing effort of both countries.[16] This will be referred to as TOTAL CPUE. In multispecies trawl fisheries it is difficult if not impossible to identify accurately the effective fishing effort directed at a single species. In some areas much of the U.S. fishing effort is directed to species which are clearly beyond the bathymetric range of lingcod. Although TOTAL CPUE is based on total Canada-U.S. production, this method will include effort directed to species other than lingcod and will therefore bias CPUE calculations based on total Canada-U.S. effort.

There are several techniques for eliminating extraneous effort, but for present purposes attention will be confined to separation of Canadian

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[16] Source of data: 1950-55. Ketchen, K.S. 1976. Catch and effort statistics of the Canadian and United States trawl fisheries in waters adjacent to the British Columbia coast 1950-1975. Fish. Mar. Serv. Data Rec. 6: 57 p.
1956-77. Pacific Marine Fisheries Commission (PMFC), Data Series, Bottom Trawl Fish.
NOTE: Some differences in catch statistics exist between those given in Data Rec. 6 and the PMFC Data Series for early years (1954-1959) covered by both sources. However the magnitude of the differences is small.

fishing effort according to three levels of catch qualification. For example, we may confine the analysis to those hauls or trips in which lingcod constitute say 25% or more of the Canadian catch. Dividing this catch by the corresponding fishing effort yields what we shall call a Type 1 CPUE. Alternatively, we may examine those hauls or trips in which lingcod were recorded -- regardless of proportion of the total catch. In other words the catch qualification level is > 0%, which, when divided by the corresponding effort provides a Type 2 CPUE. Finally, we may obtain a Type 3 CPUE in which the catch of lingcod is divided by all fishing effort whether it resulted in the capture of lingcod or not.

In the situation where an actual decline in abundance is in progress year by year, Type 1 CPUE may under-estimate the decline, since no allowance is made for the possibility that the number of qualifying hauls or trips is diminishing and the analysis is being confined to only the most successful operations. At the other extreme, Type 3 CPUE will tend to over-estimate the decline, because no allowance is made for the possibility that fishermen have turned their attention to species more renumerative than lingcod.

5.3 Strait of Georgia and Vicinity (Area 4B)

5.3.1 Catch statistics

In Area 4B lingcod have been caught by Canadian vessels only using handlining, trolling, trawling, longlining, and sports fishing gears.

The trawl fishery in the Strait of Georgia has accounted for only about 10% of the total annual commercial lingcod production since 1965. For this reason trawl catch and effort statistics are of little value in assessing state of stocks. Incomplete biological data have also precluded analysis based on trends in size composition. Suffice it to say that over the long term, trawl production of lingcod has shown little or no trend (Fig. 2A), except for a brief flurry of activity in 1959 and 1960 associated with the discovery and fishing down of a stock inhabiting waters near Victoria (Ketchen, In press).

Production from the commercial handline and troll fisheries account for about 88% of the annual commercial landings since 1965. Catch records for the line fishery are only reported on sales slips that do not permit the separation of handline landings from troll landings.[16] Landings from the commercial handline/troll fisheries have declined substantially from an average of 1,330 m.t./yr during 1951-62 to little more than 360 m.t./yr during 1973-77 (Table 5.1, Fig. 5.2A). Since 1967 handline/troll effort (boat-days) has been partitioned between that directed primarily at lingcod and that directed primarily at salmonids. During 1967-75 the decline in handline/troll lingcod landings was closely paralleled by a decline in the effort directed to lingcod (Fig. 5.2B). CPUE during this period remained fairly constant. After 1975 handline/troll effort increased substantially, however landings remained at low levels. CPUE subsequently declined, reaching a recorded low in 1977. At this time we do not have an estimate of the sports fishing effort applied to lingcod but in 1976 an estimated 270 m.t., excluding SCUBA catches, were taken from the Strait of Georgia (R. Boyd, pers. comm.).

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[16] Source: British Columbia Catch Statistics, Department of Fisheries and Environment, Annual Reports 1951-1977.

5.3.2 Stock condition

Of primary concern is the pronounced 70% decline in the average handline/troll landings of lingcod from the 1951-62 period to the 1973-77 period. The decline in lingcod handline/troll landings and effort during 1967-75 suggests the drop in landings resulted from a reduction in the amount of fishing effort. The decline in handline/troll CPUE after 1975 to a recorded low in 1977 indicates stocks have declined in recent years. The reason(s) for the decline in handline/troll landings prior to 1967 are difficult to explain using sales slip information because of the problems associated with determining the amount of effort directed at lingcod. In an attempt to provide an additional assessment of the condition of the lingcod stocks, a survey of commercial line and recreational fishermen, including SCUBA divers was conducted in February, 1979. The preliminary results indicate that of the fishermen who fished lingcod intentionally in the Strait of Georgia for five or more years, 73% feel lingcod stocks have declined. Of the fishermen who fished lingcod intentionally for ten or more years, 82% feel stocks have declined. Although these results are preliminary, they also indicate stocks have declined.

5.3.3 Recommendations

The growing sports fishery including SCUBA divers, the declining production of the line fishery and the apparent decline in lingcod abundance urge that some conservation measures be adopted. The timing of the winter fishing closure appears to be based on little empirical evidence. Recent studies (Low and Beamish, 1979, indicate the pre-spawning aggregation of lingcod begins in November. Spawning occurs in January and February and the nesting period extends to mid-June. The peak hatching period occurs in March. Starting in November with pre-spawning aggregation and lasting until hatching is completed, male lingcod assume a territorial behaviour pattern that makes them highly vulnerable to fishing. The presence of the male during incubation is absolutely essential for the survival of the nest and consequently forms a primary basis for maintaining lingcod stocks. Accordingly, it is recommended that the closed season, for all types of fishing, extend from November 1 to April 30 to provide greater protection during the pre-spawning aggregation, spawning and nesting periods and to reduce the catch in an attempt to rebuild stocks.

5.4 Southwest coast of Vancouver Island (Area 3C)

5.4.1 Catch statistics

Trawling grounds off the southwest coast of Vancouver Island are the most important in terms of lingcod production from waters off Canada. During 1973-77, an average of 1,200 m.t. or 56% of all Canada-U.S. trawl-caught lingcod landed from international statistical areas adjacent to the coast originated in Area 3C, yet trawl production from this area has fluctuated substantially (600-2,000 m.t./yr) in a quasi-cyclical manner (without trend) since 1950 (Table 5.2, Fig. 5.3). Production from the line fisheries has also fluctuated without trend but the fluctuations have been modest (100-300 m.t./yr).

Fluctuations in TOTAL CPUE have closely paralleled total trawl landings, as a reflection of highly variable natural fluctuations in recruitment. Evidence in support of this view is contained in length-frequency data which show an above-average presence of small (young) fish when CPUE is rising and below-average when CPUE is declining.

5.4.2 Stock condition

There are no outstanding differences in trends exhibited by the three CPUE estimates for the Canadian fishery (Fig. 5.4B). All three, including TOTAL CPUE (Fig. 5.3) display no evident trend in the presence of a rising trend in Canadian total, Type 1 and Type 2 effort (Fig. 5.4A). Although catch has been highly variable there is no indication of trend. Thus, on balance it appears that there are no evident signs of stock depletion in Area 3C as a whole, assuming that a more obvious decline in CPUE is not being masked by increased fishing efficiency.

5.4.3 Recommendations

A provisional total allowable catch (TAC) of 800 m.t. of lingcod is recommended for Area 3C and will be reviewed in mid-season.

5.5 Northwest coast of Vancouver Island (Area 3D)

5.5.1 Catch statistics

Canada-U.S. trawl landings of lingcod from the northwest coast of Vancouver Island were relatively low during the period 1950-64, frequency being lower than those of the line fisheries (Table 5.2, Fig. 5.5). However, during the 1965-70 period, Canadian effort in Area 3D increased substantially and was directed primarily at lingcod. During this time the Canadian trawl fleet was responsible for 84% of the Canada-U.S. lingcod trawl landings compared to an expenditure of only 36% of the total Canada-U.S. trawl effort. The fact that lingcod was the target species is supported by the closeness (relative to Area 3C) of the Type 1, 2 and 3 CPUE estimates (Fig. 5.6A). Catch reached a peak of 870 m.t. in 1968 but fell abruptly between then and 1972. All CPUE indices followed a similar significant increase in annual trawl landings and Total CPUE during the 1965-71 course. The sharp decline in Canadian effort between 1971 and 1972 (Fig. 5.6A) suggests that abundance of lingcod had fallen to a level which could no longer support a target fishery. From 1972 onwards calculated fishing effort stabilized at a low level even though CPUE rebounded sharply from its 1968-72 slide, to a 1974 peak almost equal to that which prevailed in 1968. The small line fishery has fluctuated without trend during the 1951-77 period.

5.5.2 Stock condition

Canada-U.S. trawl landings and effort during 1959-77 indicate that lingcod abundance was relatively low during 1959-64, high during 1965-71, and relatively low again during 1972-77. Canadian CPUE has fluctuated substantially during 1959-77, but without trend. In summary, the lingcod stock in Area 3D exhibits no symptom of depletion.

5.5.3 Recommendations

A provisional TAC of 200 m.t. of lingcod is recommended for Area 3D. This will be reviewed in mid-season.

5.6 Capt Scott grounds (Area 5A)

5.6.1 Catch statistics

Total Canada-U.S. trawl landings followed an irregular upward trend from 1950 to 1968 (Table 5.2; Fig. 5.7). Apparently this was the result of increased effort, which did not reach a peak until 1969 (Fig. 5.8A), after which both effort and catch followed a general decline until 1976. Throughout the 1961-77 period Canadian CPUE (all 3 types) exhibited a slight downward trend. Total CPUE on the other hand followed a sharp downward course after 1968 paralleling the decline in catch (Table 5.2; Fig. 5.7). This inconsistency might be attributed to extraneous U.S. fishing effort (directed to rockfish) prompted by declining lingcod abundance or increasing markets of other species (rockfish) or both. This would tend to exaggerate a CPUE decline in lingcod, if fishing effort was being diverted to other species beyond the normal bathymetric range of lingcod. Landings from the line fishery have been negligible.

5.6.2 Stock condition

There has been a gradual downward trend in CPUE during the past decade which was less evident in the Type 1 than the Type 2 and 3 analysis (Fig. 5.8B). No strong fluctuations in recruitment (as in Areas 3C and 3D) were evident except during 1967-69 when one or more strong year-classes evidently produced the sudden and substantial increase in production. Disregarding this peak, there has been a gradual downward trend in CPUE.

5.6.3 Recommendation

CPUE (Total Canada-U.S. and Canadian Type 2 and 3) declined to record lows in 1977. Concern for lingcod stocks is warranted, particularly if fishing efficiency has increased. A provisional TAC of 100 m.t. is recommended, subject to review in mid-season. This will maintain landings at present levels. In the next year it is hoped more information will be acquired to assess the stock condition in this area.

5.7 Goose Island grounds (Area 5B)

5.7.1 Catch statistics

Following a pattern rather similar to that observed in Area 5A, Canada-U.S. trawl production of lingcod from the Goose Island grounds rose to a peak of 1,050 m.t. in 1968 as a result of increasing effort. A sharp drop occurred immediately thereafter (Table 5.2; Fig. 5.9) though total effort remained relatively high. Landings stabilized from 1969 to 1975 at 400-500 m.t. and then entered another decline reaching 250 m.t. in 1977, the lowest point since 1957. Canadian CPUE values may not have reflected abundance as well in Area 5B as in other areas because in some years Canadian landings were a small proportion of the total (Fig. 5.9).

Landings of line-caught lingcod have remained negligible throughout 1951-77.

5.7.2 Stock condition

The lingcod stock in Area 5B appears to be in a similar condition to that in Area 5A. That is CPUE is currently at levels lower than previous years.

5.7.3 Recommendation

A TAC of 200 m.t. is recommended for Area 5B. This will be reviewed in mid-season.

5.8 Hecate Strait and Dixon Entrance (Areas 5C and 5D)

5.8.1 Catch statistics

Throughout the history of the Canada-U.S. trawl fishery in Hecate Strait, lingcod has never been an important species. Landings have mainly been incidental to those of other species and have averaged about 200 m.t./yr (Table 5.2;Fig. 5.10). Peak production of 380 m.t. was reached in 1968, as in Areas 3D, 5A, and 5B. Although production in large measure is a function of fishing effort, the 1968 peak and adjacent years may have marked a period of above-average recruitment.

Landings by the line fishery, as in most other areas, have always been at a relatively low level. The sag in production while the trawl catches were high between 1965 and 1970 suggests gear competition, the existence of limited markets, or perhaps it was merely a coincidence. The question cannot be addressed intelligently without information on the geographical distribution of the line fishery and without a grasp of economic conditions.

5.8.2 Stock condition

Abundance of lingcod in Hecate Strait and Dixon Entrance appears to be currently at relatively low levels based on Canada-U.S. trawl landings (Table 5.2; Fig. 5.10) and Canadian CPUE (Fig. 5.11, 5.12). However, the species is a minor component in the trawl and line landings.

5.8.3 Recommendations

A provisional TAC of 200 m.t. is recommended. This will be reviewed in mid-season.

5.9 West coast of the Queen Charlotte Islands (Area 5E)

Trawling in waters off the Queen Charlotte Islands was first reported in late 1976. The incidental landing of lingcod was 0.03 m.t. In the much-expanded rockfish fishery of the following year, lingcod production was again incidental. The lingcod catch was 4.6 m.t. A small line fishery has been active since at least 1951, probably occurring in sheltered inlets. Landings during the past decade have averaged about 12 m.t./yr.

5.10 General summary of lingcod stock conditions

Except for the early growth period of offshore trawl fisheries production of lingcod appears to be dependent on recruitment. This dependence is most evident in Area 3C and Area 3D and less so in grounds further to the north (Areas 5A-5D). In the latter areas the most recent surge of recruitment was around 1968 and abundance is at a relatively low level, showing some indication of decline. Stocks off the west coast of Vancouver Island (Areas 3C and 3D) have received more recent surges of recruitment (ca. 1974) and abundance levels are nearer averager or better. There is insufficient evidence to say whether intervention in the fishery would have any measurable impact. The current minimum size limit of 58 cm permits capture of a large number of 3-year-olds which are immature (50% of the fish are mature at 75 cm -- Cass & Beamish, In prep.). Assuming that mesh size cannot be increased because it would result in excessive gilling of the ubiquitous dogfish, the benefit of a larger minimum size limit would depend on the survival prospects for discards and their later potential yield. In the next year, research will be proposed to address the problems associated with survival of discards.

Table 5.1. Lingcod production from Major Area 4B by handline/troll vessels.[a]

Year	Handline/troll Landings (m.t.)	Handline/troll Effort (Boat-days)	Handline/troll CPUE (m.t./boat-day)
1951	1279.4	-	-
1952	1488.7	-	-
1953	1178.8	-	-
1954	1449.3	-	-
1955	1157.4	-	-
1956	1510.7	-	-
1957	1539.6	-	-
1958	1445.7	-	-
1959	1182.9	-	-
1960	1250.5	-	-
1961	1157.5	-	-
1962	1272.8	-	-
1963	989.2	-	-
1964	870.3	-	-
1965	779.7	-	-
1966	771.3	-	-
1967	778.5	4776	0.163
1968	728.0	4758	0.153
1969	875.5	4974	0.176
1970	788.7	4065	0.194
1971	564.1	3973	0.142
1972	513.3	3693	0.139
1973	371.9	2353	0.158
1974	363.7	2393	0.152
1975	330.5	1933	0.171
1976	315.5	2607	0.121
1977	410.2	4508	0.091

[a] Source: British Columbia Catch Statistics, Department of Fisheries and Environment, Annual Reports 1951-1977.

Table 5.2. Total lingcod production in waters off Canada's west coast.[a]

Year	Major Area 4B		
	Total trawl[b] landings (m.t.)	Total trawl[b] CPUE (m.t./hr)	Line fishery[c] landings (m.t.)
1950	34.5	-	-
1951	48.1	-	1317.1
1952	54.0	-	1512.5
1953	28.1	-	1187.4
1954	68.0	-	1462.3
1955	49.0	-	1169.2
1956	49.4	-	1523.9
1957	34.5	-	1545.8
1958	75.7	-	1451.2
1959	310.3	-	1192.1
1960	198.7	0.018	1280.2
1961	102.1	0.011	1199.9
1962	75.7	0.008	1292.6
1963	39.9	0.004	1002.1
1964	92.1	0.008	877.9
1965	93.9	0.012	788.7
1966	53.1	0.010	798.8
1967	50.8	0.007	793.0
1968	83.9	0.014	740.5
1969	64.9	0.010	905.9
1970	47.6	0.008	819.7
1971	55.3	0.008	598.5
1972	36.7	0.008	533.5
1973	15.0	0.002	403.2
1974	49.0	0.008	381.2
1975	33.1	0.005	368.1
1976	43.5	0.007	334.6
1977	27.4	0.004	435.2

Table 5.2 (cont'd)

Year	Major Area 3C			Major Area 3D		
	Total trawl[b] landings(m.t.)	Total trawl[b] CPUE(m.t./hr)	Line fishery[c] landings(m.t.)	Total trawl[b] landings(m.t.)	Total trawl[b] CPUE(m.t./hr)	Line fishery[c] landings(m.t.)
1950	970.7	-	-	135.6	-	-
1951	978.4	-	210.7	122.9	-	166.5
1952	766.1	-	188.7	115.2	-	184.2
1953	625.5	-	82.4	72.6	-	88.0
1954	781.1	-	239.5	59.0	-	105.9
1955	1246.9	-	167.5	141.1	-	92.5
1956	1142.1	-	154.5	164.2	-	124.2
1957	1035.6	-	293.0	129.7	-	134.6
1958	1018.3	-	154.4	110.2	-	119.5
1959	1743.2	0.192	179.6	64.0	0.016	93.4
1960	1866.5	0.158	216.8	87.1	0.023	105.5
1961	1971.3	0.136	135.4	199.6	0.042	114.8
1962	889.9	0.057	226.4	285.8	0.037	103.1
1963	645.5	0.049	152.0	115.2	0.023	121.4
1964	1183.0	0.110	100.0	225.9	0.070	84.5
1965	1889.2	0.120	121.2	505.3	0.117	89.6
1966	2053.4	0.155	156.9	584.7	0.146	135.1
1967	1784.0	0.181	244.2	459.5	0.152	165.8
1968	1693.7	0.201	160.6	868.2	0.226	107.2
1969	1082.7	0.132	169.3	618.7	0.119	77.1
1970	729.8	0.084	112.3	455.9	0.075	157.4
1971	984.7	0.087	229.6	264.0	0.065	113.7
1972	629.1	0.048	265.0	84.8	0.033	180.8
1973	879.5	0.093	182.5	172.4	0.062	83.9
1974	1044.2	0.108	224.1	241.8	0.079	112.7
1975	1798.9	0.134	214.7	347.0	0.092	89.5
1976	1304.5	0.081	251.0	245.4	0.090	90.1
1977	1042.6	0.069	264.8	157.9	0.086	107.0

Table 5.2 (cont'd)

Year	Major Area 5A: Total trawl[b] landings(m.t.)	Major Area 5A: Total trawl[b] CPUE(m.t./hr)	Major Area 5A: Line fishery[c] landings(m.t.)	Major Area 5B: Total trawl[b] landings(m.t.)	Major Area 5B: Total trawl[b] CPUE(m.t./hr)	Major Area 5B: Line fishery[c] landings(m.t.)
1950	65.8	-	-	140.2	-	-
1951	264.0	-	1.1	193.2	-	33.2
1952	288.0	-	5.4	188.2	-	32.1
1953	42.2	-	0.6	103.4	-	2.9
1954	47.6	-	5.5	168.7	-	4.4
1955	373.3	-	0.0	161.5	-	18.4
1956	346.5	-	2.1	250.4	-	33.0
1957	417.8	-	1.2	162.4	-	10.6
1958	304.8	-	0.1	267.6	-	1.7
1959	192.3	0.033	0.1	428.6	0.140	3.7
1960	280.3	0.056	1.8	377.4	0.079	20.8
1961	387.8	0.097	1.1	323.0	0.082	47.4
1962	531.2	0.105	10.6	406.9	0.076	57.9
1963	285.3	0.061	7.7	357.0	0.047	68.4
1964	352.0	0.063	5.2	335.2	0.050	27.7
1965	331.1	0.058	15.6	566.1	0.084	7.4
1966	706.7	0.086	23.6	826.4	0.087	35.2
1967	759.3	0.093	21.3	900.8	0.087	18.5
1968	1226.5	0.124	81.8	1042.8	0.102	15.5
1969	616.9	0.049	28.8	516.6	0.038	27.7
1970	590.1	0.067	28.6	389.6	0.040	53.3
1971	229.5	0.034	29.0	414.6	0.043	29.0
1972	163.7	0.028	50.4	476.3	0.040	58.3
1973	232.2	0.035	36.3	349.3	0.039	30.0
1974	338.8	0.059	38.8	532.1	0.055	44.4
1975	82.1	0.023	40.1	450.9	0.039	34.4
1976	257.6	0.037	38.8	345.2	0.049	52.6
1977	120.9	0.018	45.7	257.0	0.036	31.9

Table 5.2 (cont'd)

Year	Major Areas 5C-5D: Total trawl landings(m.t.)[b]	Major Areas 5C-5D: Total trawl CPUE(m.t./hr)[b]	Major Areas 5C-5D: Ling fishery landings(m.t.)[c]	Major Area 5E: Total trawl landings(m.t.)[b]	Major Area 5E: Total trawl CPUE(m.t./hr)[b]	Major Area 5E: Line fishery landings(m.t.)[c]
1950	190.1	-	-	0.0	0.0	-
1951	249.0	-	52.3	0.0	0.0	13.8
1952	230.0	-	46.2	0.0	0.0	1.9
1953	87.1	-	5.2	0.0	0.0	0.1
1954	99.3	-	9.8	0.0	0.0	0.6
1955	198.2	-	3.2	0.0	0.0	0.4
1956	100.7	-	4.6	0.0	0.0	0.1
1957	125.2	-	5.8	0.0	0.0	2.9
1958	278.1	-	8.9	0.0	0.0	0.4
1959	117.5	0.012	16.7	0.0	0.0	0.8
1960	154.2	0.018	21.3	0.0	0.0	1.0
1961	95.7	0.013	33.9	0.0	0.0	1.7
1962	112.9	0.017	53.5	0.0	0.0	4.0
1963	146.1	0.021	65.3	0.0	0.0	4.5
1964	214.5	0.025	42.3	0.0	0.0	5.6
1965	255.4	0.024	63.4	0.0	0.0	9.3
1966	264.4	0.022	46.7	0.0	0.0	7.4
1967	325.2	0.031	61.3	0.0	0.0	6.5
1968	382.8	0.031	42.3	0.0	0.0	5.7
1969	243.1	0.020	91.1	0.0	0.0	13.1
1970	208.7	0.021	118.7	0.0	0.0	10.1
1971	264.9	0.026	135.2	0.0	0.0	16.3
1972	151.5	0.020	127.5	0.0	0.0	10.6
1973	122.0	0.018	92.0	0.0	0.0	9.4
1974	119.7	0.019	112.0	0.0	0.0	18.1
1975	172.8	0.017	105.8	0.0	0.0	14.4
1976	98.8	0.007	73.2	0.0	0.0	13.1
1977	119.8	0.011	62.6	4.6	0.004	5.0

Footnotes to Table 5.2

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[a] Landings do not include production from recreational fisheries, shrimp trawling, trap, gillnet, beach seining or spear fishing.

[b] Source: 1950-55. Ketchen, K. S. 1976. Catch and effort statistics of the Canadian and United States trawl fisheries in waters adjacent to the British Columbia coast 1950-75. Fish. Mar. Serv. Data Rec. 6: 57 p.

1956-77. Pacific Marine Fisheries Commission (PMFC), Data Series, Bottom Trawl Fish.

[c] Source: 1951-77. British Columbia Catch Statistics, Department of Fisheries and Environment, Annual Reports.

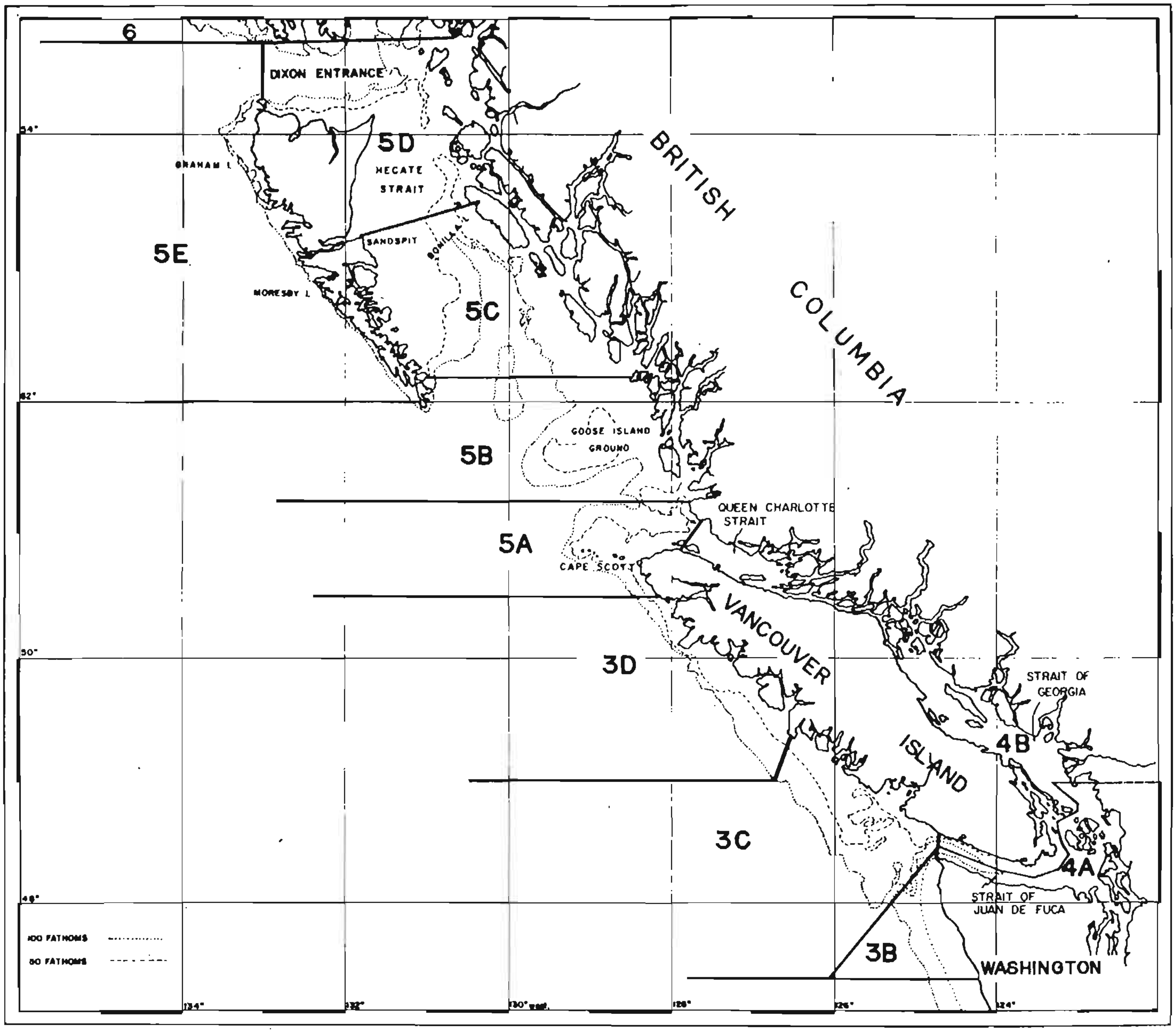

Fig. 5.1. Major statistical areas for the trawl fishery adjacent to British Columbia.

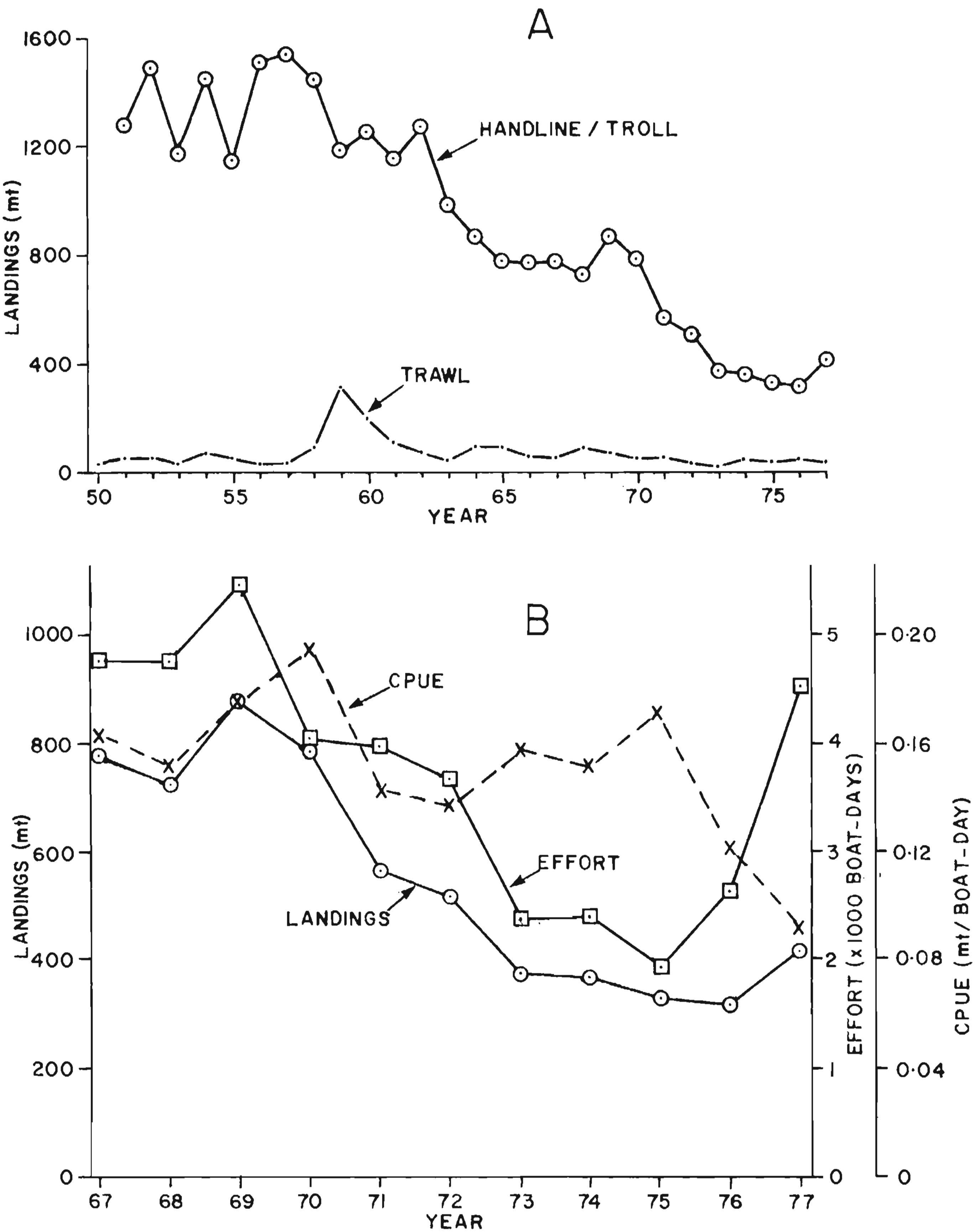

Fig. 5.2. Lingcod catch statistics for Area 4B (Strait of Georgia and vicinity): A. Handline/troll and trawl landings, 1950-77. B. Handline/troll landings, effort and CPUE 1967-77.

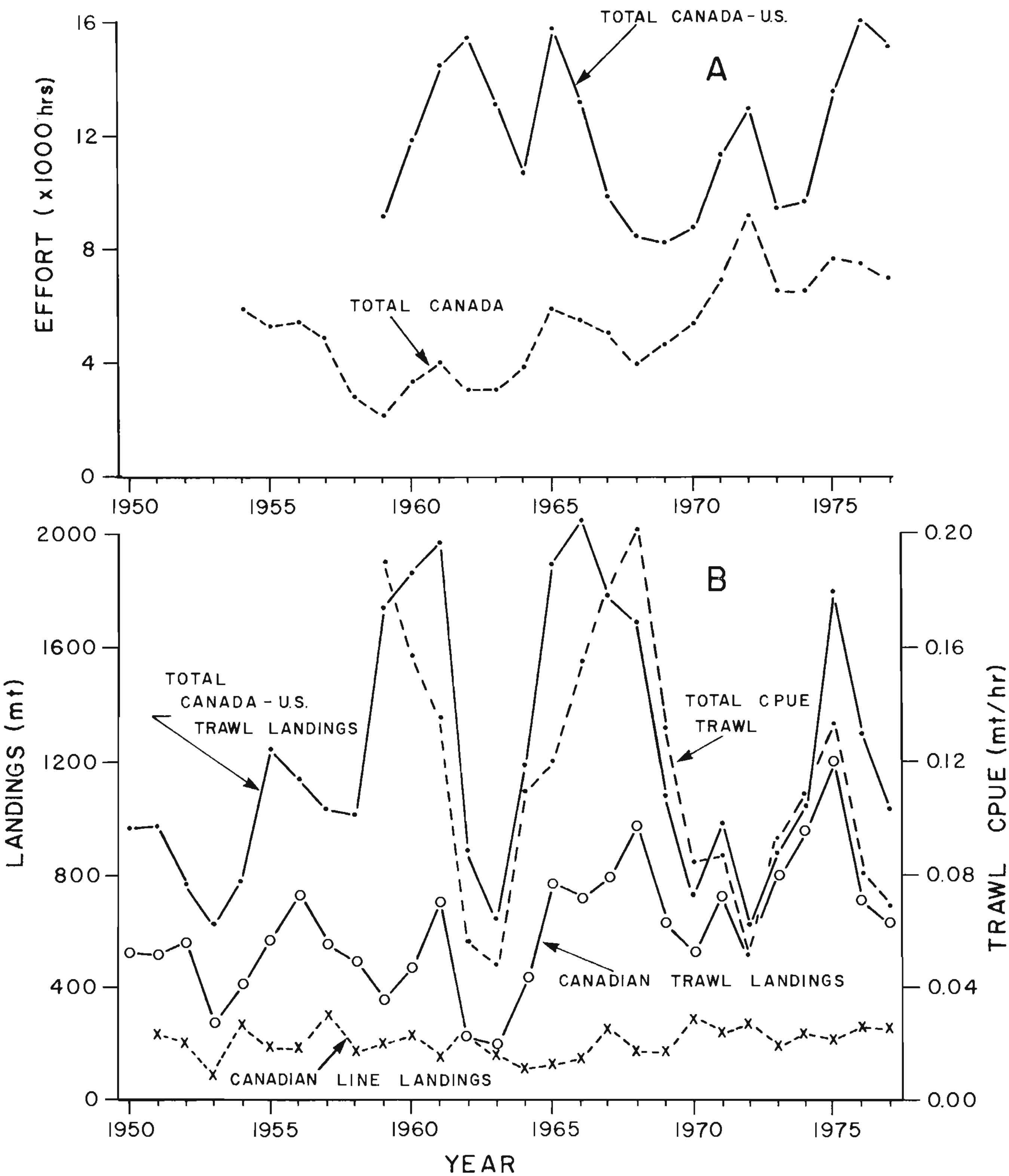

Fig. 5.3 Lingcod catch statistics for Area 3C (southwest Vancouver Island) 1950-77: A. Total trawl effort (hr), Canada-U.S. and Canada. B. Total landings (m.t.); Canada-U.S. and Canada trawl, and Canada line; and total Canada-U.S. CPUE (m.t./hr).

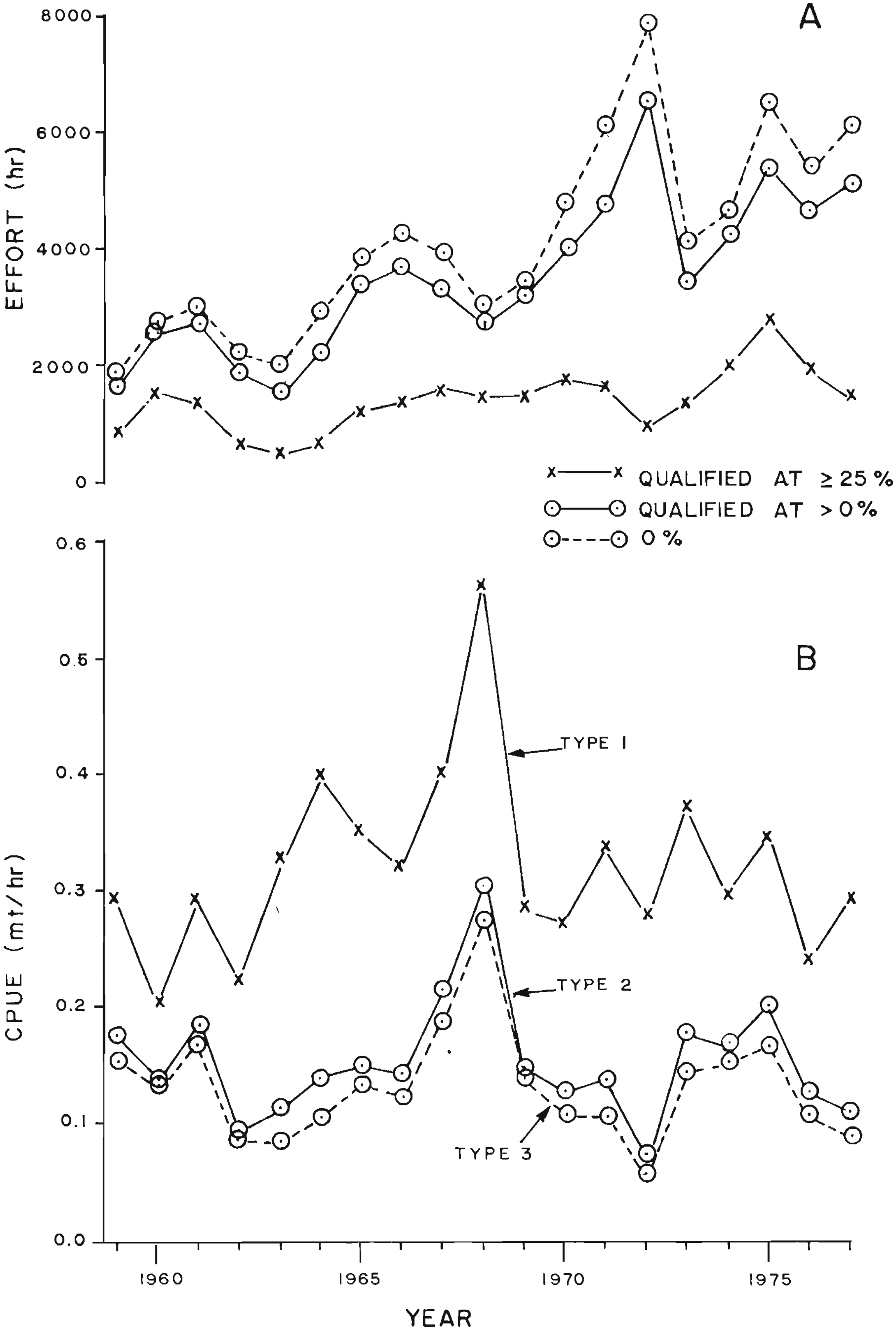

Fig. 5.4. Interviewed Canadian fishing effort (A) and CPUE (B) for lingcod in Area 3C.

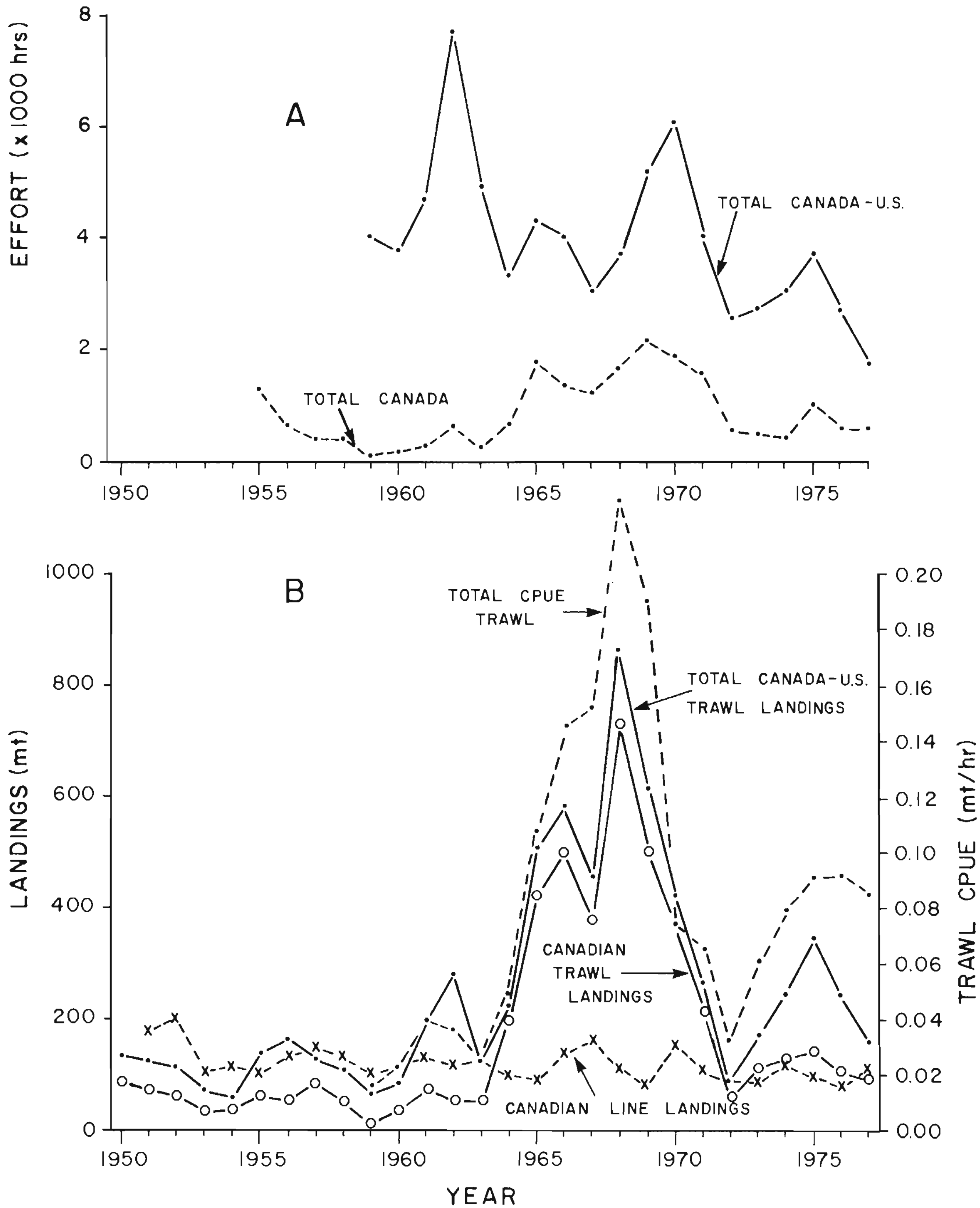

Fig. 5.5. Lingcod catch statistics for Area 3D (northwest Vancouver Island) 1950-77: A. Total trawl effort (hr), Canada-U.S. and Canada. B. Total landings (m.t.); Canada-U.S. and Canada trawl, and Canada line; and total Canada-U.S. CPUE (m.t./hr).

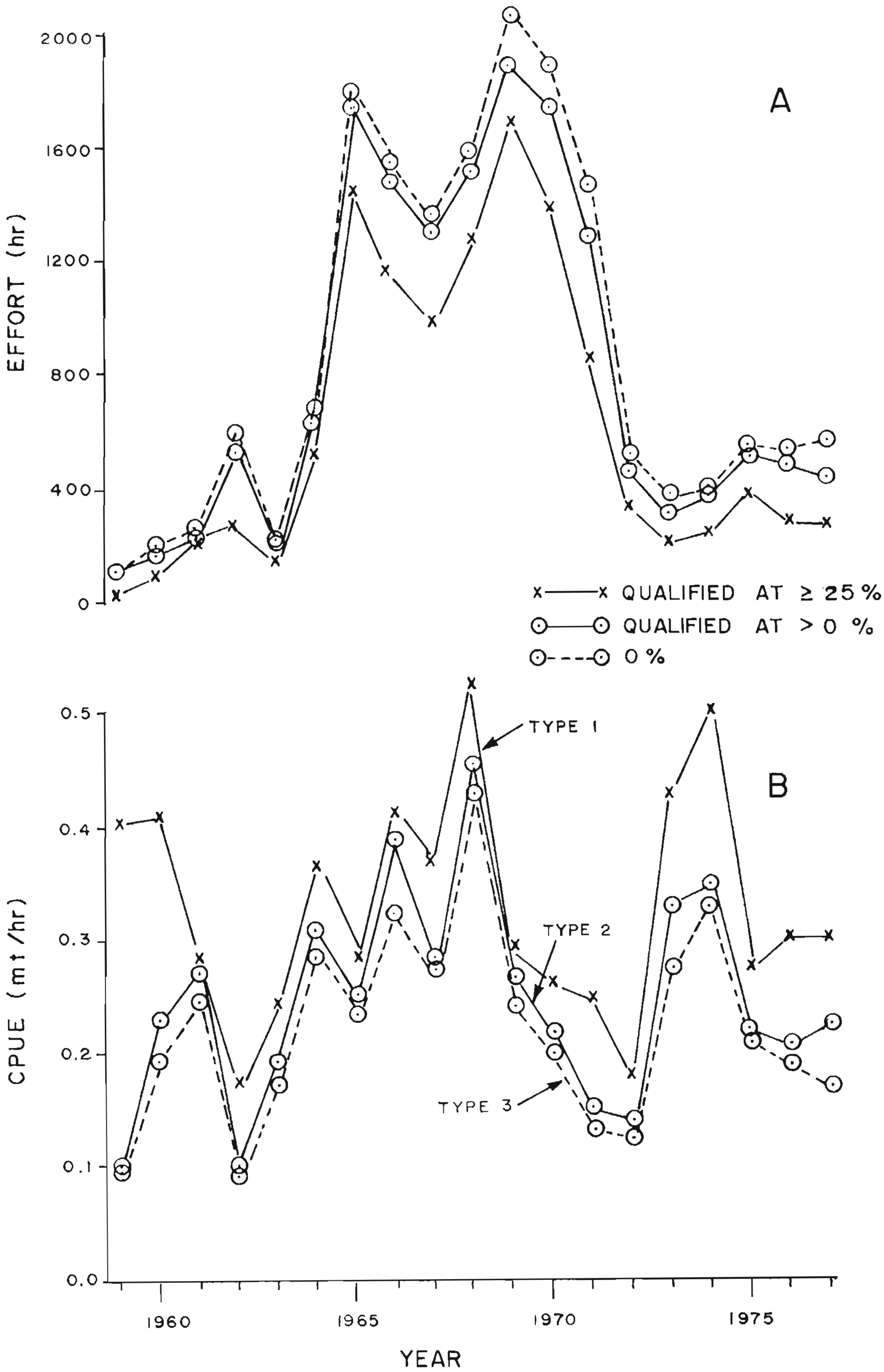

Fig. 5.6. Interviewed Canadian fishing effort (A) and CPUE (B) for lingcod in Area 3D.

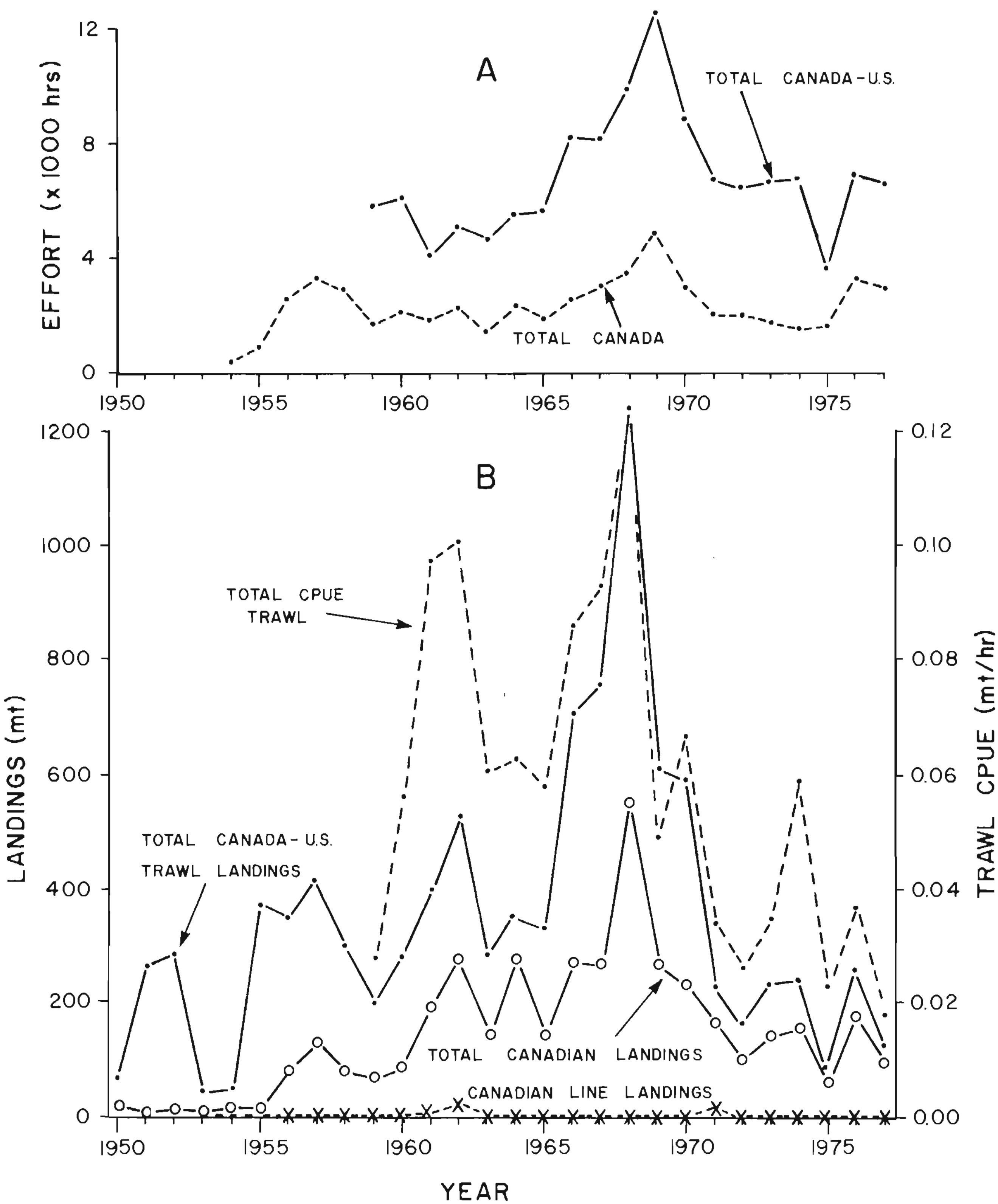

Fig. 5.7. Lingcod catch statistics for Area 5A (Cape Scott grounds) 1950-77:
A. Total trawl effort (hr), Canada-U.S. and Canada.
B. Total landings (m.t.); Canada-U.S. and Canada trawl, and Canada line; and total Canada-U.S. CPUE (m.t./hr.).

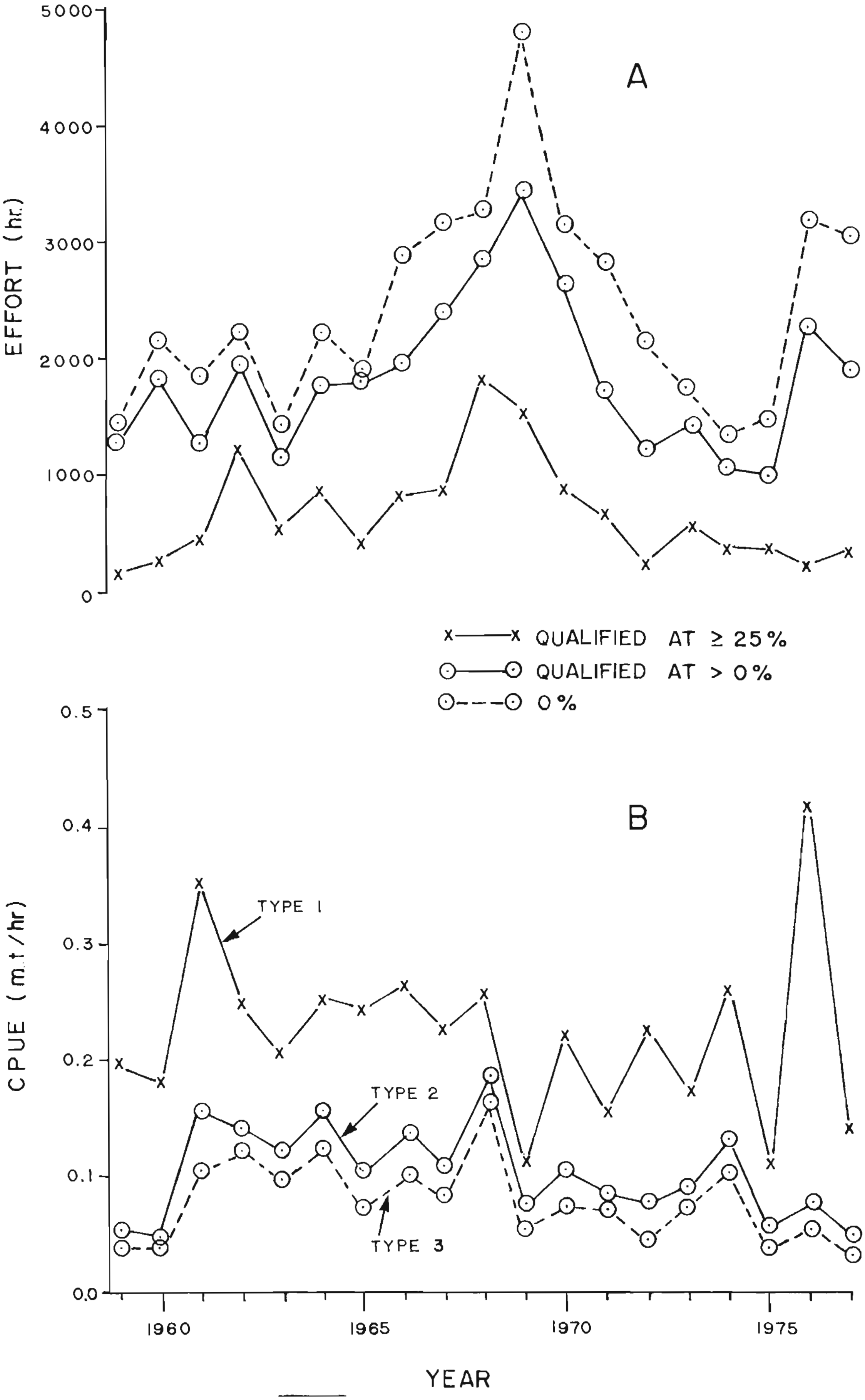

Fig. 5.8. Interviewed Canadian fishing effort (A) and CPUE (B) for lingcod in Area 5A.

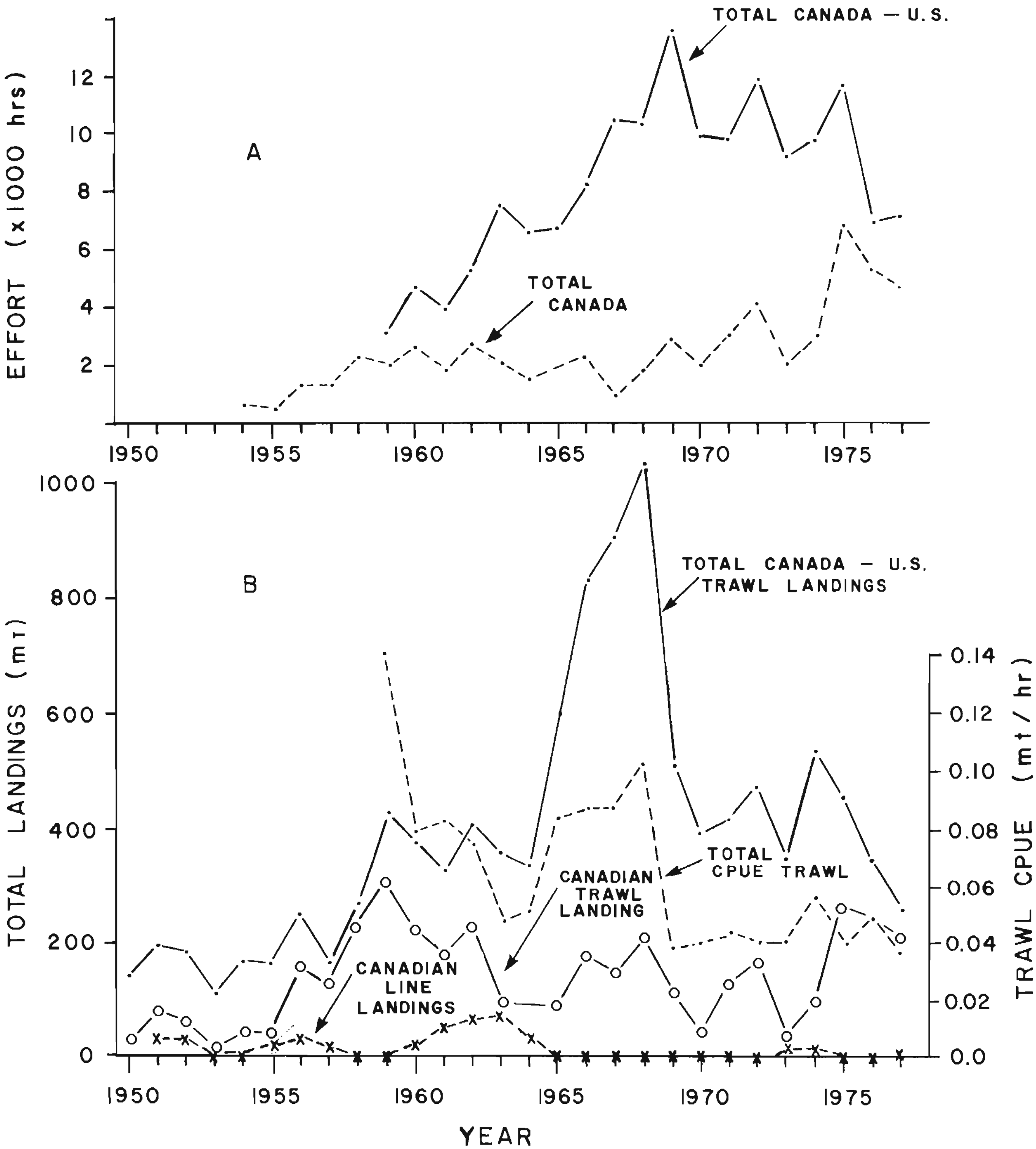

Fig. 5.9. Lingcod catch statistics for Area 5B (Goose Island grounds) 1950-77: A. Total trawl effort (hr), Canada-U.S. and Canada. B. Total landings (m.t.); Canada-U.S. and Canada trawl, and Canada line; and total Canada-U.S. CPUE (m.t./hr).

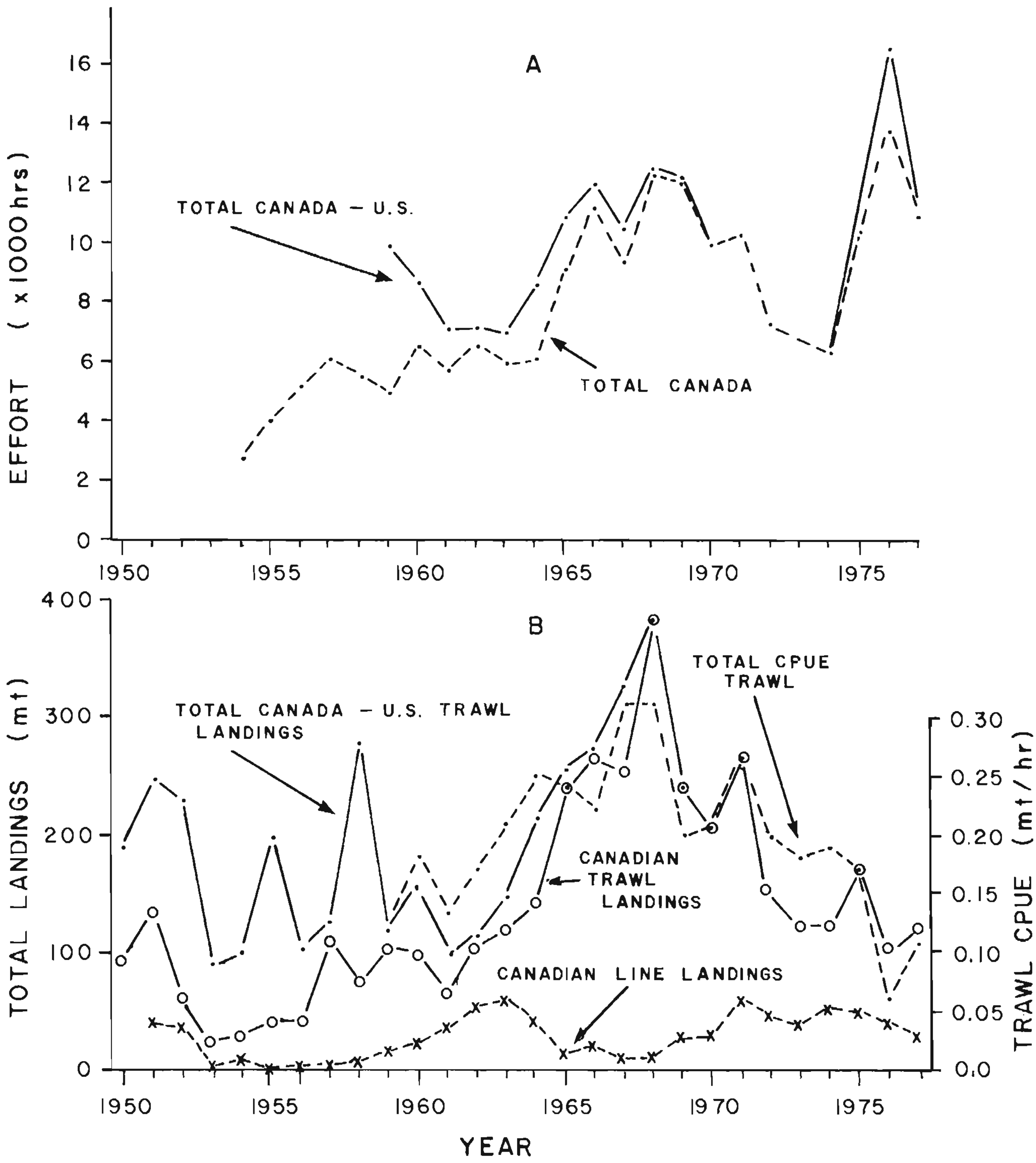

Fig. 5.10. Lingcod catch statistics for Areas 5C and 5D (Hecate Strait and Dixon Entrance) 1950-77: A. Total trawl effort (hr), Canada-U.S. and Canada. B. Total landings (m.t.); Canada-U.S. and Canada trawl, and Canada line; and total Canada-U.S. CPUE (m.t./hr).

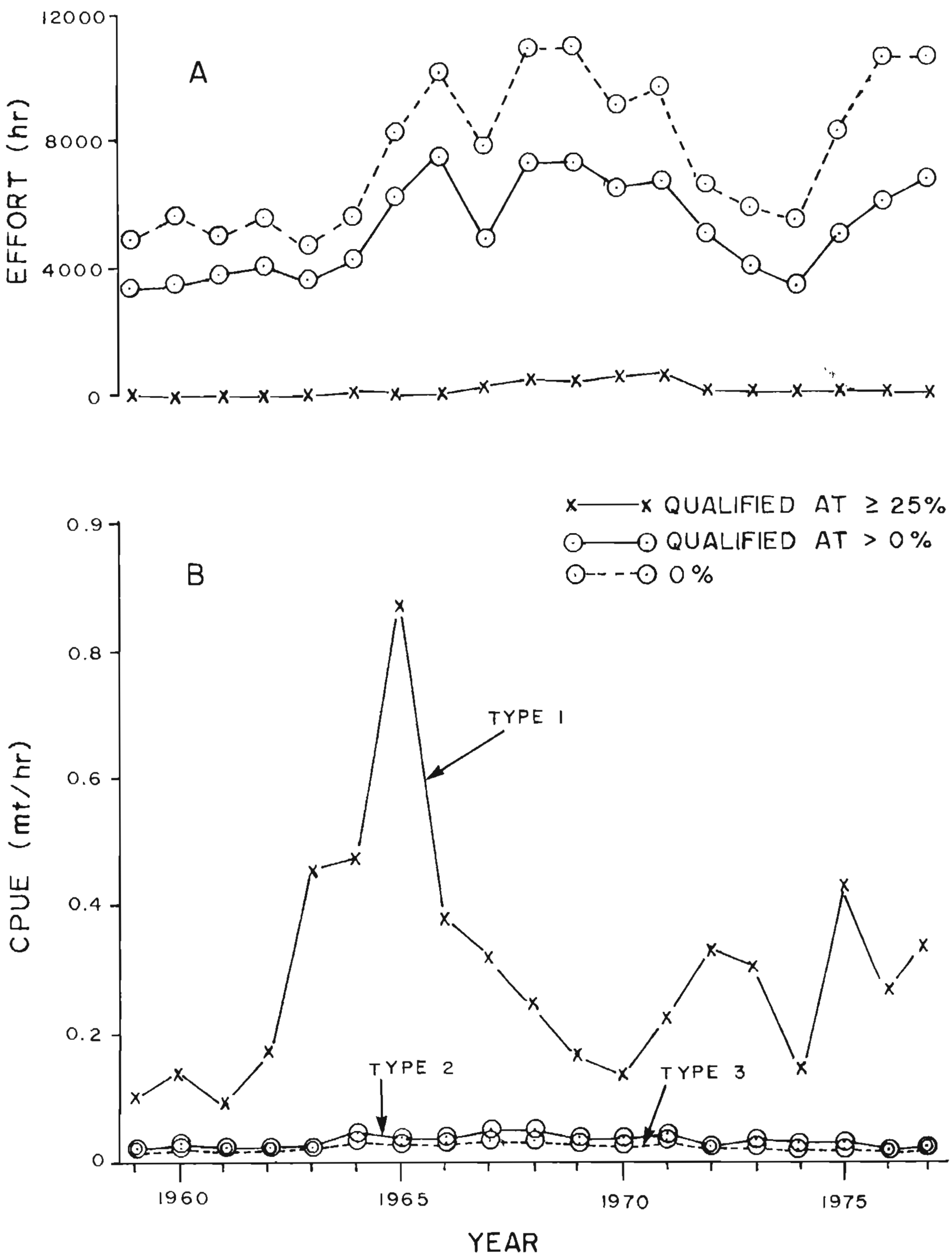

Fig. 5.11. Interviewed Canadian fishing effort (A) and CPUE (B) for lingcod in Areas 5C and 5D.

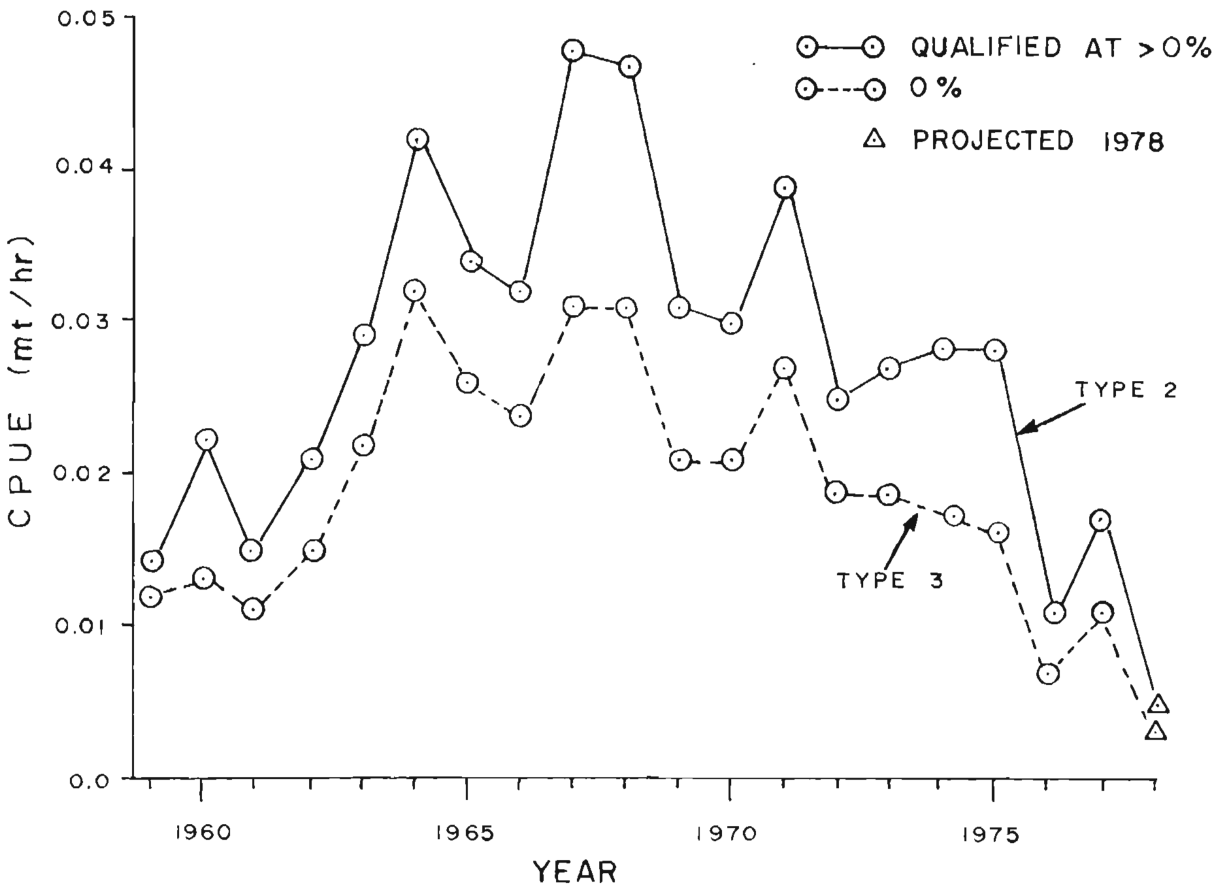

Fig. 5.12. Interviewed Canadian CPUE showing Type 2 and 3 for lingcod in Areas 5C and 5D.

6. DOGFISH STOCK ASSESSMENT

6.1 History of the fishery

During 1940-49 dogfish were the object of an intensive liver fishery along the British Columbia coast which reached a peak production of about 35,000 m.t. in 1944. With the development of synthetic Vitamin A and importation of low-priced liver products in 1949, the fishery collapsed and remained dormant until 1958. From 1958 until 1962 a small fishery, mainly in the Strait of Georgia, took place under a federal subsidy. In more recent years, attempts have been made to develop a foodfish fishery, but economic and processing difficulties have kept it at a low level.

6.2 Stock assessment

The absence of a continuing fishery for dogfish makes it very difficult to clearly define the number of stocks present in the Canadian zone or to determine current stock size. Catch and effort statistics from the 'liver fishery' of the 1940's indicate that the virgin biomass of marketable stock (>78 cm) in British Columbia waters was in the order of 200,000 m.t. These statistics also suggest that the marketable stock was reduced to perhaps as little as one quarter of its primitive abundance by a fishery which averaged about 15,000 m.t./yr between 1937 and 1949 -- a period of 13 years (Ketchen, 1969).

A discrete-time, deterministic 'age-structure model' incorporating recent information on growth and reproduction of dogfish in the northeast Pacific has been developed to assess the overall potential of the dogfish resource (Wood et al., in preparation). This analysis treats dogfish in British Columbia waters as a single stock and utilizes the estimate of primitive abundance and historical catch data to simulate past fisheries (Fig. 6.1). The model predicts that the liver fishery would have reduced the marketable biomass to at least half of its primitive abundance but that this portion of the stock would recover as early as 1960, due to the considerable biomass of juveniles inhabiting midwater regions that would have escaped the fishery. This apparent recovery is corroborated by the growing number of complaints about the 'dogfish problem' as early as the late 1950's which led to the introduction of the subsidized 'eradication fishery' of 1959-1962. But while the marketable stock appeared to recover quickly, it is likely that the population is only beginning to approach its historic levels. The present biomass of marketable stock is probably in the order of 120,000-150,000 m.t.

6.3 Sustainable yields

From the biomass estimates it might be expected that the current stock(s) off British Columbia could support a substantial fishery indefinitely. However, because of the unique biological features of the dogfish, it is extremely sensitive to overfishing.

If the stocks were to be fished with the object of obtaining a maximum sustainable yield of large fish (over 78 cm), the yield would be only about 8,000-10,000 m.t. with one-third (3,000 m.t.) assignable to the Strait of Georgia and the remaining two-thirds (6,000 m.t.) to all other areas. (Projected 1978 production from the Strait of Georgia is close to 2,500 m.t.). However, there are other possible fishing strategies which can be employed depending on whether the dogfish stock is to be maintained at its MSY or is to be reduced as efficiently and quickly as possible to a level where the species ceases to be a nuisance to fisheries for other species. A periodic fishery which attempts to fish dogfish intensively for short periods can harvest up to 16,000 m.t. per year (11,000 m.t. in Zones 5 and 3) of fish larger than 78 cm and may reduce abundance below some "nuisance" level. If our calculations of stock size are correct, then the stocks could not sustain this fishing pressure for more than 10-15 yr and would quickly be reduced to levels where fishing would discontinue for economic reasons.

A periodic fishery will only reduce the dogfish stocks below a "nuisance" level for a short time (5-15 yr). Because a considerable biomass of juvenile dogfish exist in the midwater, they are not fished and become recruited into the fishable stock after a fishery ends. This recruitment of juveniles from the midwater and the disruptions in age structure caused by a periodic fishery,will result in oscillations in abundance (Fig. 6.2, 6.3). A sustained fishery will also produce oscillations in abundance but these oscillations will dampen with time (Fig. 6.2). Any type of periodic fishery will perpetuate these cycles of abundance (Fig. 6.3). Furthermore, the greater the intensity or longer the duration of the periodic fishery, the greater are the oscillations in abundance. It is somewhat paradoxical that an intensive periodic effort to reduce dogfish as a nuisance can result in a perpetuation of the problem.

6.4 Recommendations

It is recommended that a TAC of 3,000 m.t. be assigned for the Strait of Georgia (PMFC Area 4B) and a TAC of 6,000 m.t. be set to cover all other areas of the Canadian Zone.

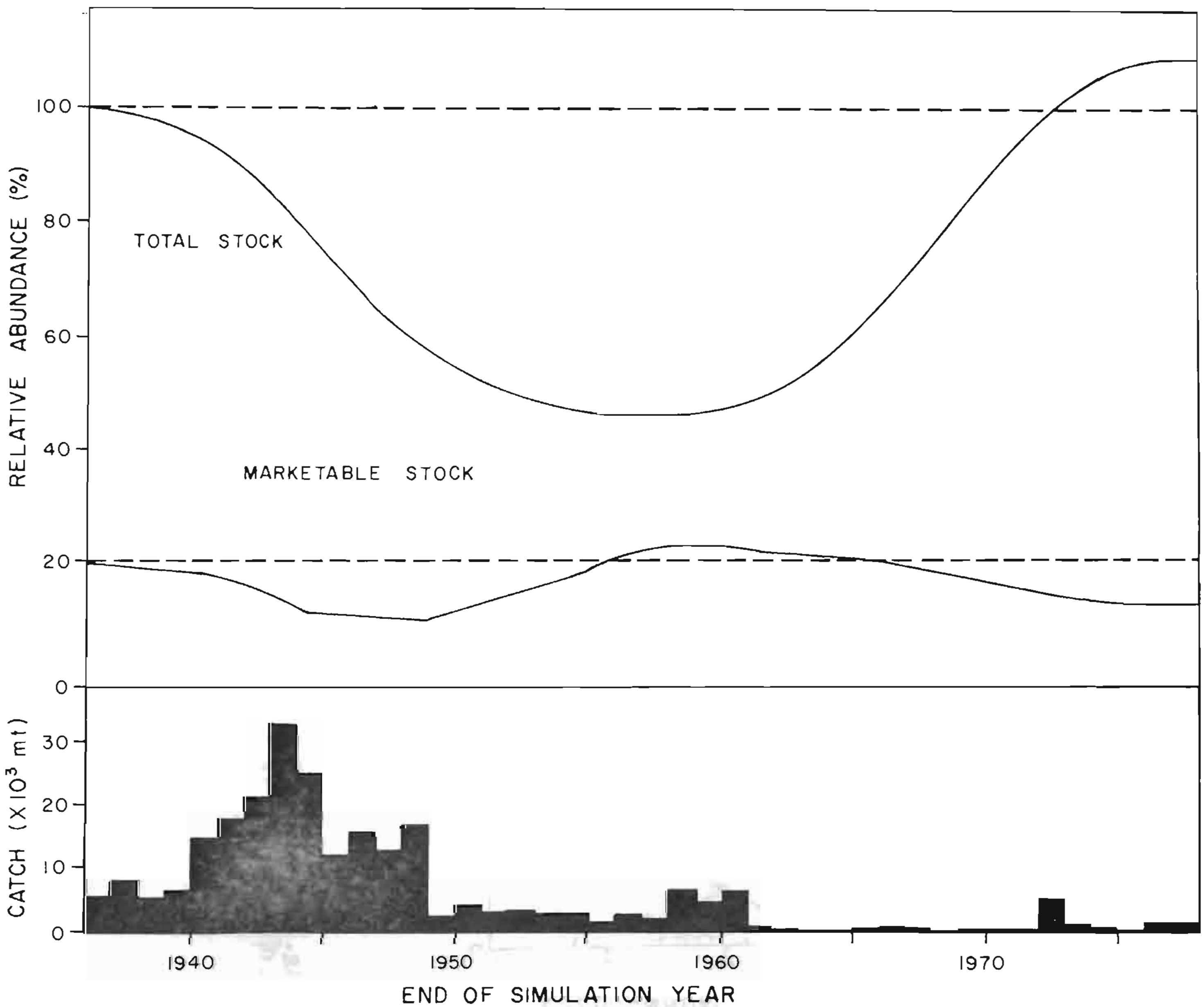

Fig. 6.1. Simulation of dogfish abundance following intensive 'liver fishery'.

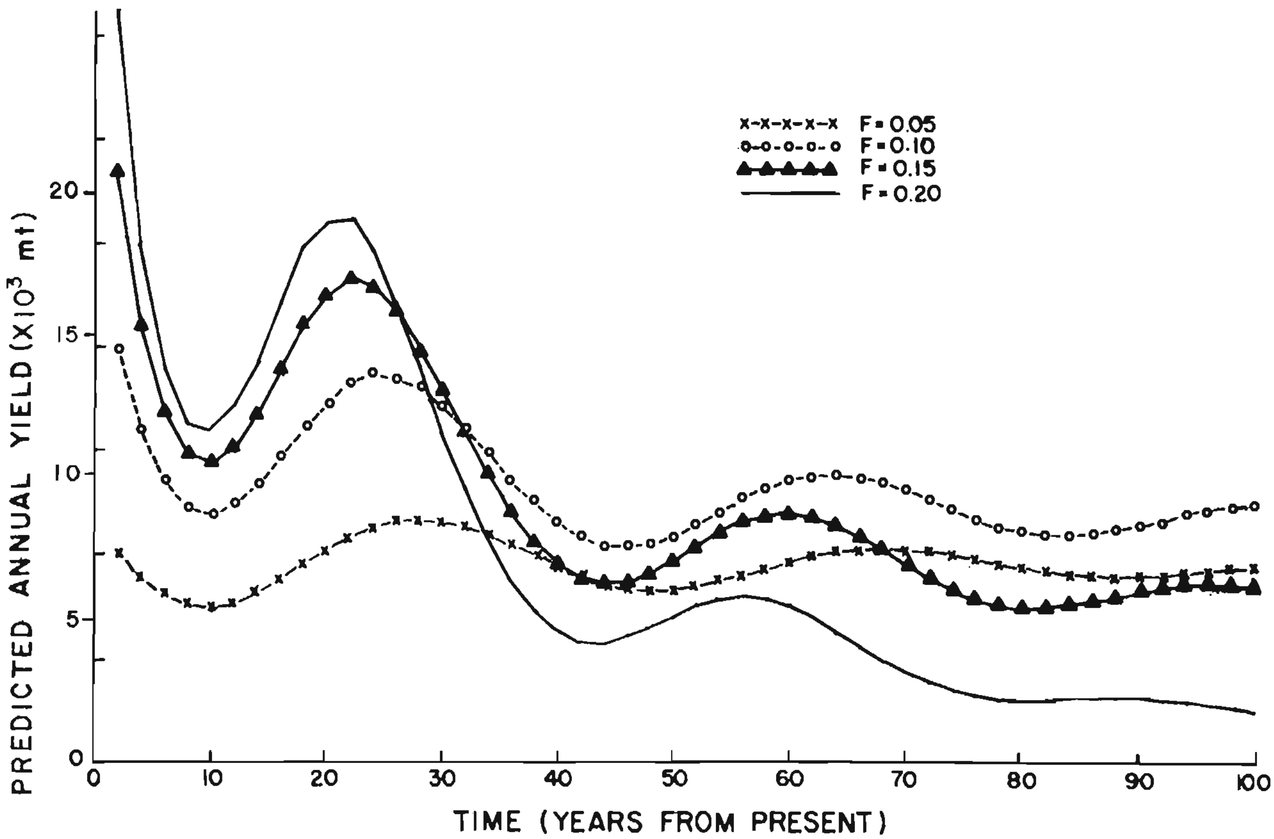

Fig. 6.2. Predicted yield to hypothetical dogfish fishery at four sustained fishing rates. (F = instantaneous rate of fishing mortality.)

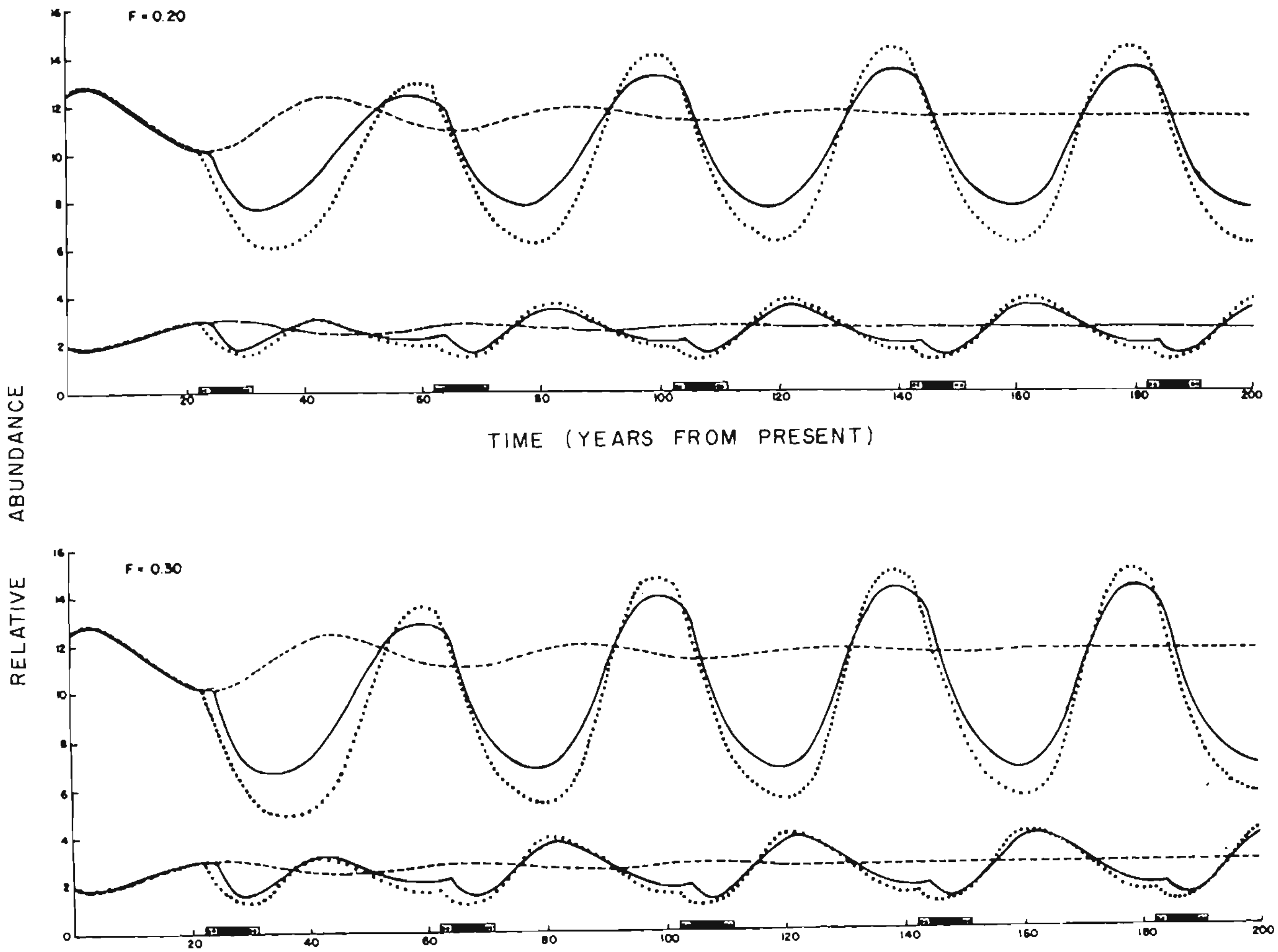

Fig. 6.3. Abundance of dogfish predicted by model when exploited by a periodic fishery commencing every 40 yr. The upper lines in each diagram represent the total stock (i.e., all age groups) whereas the lower lines represent only the marketable-sized stock. Dashed lines predict the abundance with no fishery; solid lines, the abundance during a 5-yr periodic fishery; and dotted lines, the abundance during a 9-yr periodic fishery. F = instantaneous rate of fishing mortality.

7. ROCK SOLE STOCK ASSESSMENTS

7.1 History of the fishery

The rock sole is an important component of the Canadian trawl fishery off the coast of British Columbia. Since the early 1950's the species has been the dominant flatfish in landings in British Columbia, and production has varied between 811 m.t. and 3285 m.t. with an average of 1740 m.t./yr (Table 7.1). The bulk of landings have originated from fishing grounds between Cape Scott and Dixon Entrance, the principal fishing grounds being Two Peaks-Butterworth and Ole Spot in Hecate Strait. In recent years the rock sole fishery in North Hecate Strait has declined in relation to that for other species, as indicated by Canadian trip report catch data (Table 7.2). Since the late 1950's, Pacific cod has dominated the landings, but there have also been significant landings of English and Dover sole. However, as noted by Forrester and Thomson (1969), there appears to be little competition between the rock sole fishery and those for the other species due to temporal or bathymetric segregation of the stocks. This suggests that rock sole abundance may be declining.

7.2 Stock assessment

A measure of abundance based only on partial observation of the catch (i.e. only interviewed catch data) was used for this investigation. Abundance of rock sole in the Canadian zone was estimated by dividing the qualified (25%) catch of Canadian trawlers landing rock sole during the entire annual fishing period by the qualified number of fishing hours. Of course forecasting made from the partial observations will have to be adjusted.

For present purposes the analysis will be conducted in two ways:

(i) treatment of rock sole as a single resource within the Canadian zone as a whole, recognizing that there are probably numerous stocks comprising the resource, and
(ii) treatment as a minimum of 5 discrete units or stocks: North Hecate Strait (Area 5D), Middle Hecate Strait (Area 5C)[16], Goose Island ground (Area 5B), Cape Scott ground (Area 5A), and west coast of Vancouver Island grounds (Areas 3C and 3D), as illustrated in Fig. 7.1.

7.2.1 Entire Canadian zone

CPUE from partial observation of catch data shows a general decline in abundance of rock sole in Canadian waters from 1954 to 1959, followed by a gradual increase to a maximum level of 0.52 m.t./hr in 1966 (Table 7.3). CPUE declined sharply from 1966 to 1968, but has been relatively stable since then. CPUE in

[16] Actually some of the grounds comprising this unit lie inside the southern boundary of Area 5D.

1978 is projected as 0.34 m.t./hr, up 0.07 m.t./hr from the previous year. Fishing effort generally fluctuates directly with catch, indicating that fishing effort may be directed towards other species when abundance or possibly market demands are low.

7.2.2 Sub-areas in the Canadian zone

CPUE for partial observation of catch data in North Hecate Strait has fluctuated widely since 1954 (Table 7.4). Rock sole abundance in this important fishing sub-area peaked in 1960-61 and 1965, and gradually declined to a low of 0.29 m.t./hr in 1972. In recent years, CPUE has been fluctuating around 0.4 m.t./hr.

In Middle Hecate Strait production has also been quite variable (Table 7.4). Catches peaked in 1957 and were fairly uniformly high from 1966 to 1970 and then declined sharply to a low of 119 m.t. in 1972. In recent years catches have increased and CPUE has not shown a significant trend.

In the Goose Island and Cape Scott sub-areas, rock sole production showed moderate fluctuations (Table 7.4). For the time period considered CPUE remained notably stable. Similarly no trend in CPUE is shown in the West Coast of Vancouver Island sub-area (Table 7.4).

In summary, although no drastic decline in rock sole abundance seems evident, when looking at the CPUE within the entire Canadian zone, individual stocks, particularly in Hecate Strait, have dropped to levels below those which prevailed during the mid-1960's.

7.3 Yield

A variety of dynamic models have been used recently to help establish fishery regulations and catch quotas. Most models are used only to predict maximum equilibrium harvests. Here an attempt is made to establish harvest recommendations for a non-equilibrium situation. The dynamic model used for the following analysis is a discrete-time, stochastic version of Schaefer's production model (Schnute, 1977). The analysis provides estimates of biological, fisheries, and variance parameters of the rock sole fishery. The basic assumptions of the model are:

1) Growth rate of the population biomass equals its natural logistic growth rate minus the catch rate.
2) Catch rate is directly proportional to effort rate and to available biomass.
3) Present state of the fishery is represented in terms of its past state (previous catch and effort).
4) Since it is never possible to predict catch exactly, a random predictive error is included for estimating uncertainty in the parameters.

The Schaefer model uses the data stream of average effort rates and catch per unit of effort from 1954 to 1978. The estimated maximum sustainable yield, effort rate and CPUE for the combined areas of the Canadian zone, North Hecate Strait, and Middle Hecate Strait are shown in Table 7.5. MSY's for the three stock situations investigated were predicted as 1596 m.t. for the combined areas, 589 m.t. for North Hecate Strait, and 456 m.t. for Middle Hecate Strait. By comparing these results to catch trends (Table 7.4) it is evident that high effort expended on rock sole in the late 1960's drove stocks down to levels considerably below MSY levels in the 1970's. The low effort expended during 1972 to 1974 allowed steady increases to levels that should gradually approach MSY levels. These observations are similar whether separate stocks or a combined stock is assumed.

The Schaefer model gives a good fit to historical data for the rock sole fishery, as shown in Fig. 7.2.

7.4 Yield forecasts for 1979

The estimates of the biological and variance parameters from the partial observations predict 1979 yields for the existing non-equilibrium situations. The predictions and upper and lower 95% confidence limits are shown in relation to possible effort rates for 1979 (total hours of directed fishing) in the combined zone, North Hecate Strait, and Middle Hecate Strait in Fig. 7.3. Although there seems to be an upward trend in CPUE from 1970 onwards (Fig. 7.2) the present stock abundance would only yield about two-thirds of the predicted MSY level in 1979 if fished at the predicted equilibrium effort level for the combined Canadian zone (Fig. 7.3). Similarly for North Hecate Strait and Middle Hecate, the average predictions are less than half MSY and about three-fourths MSY, respectively, if equilibrium efforts were expended in 1979. These results suggest that effort should be held at levels below equilibrium levels in order to allow steady increase of stocks if MSY catches are indeed the desirable objective.

No forecasts of rock sole yield are available at this time for the Goose Island, Cape Scott and west coast of Vancouver Island stocks. These areas are of relatively minor importance accounting less than 30% of the Canadian production. Nevertheless, further studies are planned and these will include re-analysis to take account of the United States fishery and various biological considerations such as recruitment.

7.5 Recruitment considerations

It has been postulated (Forrester and Thomson, 1969) that changes in environmental conditions may play some part in the variations in strength of rock sole year-classes. Particularly water temperatures during the spawning periods were presumed to provide a predictor of year-class strength. However, recent analysis by Wickett (Appendix 2, Fig. 5) showed that recent values of favourable temperatures were not associated with high values of recruitment as expected. These findings cast severe doubts on the originally proposed predictor. Wickett's analysis indicates however, that the environmental factors (in this case sunlight) may be used to make year-class strength predictions employing a Ricker stock-recruitment relationship. Furthermore, indications of density dependent competition emerged from the investigation, which will undoubtly be useful in further population studies.

7.6 Recommendations

At present the relationship between biological, fisheries and variance parameters estimated from partial observation and total catch information are poorly understood. In light of this lack of understanding the following recommendations are made:

For the entire Canadian zone the TAC is set at approximately 900 m.t. This reduced catch rate should allow the resource to increase.

For individual rock sole stocks the following TAC's are set:

North Hecate Strait (5D)	400 m.t.
Middle Hecate Strait (5C)	300 m.t.
Goose Island ground (5B)	100 m.t.
Cape Scott ground (5A)	50 m.t.
West coast of Vancouver Island grounds (3C and 3D)	40 m.t.
Georgia Strait (4B)	20 m.t.

If further analysis establishes considerable changes in parameter estimates these figures may be altered accordingly during a mid-season review.

Table 7.1. Total Canadian trawl catch of rock sole in British Columbia waters, 1954-1977.

Year	B.C. Catch (m.t.)
1954	1256
1955	1662
1956	1895
1957	1907
1958	2073
1959	864
1960	1838
1961	1311
1962	1481
1963	1351
1964	1198
1965	1397
1966	3285
1967	2584
1968	3059
1969	3018
1970	1772
1971	1955
1972	957
1973	811
1974	945
1975	1744
1976	2154
1977	1249

Sources : 1954-64 (Forrester and Thomson, 1969)
1965-75 (Smith, 1976)
1976 (Smith, 1977)
1977 (File data)

Table 7.2. Canadian catch of main species of trawl caught fish from North Hecate Strait (figures are from interviewed catch data only).

Year	Rock sole (m.t.)	English sole (m.t.)	Dover sole (m.t.)	Pacific cod (m.t.)
1954	768	290	75	616
1955	1066	370	85	409
1956	365	661	91	722
1957	157	197	88	465
1958	720	293	44	1427
1959	106	392	7	1062
1960	577	476	25	881
1961	611	499	19	561
1962	445	308	27	620
1963	594	174	24	1365
1964	476	203	75	3813
1965	214	200	41	5497
1966	1252	201	54	7549
1967	953	290	3	2874
1968	1092	434	24	3490
1969	1164	683	248	2022
1970	403	805	900	849
1971	738	405	882	1049
1972	145	278	908	1923
1973	115	322	760	3105
1974	153	339	695	3010
1975	527	648	711	2480
1976	720	568	749	2242
1977	428	815	371	2625

Table 7.3. Rock sole catch and effort statistics based on interviewed catch only, combined for five subareas of the Canadian zone, 1954-1978.

Year	Catch (m.t.)	Effort (hr.)	CPUE (m.t./hr.)
1954	984	2124	0.46
1955	1402	3522	0.40
1956	1681	4510	0.37
1957	1632	5076	0.32
1958	1844	5912	0.31
1959	749	2943	0.25
1960	1594	4937	0.32
1961	1128	3378	0.33
1962	1209	4127	0.29
1963	1046	3015	0.35
1964	821	2562	0.32
1965	871	2255	0.39
1966	2408	4653	0.52
1967	2075	4777	0.43
1968	2315	7056	0.33
1969	2493	7689	0.32
1970	1462	5722	0.26
1971	1541	5875	0.26
1972	438	1669	0.26
1973	399	1587	0.25
1974	416	1335	0.31
1975	1018	3403	0.30
1976	1258	3881	0.32
1977	771	2844	0.27
1978[a]	762	2238	0.34

[a] Projected estimate.

Table 7.4. Rock sole catch and effort statistics based on interviewed catch only for subareas of the Canadian zone, 1954-1978.

Year	North Hecate Strait			Middle Hecate Strait			Goose Island Ground		
	Catch (m.t.)	Effort (hrs.)	CPUE (m.t./h.)	Catch (m.t.)	Effort (hrs.)	CPUE (m.t./h.)	Catch (m.t.)	Effort (hrs.)	CPUE (m.t./h.)
1954	750	742	1.01	47	101	0.46	61	133	0.46
1955	1050	1425	0.74	105	142	0.74	75	259	0.29
1956	350	556	0.63	665	906	0.73	190	621	0.31
1957	150	291	0.52	863	1792	0.48	147	570	0.26
1958	717	661	1.08	335	719	0.47	275	1403	0.20
1959	96	113	0.85	234	548	0.43	249	985	0.25
1960	550	371	1.48	345	770	0.45	351	1526	0.23
1961	587	378	1.55	97	331	0.29	247	1264	0.20
1962	420	357	1.18	267	527	0.51	314	1408	0.22
1963	569	556	1.02	121	299	0.40	237	1019	0.23
1964	405	528	0.77	183	443	0.41	123	639	0.19
1965	159	119	1.33	426	574	0.74	176	749	0.24
1966	1073	1308	0.82	845	1214	0.70	223	868	0.26
1967	859	1006	0.85	817	1576	0.52	149	505	0.29
1968	1002	2199	0.46	834	2216	0.38	122	556	0.22
1969	1091	1390	0.78	975	3378	0.29	225	1157	0.19
1970	348	753	0.46	879	3081	0.29	75	360	0.13
1971	686	1746	0.39	566	2213	0.26	173	942	0.18
1972	83	283	0.29	119	524	0.23	127	545	0.23
1973	75	164	0.46	199	588	0.34	64	258	0.25
1974	66	210	0.32	252	530	0.48	31	168	0.19
1975	415	649	0.64	402	1419	0.28	131	575	0.23
1976	641	1165	0.55	270	931	0.29	213	913	0.23
1977	298	836	0.36	298	1096	0.27	90	407	0.22
1978[a]	245	551	0.44	387	1085	0.36	92	315	0.29

[a]Projected estimate.

Table 7.4. (cont'd)

Year	Cape Scott Catch (m.t.)	Cape Scott Effort (hrs.)	Cape Scott CPUE (m.t./h.)	West Coast Vancouver Island Catch (m.t.)	West Coast Vancouver Island Effort (hrs.)	West Coast Vancouver Island CPUE (m.t./h.)
1954	31	176	0.18	95	972	0.10
1955	74	301	0.24	99	1395	0.07
1956	388	1485	0.26	88	942	0.09
1957	416	1806	0.23	55	617	0.09
1958	455	2377	0.19	63	752	0.08
1959	141	864	0.16	29	433	0.07
1960	306	1674	0.18	42	596	0.07
1961	163	830	0.20	34	575	0.06
1962	125	1054	0.12	84	781	0.11
1963	78	562	0.14	41	579	0.07
1964	72	401	0.18	39	551	0.07
1965	77	414	0.19	34	399	0.08
1966	215	798	0.27	53	465	0.11
1967	179	882	0.20	70	808	0.09
1968	318	1554	0.20	38	531	0.07
1969	159	1286	0.12	43	478	0.09
1970	113	850	0.13	47	651	0.07
1971	81	484	0.17	35	490	0.07
1972	6	54	0.12	24	250	0.10
1973	20	147	0.13	41	430	0.10
1974	13	69	0.19	53	358	0.15
1975	24	272	0.09	47	488	0.10
1976	98	539	0.18	37	333	0.11
1977	40	240	0.17	45	264	0.17
1978	30	219	0.14	8	68	0.12

Table 7.5. Parameter estimates obtained by fitting a dynamic discrete-time stochastic Schaefer model to rock sole catch statistics, based on interviewed data, 1954-1978.

Parameters	Entire Canadian Zone	North Hecate Strait	Middle Hecate Strait
Biological parameters			
Natural growth rate (r) (yr^{-1})	0.23	0.24	0.31
Natural unfished equilibrium (k) (m.t.)	27514.00	9663.00	5948.00
Fishing parameters			
Catchability coefficient (q) ($hr.^{-1}$)	4.69×10^{-5}	2.87×10^{-4}	1.65×10^{-4}
MSY (m.t./yr.)	1596.00	589.00	456.00
Optimum fishing effort (hr.)	2472.00	425.00	930.00
Optimum CPUE (m.t./hr.)	0.65	1.38	0.49
Variance parameters			
σ	0.15	0.41	0.30
Failure index[a]	0.81	0.91	0.84

[a] The failure index is a rough gauge of the model's overall success in predicting present catches from past years' data. Although a value of 1.0 indicates a very poor fit, values less than 0.9 appear reasonable.

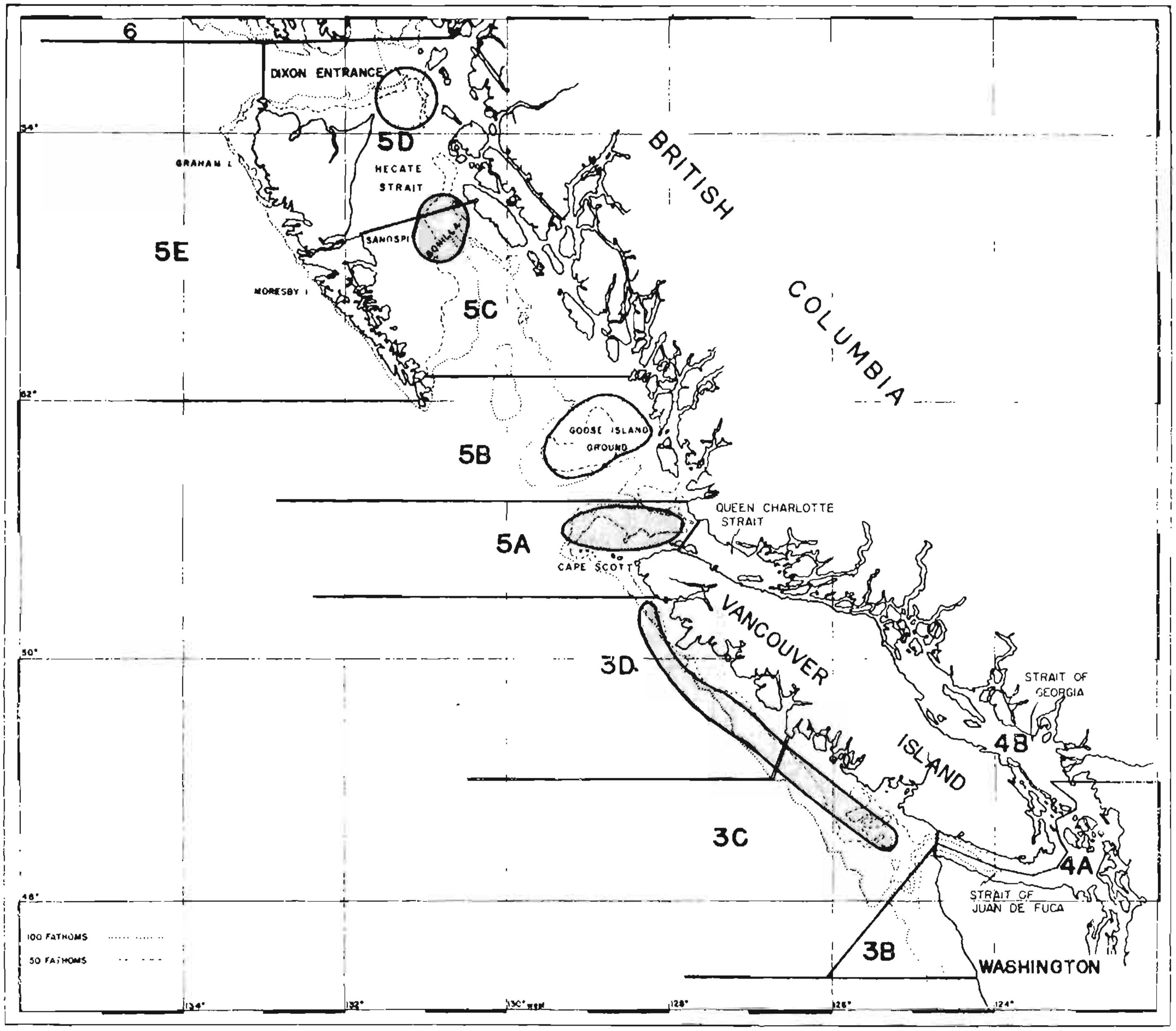

Fig. 7.1. International (Pacific Marine Fisheries Commission) Statistical Areas along the British Columbia coast and rock sole sub-areas.

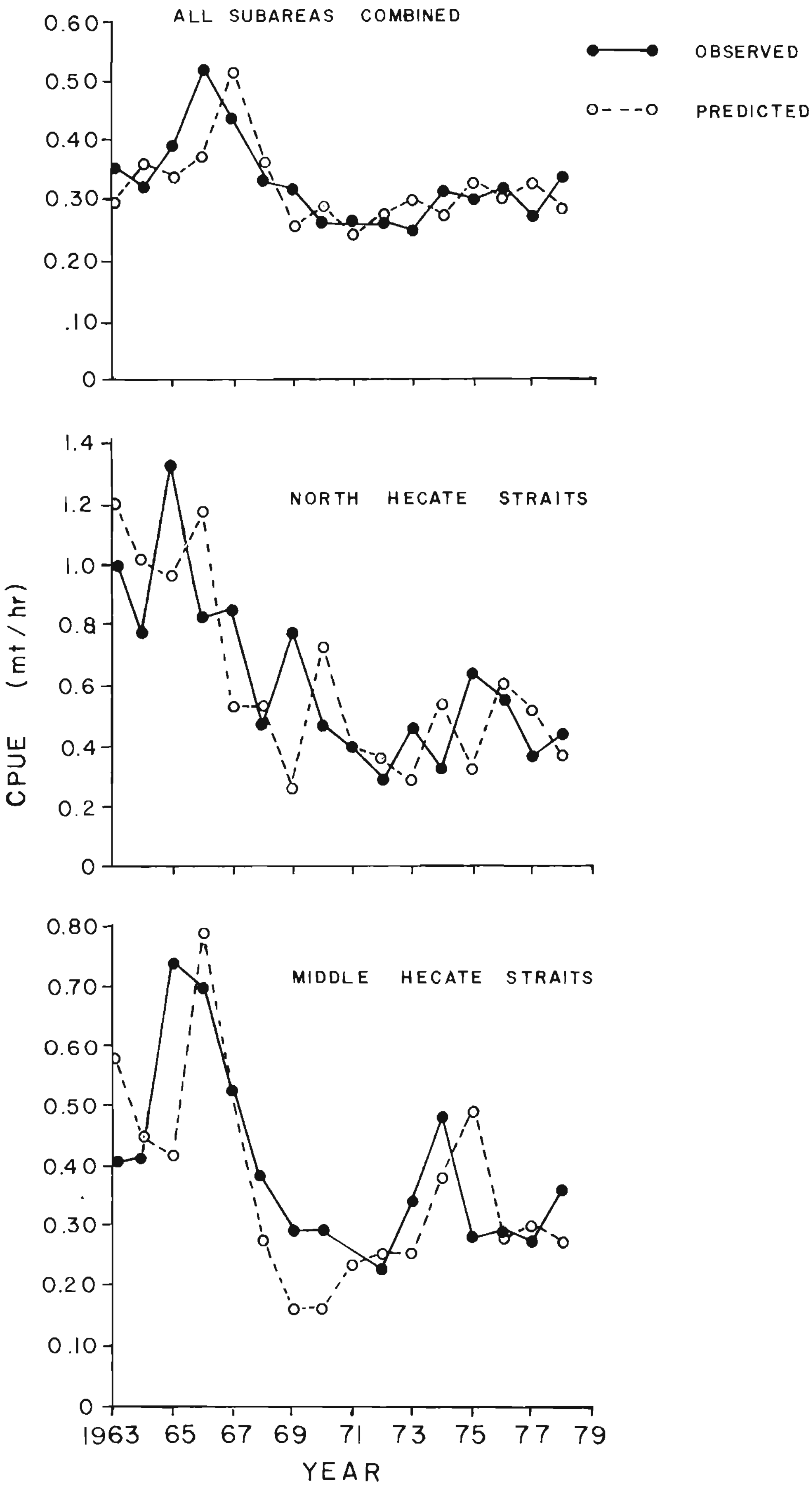

Fig. 7.2. Observed and predicted time series of catch per hour (interviewed catch) for rock sole 1954-1978.

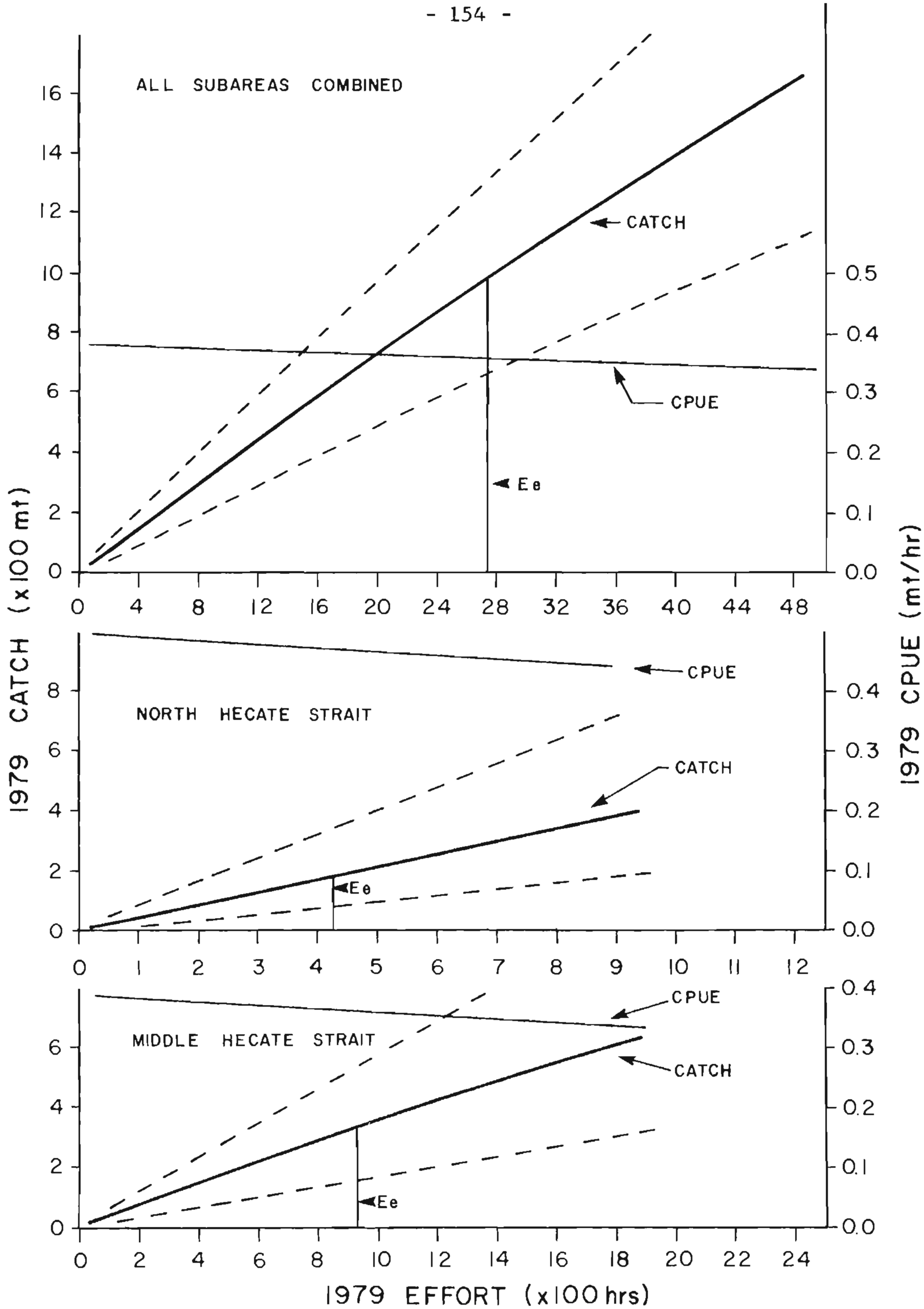

Fig. 7.3. Predicted 1979 catches and CPUE's for given efforts.

8. DOVER SOLE STOCK ASSESSMENT

8.1 Introduction

Moderate quantities of Dover sole are known to exist throughout British Columbia waters, but the only directed fisheries take place in the relatively deep water of northern Hecate Strait (Area 5D). A small fishery developed in the late 1940's adjacent to the Butterworth Edge and reached a peak production of 210.4 m.t. in 1952. (A fishery of lesser significance also occurred off White Rocks in what would now be called the northern limit of the Moresby Gully.) From 1952 onwards, production followed an irregular downward trend with landings becoming incidental to other species by the 1960's. Marketing problems or distraction by the more lucrative fishery for Pacific cod may have been responsible for the decline.

A reawakening of interest occurred in 1969 with development of an entirely new fishery on the Dundas ground (see Fig. 4.3) combined with resumption of fishing on the Two Peaks-Butterworth ground.

8.2 Catch statistics

During the period 1969-77 production averaged 771 m.t., with Dundas accounting for 65% and Two Peaks-Butterworth 34% (Westrheim, 1977).

Mean percentage landings by quarter-year were: 61% (III), 22% (II) and 16% (IV) (Table 8.1). For Area 5D as a whole, production has been on a general downward trend since 1970, but more noticeably since 1976 (Table 8.2).

Detailed catch statistics for the Dundas ground indicates a generally level trend in landings during 1970-76 (544-726 m.t.) followed by a substantial decrease during 1977-78 (181 m.t.)(Table 8.2)]. Calculated fishing effort (hours trawled) followed a similar pattern: 662-1,609 hr during 1970-76; 673 in 1977; and an estimated 298 hr in 1978. Catch rate (m.t. landed per hr trawled) rose steadily to a peak of 0.828 m.t./hr in 1974; declined steadily to 0.290 m.t./hr in 1977; then rose abruptly to an estimated 0.609 m.t./hr in 1978.

8.3 Stock condition

In general, these data suggest a substantial decline in abundance of Dover sole on the Dundas ground. Catch, effort, and catch rate have declined substantially. The anomalous increase in catch rate in 1978 was probably caused by a disproportionate decrease in fishing effort. Unfortunately, we cannot ascertain the cause of the apparent decline in abundance. No information on size composition or age composition is available to determine whether the initial fishery was supported by a series of strong year-classes and is now collapsing because of a recruitment failure. While overfishing by the Canadian fleet is a real possibility, there is a complication in that the Dover sole stock, in its seasonal inshore-offshore movements, may have been exposed to the Japanese trawl fishery off Dixon Entrance during the winter (spawning) months. Catches by that fishery are unknown.

8.4 Recommendations

A TAC of 200 m.t. of Dover sole is recommended for Hecate Strait (Areas 5C and 5D) and a closure to target fishing during the months of January-March in Area 5E. Elsewhere in Canadian waters where Dover sole is a minor component, the recommended TAC's are: Area 4B, 40 m.t.; Area 3C (Canada), 100 m.t.; Area 3D, 40 m.t.; Area 5A, 30 m.t.; Area 5B, 100 m.t.; and Area 5E, free fishery.

Table 8.1 Distribution (%) of Canada-U.S. landings of Dover sole from northern Hecate Strait (Area 5D), by quarter-year, 1969-77.

Year	Quarter I	Quarter II	Quarter III	Quarter IV	Quarter T	Total Can.-U.S. landings (m.t.)
1969	-	17	53	30	100	265
1970	-	33	52	15	100	965
1971	-	17	70	13	100	913
1972	-	17	69	14	100	922
1973	-	16	69	15	100	767
1974	T	11	70	19	100	759
1975	-	36	51	13	100	845
1976	T	28	50	21	99	1001
1977	1	24	65	9	100	476
1969-77 Mean	T	22	61	16	99	
C.V. (%)	300	39	15	37		

Table 8.2. Canada-U.S. catch statistics for Dover sole in northern Hecate Strait -- landings (m.t.) from Area 5D and Dundas ground; calculated effort (hr) and CPUE (mt/hr) for Dundas ground.

Year	Area 5D Can.-U.S. landings (m.t.)	Dundas ground		
		Can.-U.S. landings (m.t.)	Calculated effort (hr)	Canada CPUE (m.t./hr)
1969	265	1	-	-
1970	965	533	849	.628
1971	913	624	895	.697
1972	922	712	1,155	.616
1973	767	537	662	.810
1974	759	598	723	.828
1975	845	542	1,079	.502
1976	1,001	700	1,609	.435
1977	467	- [b]	-	.290
1978	350[a]	-	-	.609

[a] January-October, provisional.

[b] U.S. data not available.

9. ENGLISH SOLE STOCK ASSESSMENT

9.1 Introduction

The principal stock of English sole (*Parophrys vetulus*) in British Columbia waters inhabits northern Hecate Strait. Spawning grounds have never been accurately identified but probably lie in depths of 110-150 m in east central Hecate Strait adjacent to Banks Island. A small fishery usually occurs on the White Rocks ground in the fourth and first quarters of the year presumably on fish on their way to or returning from the spawning area. The main fishery usually occurs farther to the north in the first and second quarters along the Butterworth-Warrior edge and on the Two Peaks, during the post-spawning migration (Ketchen, 1956).

A relatively minor stock or group of stocks occurs in the Strait of Georgia and is fished primarily during the winter period.

9.2 Catch and effort statistics

Catches have varied substantially over the years rising from near zero in the early 1940's to a peak of 2,600 m.t. in 1950, followed by an irregular downward trend to about 340 m.t. in 1966 (Fig. 9.1). Between 1967 and 1978 there was an irregular upward trend with catches of more than 900 m.t. being recorded for 1970 and 1975-77.

CPUE has followed a somewhat similar course being highest in the early years of the fishery (prior to 1957) and lowest in the mid-1960's with a highly irregular upward trend thereafter.

Some of the fluctuations in catch and/or effort are associated with fluctuations in recruitment (Westrheim, 1977), but fluctuations in effort are possibly a major contributing factor. The extremely high production in 1950 was the consequence of abnormally high fishing effort (Fig. 9.1) and not related in any way to unusually strong recruitment (Ketchen, 1953). The same may have applied to later peak production periods 1959-61, 1969-70 and 1975-77. The period of lowest production 1963-66 came during a period of exceptionally heavy fishing for Pacific cod, when fishermen reportedly could not be persuaded to divert some of their effort to the flatfish fishery.

9.3 Current state of the stock

Westrheim (1977), using a correlation between year-class strength and water temperature developed earlier by Ketchen (1956), predicted that most of the 1968-75 year-classes would be above-average in strength. CPUE increased sharply between 1973 and 1975 to an above-average level, but has since stabilized slightly below the long-term average of 0.316 m.t./hr. Catches in 1975-77 rose well above the long-term average of 760 m.t. but fell abruptly in 1978 to 475 m.t. apparently in response to reduced effort. If the environment is indeed the principal determinant of the health of the English sole fishery, there would appear to be no need for regulatory measures, if no fishery restrictions are placed on other species.

Application of catch and effort data for the period 1963-78 (Table 9.1) to a modified Schaefer production model (Schnute, 1977) yields an estimate of 511 m.t. as the MSY, 1,675 hr as the optimum effort and 0.310 m.t./hr as the optimum CPUE. While considerable uncertainty attends the accuracy of these fishing parameters, the results suggest that, the yield in 1975-77 (25% qualified catches of 576 to 667 m.t.) was too high. If MSY is an appropriate management objective, the qualified catch (resulting from "directed" fishing effort) should be limited to less than 500 m.t. This figure is actually an under-estimate because the analysis was restricted to qualified catch and effort data only. Until the analysis taking into account the entire fishery (directed and incidental) can be made it is assumed that a figure of 600 m.t. will permit rebuilding of the stock to its MSY level.

Thus we are faced with conflicting conclusions regarding the need for management. Clearly, the role of recruitment versus the fishery in determining the abundance of English sole remains an open question in need of more thorough examination. Until this matter is satisfactorily resolved a conservative approach is desirable.

Regarding the Strait of Georgia stock(s) a preliminary assessment of stock conditions suggests that overfishing occurred from the early 1950's until the mid-1960's. Greatly reduced fishing during succeeding years appears to have resulted in an increase in the English sole abundance from the winter of 1973-74 onwards. Repetition of the earlier indications of overfishing should be avoided.

9.4 Recommendations

For the northern Hecate Strait stock, a TAC of 600 m.t. is recommended for 1979. For the Strait of Georgia stock a provisional TAC of 90 m.t. is recommended for the period October 1, 1978 to March 31, 1979. Nominal TAC's for areas in which the English sole is an incidental species are as follows: Area 3C -- 40 m.t.; Area 3D -- free fishing; Area 5A -- 10 m.t.; Area 5B -- 10 m.t.; and Area 5C -- 70 m.t.

Table 9.1 Statistics of the English sole fishery of northern Hecate Strait (Area 5D), 1945-78.

	Landing			LPUE		
	Catch (m.t.)			CPUE (m.t./hr)		Calculated effort in hrs.
Year	Canada	U.S.A.	Total	Old series	New series[a]	
1945	334	34	368	.620		594
1946	578	92	670	.448		1496
1947	247	203	450	.496		907
1948	747	248	995	.286		3479
1949	548	522	1295	.251		5159
1950	2145	461	2606	.423		6161
1951	605	387	992	.290		3421
1952	657	673	1330	.332		4006
1953	769	249	1018	.338		3012
1954	299	316	615	.255		2412
1955	445	418	863	.307		2811
1956	675	227	902	.394		2289
1957	250	284	534	.242		2207
1958	404	239	643	.287		2240
1959	545	356	901	.287		3139
1960	706	374	1080	.264		4091
1961	722	143	865	.254		3406
1962	402	35	437	.252		1734
1963	314	55	369	.240	.201	1836
1964	348	72	420	.232	.272	1544
1965	341	50	391		.246	1589
1966	329	9	338		.226	1496
1967	448	46	494		.303	1630
1968	629	4	633		.298	2124
1969	716	3	719		.371	1938
1970	916	3	919		.326	2819
1971	479	-	479		.186	2575
1972	353	-	353		.213	1657
1973	562	33	595		.329	1809
1974	458	-	458		.433	1058
1975	923	-	923		.485	1903
1976	943	-	943		.279	3380
1977	972	-	972		.283	3435
1978[b]	475+	-	475+			

[a]25% qualification, full year's data. Note that this differs from the qualifications used in computing CPUE for the period 1946-64 (20% qual. Jan.-June fishery by Class 3 trawlers only).

[b]Projected values.

Table 9.2. Parameters of modified Schaefer production model of the English sole stock and fishery in northern Hecate Strait.

Biological parameters:		
	Natural growth rate (r) (yr^{-1})	1.88
	Natural unfished equilibrium, k (m.t.)	1,086.00
Fishing parameters:		
	Catchability coefficient, q (hr^{-1})	5.62×10^{-4}
	MSY (m.t./yr)	511.00
	Optimum fishing effort (hr)	1,675.00
	Optimum CPUE (m.t./hr)	0.31
Variance parameters:		
	σ	0.45
	Failure index	0.74

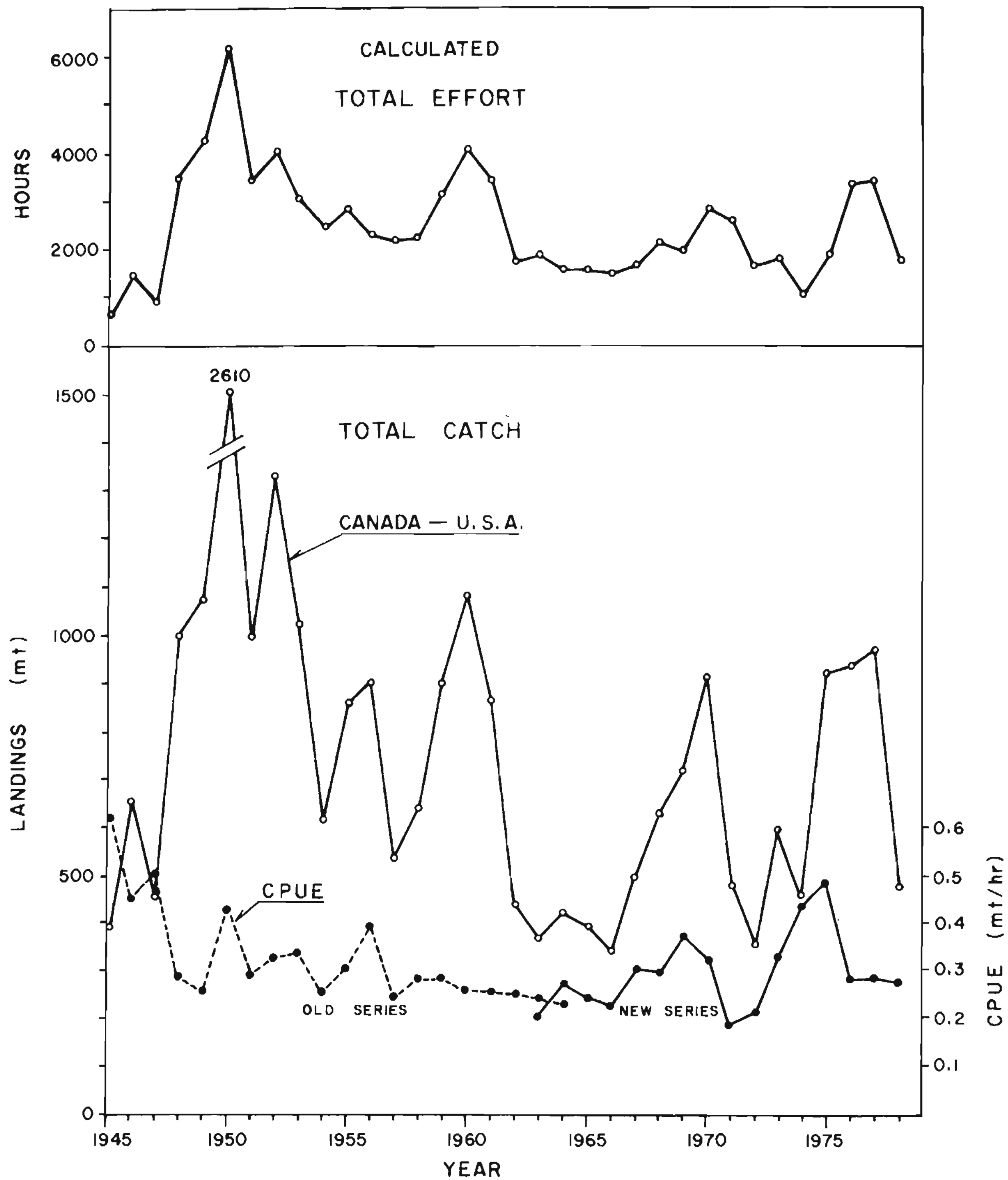

Fig. 9.1. Statistics of the English sole fishery in northern Hecate Strait (Area 5D).

10. PETRALE SOLE STOCK ASSESSMENT

10.1 Introduction

The petrale sole (*Eopsetta jordani*) is a southern flounder whose northern limit of commercial range occurs at the latitude of Dixon Entrance. It is the most valuable of trawl-caught flatfish and in 1948 accounted for 40% of all groundfish (including dogfish) landed by Canadian trawlers. From a peak of 6,200 m.t. in 1948 production by Canadian and U.S. trawlers operating in British Columbia waters followed a long downward trend to less than 500 m.t. in 1970. Since that time landings have averaged about 1,100 m.t. (Fig. 10.1).

10.2 Definition of stocks

As a result of extensive tagging Ketchen and Forrester (1966) identified two major stocks, one which spawned in deep water off the Washington coast (Cape Flattery Spit -- at the southern extremity of Area 3C) and spent its spring to autumn feeding period farther to the north in shallower water of the Canadian portion of Area 3C. This was called the "southern stock". The other, the "northern stock" spawned in deep water near the southern boundary of Area 3D adjacent to Estevan Point and spent its inshore months in Area 3D, Queen Charlotte Sound (Areas 5A and 5B) and Hecate Strait (Areas 5C and 5D).

In a more recent study, Pedersen (1975) confirmed the existence of the northern stock but concluded that the southern stock, during its summer, inshore period in Area 3C, consisted of a mixture of stocks which spawned from the Cape Flattery Spit south to the so-called Willapa Deep.

Further studies also suggest the existence of a separate northern stock of petrale sole of small magnitude, based on observations of catches by the Japanese deepwater trawl fishery off Dixon Entrance (1977), and the total non-return from tagging conducted in the shallow water of McIntyre Bay (Dixon Entrance) in 1954 (Ketchen, pers. comm.).

10.3 Production and abundance trends

10.3.1 The southern stock

In their study of the fishery from its inception in the late 1930's to 1962, Ketchen and Forrester (1966) noted that both catch and CPUE reached a peak in the late 1940's and thereafter followed an irregular decline, accompanied by a progressive increase in average size (and age) to about 1956. The latter phenomenon was associated with passage through the fishery of about 4 consecutively strong year-classes (1940-43) followed by a long succession of relatively weak year-classes. The relationship of year-class strength to environmental conditions, together with evidence that fishery on the strong year-classes had not been excessive in terms of yield per recruitment, led to the conclusion that success of the fishery during the 1940's and its subsequent decline were due largely to trends in recruitment, and further that recovery of the fishery would be dependent on the return of strong recruitment.

Subsequent to the Ketchen and Forrester analysis, a study of the Washington fishery by Pedersen (1975) arrived at essentially the same conclusion, viz. there appeared to be no need for regulation of the summer fishery, and the effects of winter fishing (on spawning concentrations) appeared to be overshadowed by environmentally induced variations in the production of recruits. This conclusion supports the Ketchen and Forrester hypothesis concerning the importance of recruitment but further verification is required. Granted there have been two surges in production since 1956, one centering around 1961 and the other around 1974 (Fig. 10.1), both may have been only partly the result of the exceptionally favourable (warm) years which produced the 1958-62 and 1970 year-classes.

10.3.2 The northern stock

Essentially the same events transpired in the fishery on the northern stock. The exceptionally high yield in 1948 consisted of the same strong 1940-43 year-classes. Subsequently production and CPUE collapsed, with the former to be arrested briefly in 1954 by discovery of the spawning ground in the Estevan Deep and by its heavy exploitation in 1957 by the U.S. fleet. Catch reached a low point in 1960 (400 m.t.) and subsequently recovered to 1,000 m.t. in 1966, slightly out of phase with the surge noted in the fishery on the southern stock. The second surge coincided with that in the south, but the 1974 peak amounted to less than 600 m.t.

10.4 Current stock condition

There is no question that the petrale stocks are at a relatively low level of abundance, especially in the case of the northern stock, catches from which barely reach 300 m.t. -- entirely incidental to other fisheries. The southern stock fares somewhat better (ca 1,000 m.t. per annum) and maintains its attractiveness only because of high market prices. Still, production is largely incidental to other fisheries (Pacific cod and lingcod).

Although Ketchen and Forrester (1966) could determine no ill effects from the 1954-57 fishery on the spawning stock (and no parent-progency relationship), their case remains uncorroborated for lack of follow-up analysis. Without an up-dated examination of available data it is impossible to say whether catch limits and/or prohibition of fishing on spawning concentrations would restore the stocks to economically more attractive levels.

10.5 Recommendations

For that part of the so-called southern stock of petrale sole occurring in the Canadian portion of Area 3C, a TAC of 500 m.t. is recommended. In regard to the northern stock is recommended that a TAC of 100 m.t. be applied to the first three months of the calendar year. Thereafter in that area and in Areas 5A-5D throughout the year free fishing should be permitted.

Table 10.1. Canada-U.S. landings (m.t.) of petrale sole from southwest Vancouver Island (Area 3C) -- the area occupied by the "southern stock", 1942-77.

Year	Flattery Spit	Northern section Area 3C	Total Area 3C	Year	Flattery Spit	Northern section Area 3C	Total Area 3C
1942	?		1561	1960	233	746	979
1943	?		2264	1961	375	734	1109
1944	?		1489	1962	215	636	851
1945	?		718	1963	90	656	746
1946	?		906	1964	71	529	600
1947	?		627	1965	140	645	785
1948	?		1321	1966	118	508	626
1949	?		1178	1967	106	256	362
1950	?		854	1968	114	232	346
1951	?		794	1969	255	142	397
1952	?		948	1970	80	143	273
1953	?		748	1971	74	518	592
1954	?		664	1972	22	756	778
1955	?		415	1973	211	452	663
1956	40	520	560	1974	230	675	905
1957	9	612	621	1975	474	465	939
1958	19	494	513	1976	304	452	756
1959	33	939	972	1977	?	?	468

Table 10.2. Canada-U.S. landings (m.t.) of petrale sole from northwest Vancouver Island, Queen Charlotte Sound and Hecate Strait (Areas 3D, 5A-5B) -- the area occupied by the "northern stock", 1942-77.

Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total	Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total
1942	-	-	-	-	1960	93	212	120	425
1943	-	-	-	-	1961	277	171	102	550
1944	499	303	-	802	1962	295	343	165	803
1945	270	1535	193	1998	1963	202	537	82	821
1946	623	1258	494	2375	1964	183	421	163	767
1947	469	986	769	2224	1965	300	418	202	920
1948	943	920	3011	4874	1966	264	469	260	993
1949	316	429	1644	2390	1967	169	485	176	830
1950	694	569	700	1963	1968	293	266	137	696
1951	305	326	642	1273	1969	262	114	22	398
1952	265	305	574	1144	1970	136	56	22	214
1953	235	450	46	731	1971	127	97	55	280
1954	712	234	300	1237	1972	50	154	33	237
1955	452	462	94	1008	1973	197	211	24	432
1956	291	528	53	872	1974	196	283	14	493
1957	1320	333	216	1869	1975	234	156	27	417
1958	174	227	171	572	1976	153	132	30	315
1959	227	160	216	603	1977	58	73	24	155

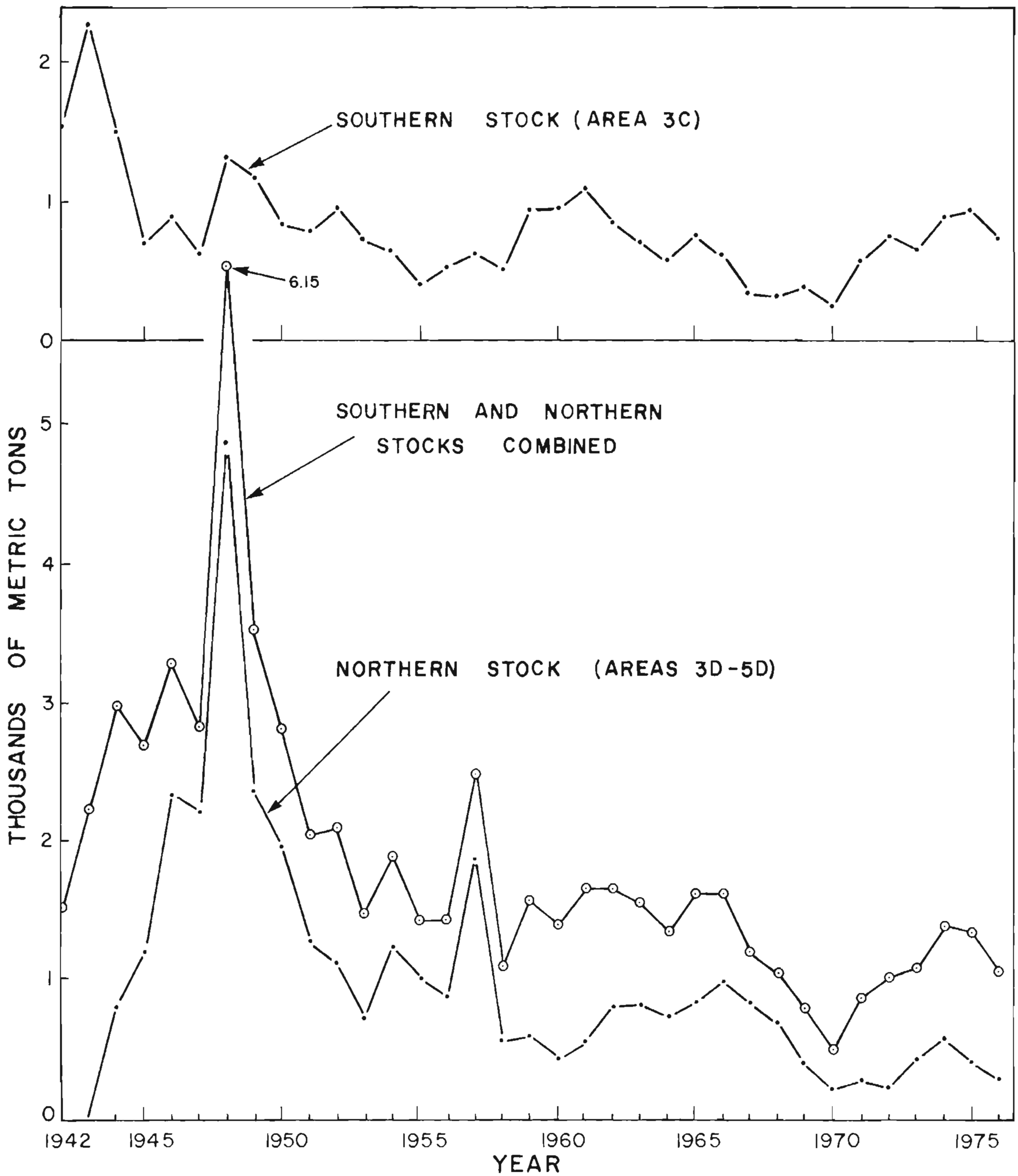

Fig. 10.1. Canada-U.S. landings of Petrale sole from grounds off the Canadian coast.

11. ARROWTOOTH FLOUNDER (TURBOT) STOCK ASSESSMENT

11.1 Introduction

The arrowtooth flounder or turbot (Atheresthes stomias) until about 1972 had never found a place on the foodfish market despite frequent attempts, dating from the early 1940's, to overcome processing problems. From those early days until about 1951, with the emergence of a market as minkfood, turbot were almost always avoided or discarded at sea.

The species has a ubiquitous distribution along the British Columbia coast and is encountered in quantity over a wide range of depths from surface waters to 500 fathoms (900 m). Little is known of the turbot's biology and life history and nothing is known of its movements. For present purposes it will be presumed that independent stocks occur in each of the major statistical areas along the coast.

11.2 Catch statistics

Significant landings of turbot as animal food began in 1951, rising rapidly to a peak of 2,700 m.t. in 1956 when most of the production originated from grounds off southwest Vancouver Island (Area 3C) and on the Cape Scott grounds (Area 5A) (Table 11.1). Thereafter landings fluctuated widely. Peaks occurring in 1961, 1967 and 1969 were primarily from Area 5A and northern Hecate Strait (Area 5D). A sharp drop in demand for animal food drove the catch to a low level between 1970 and 1972.

With the development of a foodfish market, production recovered rapidly and was still rising in 1978 at 2,100 m.t. Although the fishery expanded in all areas (except 4B), the main rise occurred in northern Hecate Strait (Area 5D) which accounted for more than half of landings over the 7-year period (Table 11.2). Production from that area reached a peak of 1,170 m.t. in 1978, but still appears to be primarily a function of fishing effort.

11.3 Condition of the resource

There is nothing to indicate that the "stocks" of turbot are as yet fully utilized. It is not yet known to what degree fishing of turbot can be fished selectively, avoiding incidental catches of other species for which catch limitations are, or may be, required. Accordingly, unrestricted development of the turbot fishery is deemed undesirable.

11.4 Recommendation

The following TAC's are recommended: Area 4B -- 50 m.t; Area 3C -- 200 m.t.; Area 3D -- 200 m.t.; Areas 5A and 5B -- 500 m.t.; Area 5C -- 100 m.t.; Area 5D -- 2,000 m.t.; Area 5E -- 100 m.t.

Table 11.1 Historical record of landings of arrowtooth flounder by Canadian trawlers operating along the British Columbia coast. (Figures in metric tons).

	Landing			Landing	
Year	Animal food	Foodfish	Year	Animal food	Foodfish
1948	2	-	1964	830	-
1949	20	-	1965	578	-
1950	9	-	1966	687	-
1951	102	-	1967	1,675	-
1952	429	-	1968	933	-
1953	434	-	1969	2,017	-
1954	486	-	1970	323	4
1955	1,521	-	1971	106	-
1956	2,712	-	1972	172	130
1957	704	-	1973	36	539
1958	399	-	1974	-	363
1959	889	-	1975	-	953
1960	1,125	-	1976	-	1,312
1961	2,362	-	1977	-	1,591
1962	1,482	-	1978	-	2,144
1963	669				

Table 11.2. Statistics of the foodfish fishery for arrowtooth flounder (turbot) in the Canadian zone. (Catch in m. tons excluding discards; effort in hours).*

	Area 4B		Area 3C		Area 3D		Area 5A		Area 5B		Area 5C		Area 5D		Total	
Year	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort
1972	50	39	5	60	-	-	37	128	-	-	tr	10	210	1717	303	1954
1973	14	31	47	17	tr	8	37	140	21	8	20	166	437	1699	576	2061
1974	4	63	19	359	-	-	9	237	62	436	18	315	251	1525	363	2935
1975	18	228	89	196	10	1	147	246	58	342	40	108	591	2437	953	3558
1976	3	183	122	480	10	30	40	300	86	115	69	130	982	3155	1312	4393
1977	5	459	281	1427	5	27	151	214	98	664	34	5227	989	163	1563?	8383
1978	15		207		4		414		260		77		1167		2144	

tr = Effort where turbot recorded in landings.

12. WALLEYE POLLOCK STOCK ASSESSMENT

12.1 Introduction

Walleye pollock (*Theragra chalcogramma*) was not harvested in quantity for human food by Canadians until 1976 (Fig. 12.1). During 1955-1959, 145-572 m.t. were landed annually by trawl (mostly from the Strait of Georgia) to supply food for fur-bearing animals (Table 12.1). Except for this brief early prominence, pollock were generally discarded or avoided by Canadian trawlers, and annual catches were less than 300 m.t. from 1945 to 1975. Foreign trawlers have encountered and processed some pollock on the British Columbia coast, but abundant stocks in the Bering Sea, western Pacific and Gulf of Alaska have produced most of the supply of this species for Asian markets.

Canadian fishermen and processors started to exploit B.C. pollock stocks in quantity for human food during 1976, when 1,320 m.t. were landed for fillets and blocks. Since the demand for white fish flesh exceeds production of traditional species such as Pacific cod and rockfish, which have been heavily exploited, the pollock fishery has continued to develop and landings have increased. By early November 1978, a record 2,102 m.t.[17] were landed from Canadian vessels.

In February 1978, a small amount of maturing pollock was landed in Prince Rupert and Vancouver during an experimental roe fishery. Good quality roe was produced for Japanese buyers. An intensive pollock roe fishery (February-March) could develop in B.C. to supply Japan, where more pollock roe is consumed than herring and salmon roe together.

12.2 Definition of stocks

Boundaries that separate stocks of pollock have not been defined in B.C. coastal waters on the basis of migratory patterns and genetic isolation, but circumstantial evidence of growth rate differences and separate spawning areas suggest that there are several different populations. For present purposes it is presumed that pollock inhabiting the Strait of Georgia and Juan de Fuca Strait (Area 4B) constitute a single stock, separate from one occupying waters off the west coast of Vancouver Island (Areas 3C and 3D). A third discrete stock could occupy Queen Charlotte Sound and southern Hecate Strait (Areas 5A, 5B and 5C), while a fourth stock is presumed to inhabit northern Hecate Strait and Dixon Entrance (Area 5D). Concentrations of pollock are known to occur in the mainland inlets adjoining Areas 4B, 5A-5D and in the inlets of the west coast of Vancouver Island. Their relationship to the stocks occurring in open waters is unknown and for the present will be excluded from discussion of stock size. Small quantities of pollock have been encountered in the

---

[17] Preliminary estimate.

inlets and along the open coast of the west coast of the Queen Charlotte Islands (Area 5E). They could consititute a separate stock from that in Dixon Entrance. If pollock are found to be more or less migratory than is now believed, the areas as defined above will have to be pooled or further subdivided for eventual management purposes.

12.3 Pollock biomass estimation

Hydroacoustic survey techniques have been used to obtain preliminary estimates of the amount of pollock in three of the five stock zones, namely Georgia Strait, the southwest coast of Vancouver Island, and Dixon Entrance (Taylor, MS). These estimates are summarized in Table 12.2 and discussed in relation to commercial catches and known biology in the sections that follow. Stock sizes have been estimated for the two other regions (5A-B-C, and 5E) by comparing catch rates of pollock with other species during both commercial operations and biological surveys, and by extrapolating from the results of hydroacoustic surveys carried out elsewhere on the coast.

12.3.1 Sustainable yields

Preliminary studies indicate that pollock grow rapidly to commercial size and experience a high natural mortality ($M = 0.5\text{-}1.0$) as adults. Such fish can be exploited fairly heavily in relation to their virgin biomass.

From estimates of virgin biomass (B_o) and M, an estimate of maximum sustainable yield can be made from Gulland's formula $Y_{max} = XMB_o$, as described by Troadec (1978). Theoretically, $X = .5$ (explained by Alverson and Pereyra 1969) however in practice it is safer to assume $X = .3$, since the fishable stock is probably smaller than the surveyed stock in all areas studied. The lower value will also allow for natural fluctuations in the abundance of pollock, which could be a significant problem in managing this species. From theory, the Schaeffer model predicts

$$(0.5)(.5)B_o \leq MSY \leq (1.0)(.5)B_o \qquad \text{Eqn. 1}$$

Since it has proved difficult to achieve MSY in other fisheries, the pollock TAC was estimated for each region from the formula

$$TAC = (0.6)(0.3)B_o \qquad \text{Eqn. 2}$$

The virgin biomass was assumed to be the biomass estimated for each area, since very little pollock was removed by fishing for several years prior to the surveys. Preliminary ageing results suggest that natural mortality is about 30-65% annually ($M = .5\text{-}1.0$). The TACs listed below are conservatively based on $M = .6$, but studies now in progress could demonstrate that natural mortality is higher.

12.3.2 Georgia Strait and Juan de Fuca Strait (Area 4B)

Most B.C. pollock landings during the small 1951-61 fishery for pollock (Fig. 12.1) originated in Georgia Strait (Table 12.1). Bottom trawling by the commercial fleet at that time revealed concentrations of pollock among the Gulf Islands, particularly in Swanson Channel and Plumper Sound. About 51% (200 m.t.) of the mean annual landing when the fishery was at its height (1955-57) was caught among the islands, and another 16% (60 m.t.) originated in the open strait between Point Roberts and Active Pass. About 3% (11 m.t.) came from Juan de Fuca Strait. The remainder was caught on grounds along the east coast of Vancouver Island, north of Nanaimo. Very little pollock was landed from Georgia Strait in 1976 and 1977, but during 1978 the Gulf Island channels and open southern strait were again explored by commercial trawlers using both bottom and midwater trawls. Production to November 3 was 286 m.t. At the same time, U.S. vessels began fishing in the spawning area along the Canada-U.S. border and landed more than 500 m.t.

Results of five hydroacoustic surveys during January, February, and June 1975 and January and March 1976 implied that as much as 25,000 m.t. of pollock could have occupied the midwater of Georgia Strait during February and March period in each year (Taylor,MS). As shown in Table 12.2, however, migration out of the survey area seems to occur at other times of the year (i.e. from June until January [Taylor and Barner 1976a, b]). Research trawling on bottom in March 1975 (Weir et al. 1978) suggested that as much as say 10% of the total stock might have been on-bottom and missed by hydroacoustic survey. Concentrations of pollock have also been found in Swanson Channel, Juan de Fuca Strait, and Jervis Inlet -- areas which were not covered by the surveys. For these reasons, and because so little pollock was harvested from Georgia Strait prior to and during the surveys, the virgin biomass of pollock in Area 4B during 1975-76 is estimated to be 22,000 m.t.

12.3.2.1 Recommendation

A TAC of 4,000 m.t. is recommended for Area 4B.

12.3.3 West coast Vancouver Island (Areas 3C and 3D)

There has never been a significant commercial fishery for walleye pollock off the west coast of Vancouver Island. Results of research trawl surveys show that pollock appear irregularly in these waters, and are available to both midwater and bottom trawls, but catch rates were generally low. Pollock ranked as high as third in total catch behind herring and hake or dogfish during only two of nine midwater hydroacoustic surveys (1973-1977), accounting for 15% of the catch by weight. Pollock were less prominent during other surveys, ranking fourth to seventh, and not present at all during one period (August 1975). For all cruises combined, pollock comprised 5.5% of the total catch (Barner and Taylor 1977, 1978a and 1978b). Information on the foreign fishery for hake which usually occurs during late summer and autumn off the southwest coast of Vancouver Island suggests that the incidental catch of pollock in that fishery is small.

Five hydroacoustic surveys carried out in the southern half of the Area 3C during 1974-1976 suggested that the biomass of pollock was about 500-2,000 m.t. (Table 12.2), or 0.4-5.2% of the total biomass of pelagic and semi-pelagic fish in the area surveyed. These surveys generally included only the continental shelf from La Pérouse Bank to Juan de Fuca Canyon. Pollock were more rare when the trawl survey was extended north of Amphitrite Point, which is consistent with the experience of commercial trawlers.

In summary, pollock appear to be less abundant off the west coast of Vancouver Island than in the Strait of Georgia. Using 2,000 m.t. from the hydroacoustic surveys as a biomass estimate for about 40% of the region but considering the apparent scarcity of pollock farther to the north, the total adult biomass may be about 3,000 m.t.

12.3.3.1 <u>Recommendation</u>

A TAC of 500 m.t. is recommended for Areas 3C and 3D combined.

12.3.4 <u>Queen Charlotte Sound and southern Hecate Strait (Areas 5A-5C)</u>

A large proportion of the 1976-1978 Canadian pollock landing originated in this region (Table 12.1), but catch data from both research cruises and commercial operations do not yet indicate a predictable pattern of seasonal and geographical distribution. Landings peaked in September and October during 1976 and 1977 (Table 12.3), but since pollock were not searched for with the same intensity at other times and locations, then no statement can be made regarding the possibility that these fish migrate into neighbouring areas during the rest of the year.

If the abundance of pollock in Areas 5A-5C is estimated by extrapolating from hydroacoustic data collected in Areas 4A, 3C-D and 5D, namely from information on mean biomass density per volume of water, one arrives at an average of 91,000 m.t. (range 4,000 to 208,000 m.t.). However, numerous aspects of the analytical method lead to overestimation. Taking these into consideration as far as possible, we are left with an informed guess of 5,000 to 30,000 m.t., with an average of perhaps 7,000 m.t.

12.3.4.1 <u>Recommendation</u>

A TAC of 1,300 m.t. is recommended for Areas 5A, 5B, and 5C.

12.3.5 <u>Dixon Entrance and northern Hecate Strait (Area 5D)</u>

Concentrations of pollock along the McIntyre Bay-Two Peaks-Butterworth Slope, at the head of Dixon Entrance Fig. 4.5, annually produced 47-87% of the 1976-78 Canadian pollock landings (Table 12.1). Landings have also been made farther to the south from the White Rocks ground in central Hecate Strait. Pollock landed from this Area are desirable because they are large, which makes them relatively easy to fillet, and because the grounds in this Area are only 3-6 hr running time from the port of Prince Rupert.

Although the catch data prove that commercial concentrations of pollock are available throughout much of Area 5D, and abundant on the Two Peaks grounds, it is not yet clear how pollock might move within, to, or from the region. The fact that research cruise efforts failed in March 1978 to locate concentrations of pollock on grounds where there was successful commercial fishing during January and February, indicates that spawning could have occurred elsewhere (Thompson et al.,MS). In May, commercial landings from Two Peaks and Butterworth increased again to the February level (460 m.t.) and then decreased to near zero through August (Table 12.4), suggesting that the stock had moved elsewhere, or been fished to commercial extinction, or that trawlers had switched to more valuable species. In September a research trawler found small quantities of pollock on the Two Peaks, but the catches were mixed with large amounts of species that had little market value, which fact could explain low landings at that time. Total removal (including discards) in Area 5D in 1978 to November 3 was 1,607 m.t.

During July 1978 a hydroacoustic and fishing survey of midwater fish species was carried out in Dixon Entrance, Chatham Sound, and northern Hecate Strait as far south as White Rocks (Taylor et al., MS). Pollock dominated, accounting for 64% or 11,800 m.t. of the estimated total fish biomass. By assuming from trawl data that about 2% of the stock was close enough to the bottom to be missed during hydroacoustic sounding on the Two Peaks, and about 100% were on bottom in the Butterworth gully, then the standing stock of pollock in Area 5D could have been about 13,000 m.t. This estimate accounts for fish scattered throughout the region and therefore includes pollock that were not concentrated enough to be fished commercially.

12.3.5.1 Recommendation

A TAC of 2300 m.t. is recommended for Area 5D.

12.3.6 West coast Queen Charlotte Islands (Area 5E)

Very little pollock has been landed from Area 5E (Table 12.1), but small commercial and research catches from the inlets and narrow continental shelf in that area demonstrate that adult and juvenile pollock are at least present there. A token 1,000 m.t. could be added to the B.C. estimate to take account of this presumed separate stock.

12.3.6.1 Recommendation

A TAC of 200 m.t. is recommended for the west coast of the Queen Charlotte Islands (Area 5E).

12.3.7 Inlets adjacent to all areas

Adult and juvenile pollock have been encountered in the midwater by trawlers and at the surface by purse-seiners in nearly every inlet that has been examined on the B.C. coast. Commercial trawlers have had limited success because of low concentrations, but salmon seiners have reported high pollock concentrations near the surface during June and July on the west coast of Vancouver Island, and along the northern mainland coast. No attempt has been made to estimate the abundance of pollock in the inlets, and nothing is known about the relationship between these fish and offshore stocks.

12.3.8 Summary of biomass assessment

The total abundance of pollock in B.C. coastal waters may be of the order of 46,000 m.t. (Table 12.2). The validity of these estimates can only be determined by continued research, since they were derived from statistics describing a fishery that began only 2 years ago, and from a hydroacoustic survey method that has not been fully developed. Each estimate could conceivably be placed within a range that varies at least as much as 50%, and this uncertainty must be recognized if catch limits are to be imposed in the near future. Furthermore, not all of the estimated total biomass is likely to be available to the fishery.

For the whole B.C. coast maximum sustained yield of pollock could be 7,000-23,000 m.t. over the estimated range of $M = 0.5\text{-}1.0$. Considering that the present estimate of B_o could vary 30% from 46,000 m.t., the TAC could be as low as 5,000 m.t., or as high as 30,000 m.t., if the whole biomass is fishable (which is unlikely).

Table 12.1. Five-yr average pollock landings[a] by Canada in m.t. round weight, by arbitrary clusters of minor areas.

Major areas	4B		3C and 3D	5A, 5B and 5C		5D	5E	
Date	Georgia Strait	Juan de Fuca Strait	West Coast Vancouver Island	Queen Charlotte Sound	South Hecate Strait	Dixon Entrance-N. Hecate Strait	West Coast Queen Charlotte Islands	Total
1952-56	253	3	14	7	0	2	0	279
1957-61	176	12	5	3	0.05	8	0	204
1962-66	13	18	5	3	0.08	22	0	61
1967-71	22	19	4	8	2	23	0	78
1972-76	17	6	1	151	40	152	0.04	367
(1976)	3	23	6	469	193	627	0.2	1321
(1977)	22	30	9	235	16	569	12	893
(1978)[b]	(323)	(-)	(26)	(234)	(29)	(1607)	(18)	(2237)
Minor areas	13-18,29	19,20	21-27	8-9,11-12	2,6-7	1,3-5	31,34-35	-

[a]Discards included in 1978 data.

[b]November 3, 1978 (preliminary), Juan de Fuca included in Georgia Strait.

Table 12.2. Estimates of walleye pollock biomass in arbitrarily defined regions of B.C. coastal waters.

Region	Date	Biomass (m.t. round weight) — Method of estimation: Hydroacoustics	Swept volume	Total guess	Survey area
Georgia Strait	Jan/75	8,000			-excluding Gulf Islands, Juan de Fuca, and inlets.
	Feb/75	22,500			
	June/75	6,400			
	Jan/76	3,200			
	Mar/76	24,500			
Georgia Strait (Halibut Bank)	Mar/75		9,400 (Cass et al., 1978)		-region of high density only.
Dixon Entrance Chatham Sound N. Hecate Strait	July/78	11,800			
S.W. Coast Vancouver Island	Aug/74	540			
	Oct/74	1,500			
	Sept/75	1,800			
	Nov/75	1,950			
	Nov/76	500			
Juan de Fuca and Gulf Islands				3,000	
Queen Charlotte Sound and S. Hecate Strait (major areas 5A, 5B, and 5C)				5,000-30,000(15,000)	

Table 12.2 (cont'd)

Region	Date	Biomass (m.t. round weight) — Method of estimation: Hydroacoustics	Swept volume	Total guess	Survey area
Major area 4B				22,000	
Major areas 3C, 3D				3,000	
Major areas 5A, 5B, 5C				7,000	
Major area 5D				13,000	
Major area 5E				1,000	
Total				46,000	

Table 12.3. Bi-monthly walleye pollock Canadian landings in major area 5A, 5B and 5C (m.t., round weight).

Region	Annual period	Pollock landing (m.t. round weight) Bimonthly period Jan.-Feb.	March-April	May-June	July-August	September-October
Queen Charlotte Sound (Major areas 5A, 5B)	1972-76	0	0	3.9	11.2	124.8
	1976	0	0	10.3	41.3	369.0
	1977	0	0	15.5	35.8	180.1
	1978[a]	.02	0	42.6	28.7	131.3
S. Hecate Strait (Major area 5C)	1972-76	0.4	0.2	3.8	0.6	30.6
	1976	0.3	0.6	18.6	1.9	150.3
	1977	1.2	0.5	12.4	0	1.3
	1978[a]	1.4	0	0.9	0.4	0.2

Table 12.3 (cont'd)

Region	Annual period	Pollock landing (m.t. round weight)			
		Bimonthly period			
		November-December	Total pollock	Total all species	Pollock (% all species)
Queen Charlotte Sound (Major areas 5A , 5B)	1972-76	10.7	150.6	4,592	3.3
	1976	48.7	469.3	6,304	7.4
	1977	3.6	234.9	5,147	4.6
	1978[a]	n.a.	202.6	8,651	2.3
S. Hecate Strait (5C)	1972-76	4.3	39.8	2,052	1.9
	1976	21.3	193.0	2,444	7.9
	1977	0.2	15.6	1,361	1.1
	1978[a]	n.a.	2.9	1,901	0.2

[a]Preliminary estimates, discards not included, as of November 1978.

Table 12.4 Canadian walleye pollock catch and C.P.U.E. in major areas 1 and 8 during 1978. (Preliminary estimates as of September 12, 1978).

	Month (1978)							
	January	February	March	April	May	June	July	August
	Strait of Georgia (major area 4A)							
Landing (m.t.)	49.01	169.61	103.42	8.62	0.00	0.23	3.40	0.00
Discards (m.t.)	6.80	9.30	0	0.05	0.00	4.54	0.45	0.00
Catch (m.t.)	55.81	178.91	103.42	8.67	0.00	4.77	3.85	0.00
Species effort (hr)	477.2	698.25	55.45	42.00	0.00	53.25	55.00	0.00
C.P.U.E. (m.t./hr)	0.10	0.24	1.87	0.21	0	0.004	0.06	0
Total effort[a] (hr)	847.25	860.75	147.10	103.25	21.00	169.25	59.75	18.00
Total catch[a] (m.t.)	389.88	437.16	157.78	38.15	1.07	130.35	49.70	8.07
	Dixon Entrance - N. Hecate Strait (major area 5D)							
Landing (m.t.)	117.66	451.42	0	21.67	464.13	313.05	54.14	44.77
Discards (m.t.)	0.00	0.00	0	1.04	0.00	14.65	0.00	1.59
Catch (m.t.)	117.66	451.42	0	22.71	464.13	327.70	54.14	44.77
Species effort (hr)	444.50	673.95	0	465.96	743.72	914.55	336.20	581.84
C.P.U.E. (m.t./hr)	0.26	0.67	0	0.05	0.62	0.34	0.16	0.08
Total effort[a] (hr)	651.30	835.20	0	480.19	1242.32	922.55	643.70	599.24
Total catch[a] (m.t.)	438.70	775.49	0	629.86	1149.33	1195.91	714.92	590.97

[a] all species.

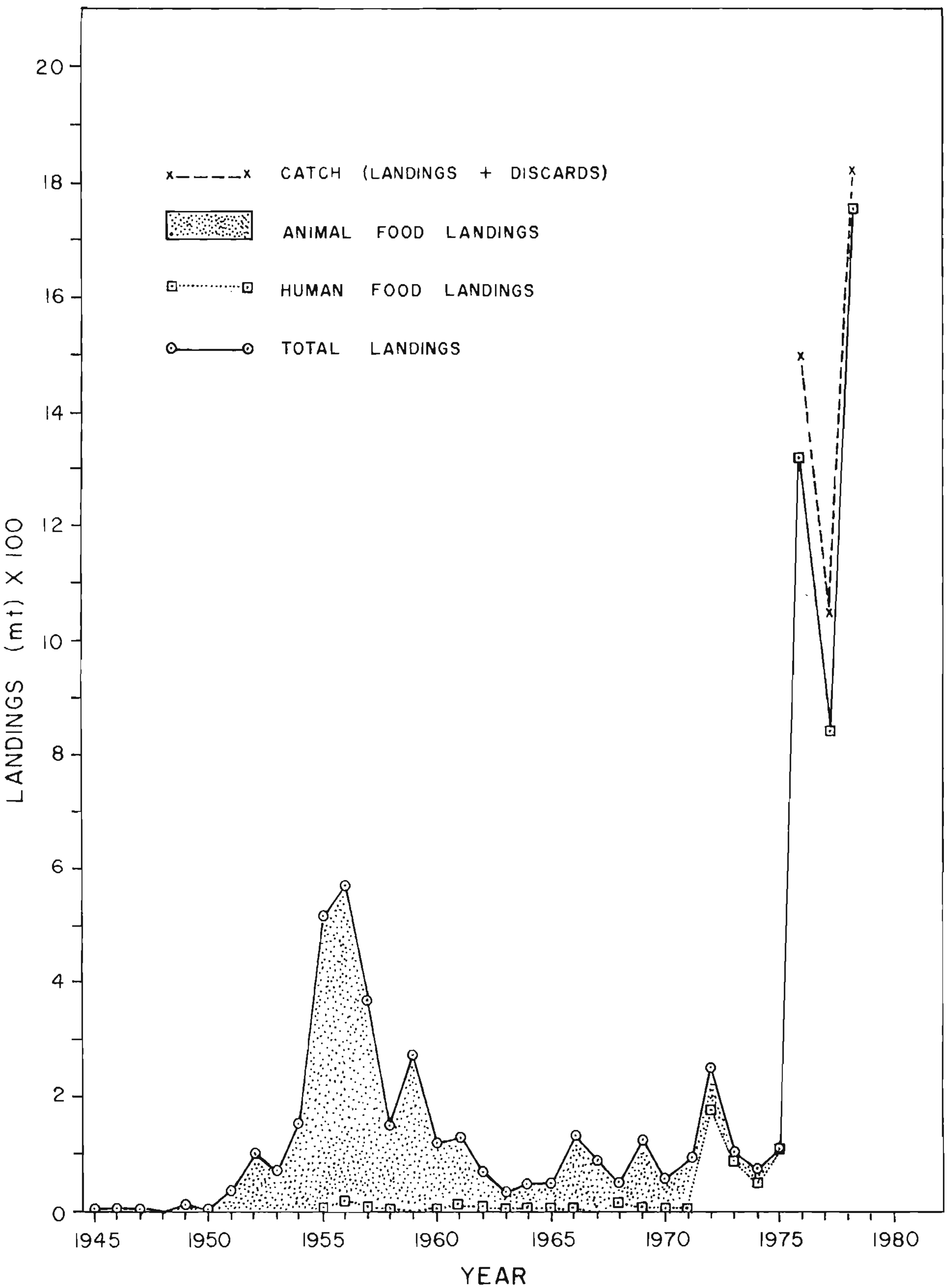

Fig.12.1 Annual Canadian trawl landings of walleye pollock. Landings estimated to July 23 in 1978. Landings in round weight.

13. PACIFIC HAKE STOCK ASSESSMENT

13.1 Introduction

The Pacific hake is not exploited domestically in waters adjacent to British Columbia and hence there are no fishery records to aid in stock assessment.

Current knowledge suggests there are at least two stocks, one donfined to the Strait of Georgia (Area 4B) and the other, large migratory population which inhabits waters from southern California to British Columbia. The latter is exploited by foreign fleets mainly in the Oregon-Washington area, but during late summer and fall the fishery frequently shifts northward to the Canadian portion of Area 3C off southwest Vancouver Island, attracted there apparently by the larger (older) elements of the stock which are believed to make longer seasonal migrations than the younger elements. Spawning occurs off southern California in winter months, but the recent discovery of age 1 and 2 hake on grounds in Area 3C indicates that there must be a local stock in or adjacent to Canadian offshore waters. Thus, it is quite possible that not all of the fish taken by foreign vessels are necessarily of United States origin.

13.2 Assessment of the Strait of Georgia stock

Results of hydroacoustic surveying suggest that the total adult biomass may be as large as 120,000 m.t. (Taylor, MS). Preliminary investigations of age composition yields an estimate of 0.63 as the instantaneous total mortality rate (Z), which, in the absence of a fishery would be equivalent to M, the instantaneous rate of natural mortality. Using the Gulland (1970) formula

$$MSY = 0.5 \times M \times B$$

where B is the unexploited biomass, the estimate of MSY is 38,000 m.t.

Intuitively, such a high yield does not seem probable for the Strait of Georgia and it is quite possible that some or all of the parameters in the estimate are incorrect. If a fishery develops it is proposed that in addition to monitoring catch rates and catch composition a more comprehensive hydroacoustic stock assessment be undertaken. In the absence of a commercial fishery, it may be several years before a re-assessment of the hydroacoustic biomass estimates can be made.

13.2.1 Recommendation

While the MSY estimate is 38,000 m.t., it is recommended that the TAC not exceed 10,000 m.t. until a reassessment of the biomass estimates can be made.

13.3 Assessment of the offshore stock

Currently assessment of the offshore stock and its sustainable yield is done entirely by U.S. (NMFS) scientists, using various techniques including the aforementioned biomass approach. In recent years the allowable biological yield has been estimated to be about 160,000 m.t., but latest investigations suggest it could be as high as 200,000 m.t.

With the coming of extended fisheries jurisdiction, Canadian management authorities somewhat arbitrarily estimated the total allowable catch (TAC) for the Canadian zone to be 20% of the TAC for the entire offshore area. The outcome of Canada-U.S. negotiations concerning "transboundary" stocks is uncertain, but the current U.S. management view is that the TAC in the Canadian zone should be no more than 10 to 15% of the total. In any event, there is a recognized need for scientific assessment of the problem. It is known that the proportion of the resource which moves into the Canadian zone is not necessarily reflected by the rate of uptake or amount caught by foreign vessels. Forthermore, there is some evidence to suggest that the proportion of the stock present in the Canadian zone varies from year to year because of variations in feeding conditions and/or oceanographic conditions. In addition, there is the new information mentioned previously concerning the presence in Area 3C (and possibly further north) of a local stock or stocks of unknown magnitude. These factors must be taken into consideration in establishing TAC's for the Canadian zone.

13.3.1 Recommendation

The TAC for hake in the Canadian zone could be as high as 35,000 m.t.

14. BUTTER SOLE STOCK ASSESSMENT

14.1 Introduction

The butter sole (Isopsetta isolepis) exists in abundance in the shallow water of the northern Hecate Strait flats. Minor quntities are to be found off the west coast of Vancouver Island. During the winter months, adults migrate to Skidegate Inlet where they traverse a shallow bar and descent into depths of ca 30 fm where they spawn. During at least one severely cold winter (1949-50), the fish apparently were unable to cross the bar, and spawning presumably occurred in the open waters of the Strait.

The main site of the fishery has normally been in Skidegate Inlet, but in the early days of the fishery (mid 1940's) large catches were made on and around Dogfish Bank, close to Rose Spit on Graham Island. The species was first used for human food, but by 1960 most of the production was diverted to animal food presumably because of the high cost of processing. (The butter sole is a thin flatfish with a relatively low fillet recovery-to-body-weight ratio.)

14.2 Catch statistics

Production of butter sole for human consumption reached a peak of 1,690 m.t. in 1952, but has always varied substantially because of market conditions or variable availability induced by such environmental conditions as those described above. (Table 14.1). During 1955-72, when the butter sole was sold in part for human consumption, but more often as animal food, landings ranged from about 200-900 m.t. The species has been essentially unfished since 1972 because of the collapse of the animal food market and because it no longer finds any demand as human food.

14.3 Stock condition

In the early days of the fishery (prior to 1953) there was concern that the butter sole could be easily overfished because of its high vulnerability to capture on the Skidegate spawning ground. However, the impact of fishing was never clearly demonstrated. High estimates of Z, instantaneous total mortality rate for females (1.36-1.68) were attributed largely to a high natural death rate (Kutty, 1963). Since the stock has been essentially unfished since 1972, it has presumably returned to a primitive level of abundance.

14.4 Recommendations

No restrictions need be placed on fishing for butter sole as long as it takes place in Skidegate Inlet. There, the stock can be fished to the exclusion of all other commercially valuable species. However, unrestricted fishing on the summer feeding grounds could result in large incidental catches of juvenile rock sole and other species which may require conservation measures.

Table 14.1 Landings (m.t.) of butter sole in British Columbia, 1945-78.

Year	Food-fish	Animal food	Total	Year	Food-fish	Animal food	Total
1945	658	-	658	1962	35	877	912
1946	699	-	699	1963	52	310	362
1947	114	-	114	1964	93	236	329
1948	295	-	295	1965	118	250	368
1949	13	-	13	1966	158	579	737
1950	5	-	5	1967	335	477	812
1951	827	-	827	1968	188	523	711
1952	1686	-	1686	1969	174	231	405
1953	170	-	170	1970	573	126	699
1954	96	21	117	1971	199	27	226
1955	213	121	334	1972	122	56	178
1956	314	351	665	1973	10	3	13
1957	586	69	655	1974	tr	-	tr
1958	227	219	446	1975	-	-	-
1959	96	108	204	1976	-	-	-
1960	46	583	629	1977	-	-	-
1961	15	324	339	1978	-	-	-

15. ALBACORE STOCK ASSESSMENT

15.1 Introduction

The albacore (*Thunnus alalunga*) is a wide-ranging pelagic species of trans-oceanic distribution in the tropical and sub-tropical waters of the North Pacific. While occurring for the most part in the international sea, it makes seasonal intrusions at various stages of its life-history into the 200-mile zones of Japan, Mexico, U.S.A., and Canada.

15.2 Summary of life history

The albacore spawns in moderately deep water across the breadth of the North Pacific in a band lying between 0° and 10°N. To judge from egg and larval surveys, most of the spawning occurs in the Western Pacific. In the first 2 years there is a seasonal south to north movement to the "front" (ca. 35°N) and south again in the fall. Between Ages 2 and 3 an east and west movement becomes superimposed on the seasonal south to north movement and is manifested by the annual arrival of juveniles off the North American coast in spring and summer. Those which make their landfall south of San Francisco to Baja California remain throughout the summer and then move southwestward to areas unknown.

Albacore making their landfall north of San Francisco move northward along the Oregon and Washington coasts, and, depending on presence of 14°-16°C water, extend northward off British Columbia to the Queen Charlottes (ca. 54°N). By early autumn the migration shifts south and then westward. Tagging suggests that this northern component traverses the Pacific to the southern coastal waters of Japan (ca. 35°N). By this time the older fish in this highly migratory component of juveniles reach maturity and presumably move southeastward to the 0°-10°N belt of latitude where they proceed to spawn. Behaviour from first spawning through the remainder of adult life is not clearly understood, but on the basis of information on the Japanese fishery their distribution is confined mainly to the west of Hawaii.

15.3 Definition of stocks

There is still some doubt as to the number of stocks present in the North Pacific. The current view is that there is one major stock in the triangle joining San Francisco, Graham Island and southern Honshu. Although some of the juvenile albacore which appear to the south of San Francisco eventually reappear in the fishery close to Japan (6% of tag recaptures), the majority apparently move southwestward from the North American coast and escape further fishing during the remainder of their life.

Thus present information suggests there are at least two stocks in the North Pacific -- one which is vulnerable to exploitation by both the North American and Japanese fisheries and one vulnerable only as juveniles to the North American fishery. This description is perhaps over-simplified. With the advance of knowledge, particularly about age and growth, it is becoming increasingly apparent that the subject of stock definition is extremely complex.

15.4 Catch and effort statistics

Table 15.1 shows the 1961-77 distribution of albacore catch by country and gear.[18] From an average of 55,000 m.t. in 1961-65, total production rose fairly sharply surpassing the 100,000 m.t. level during the early 1970's. The catch reached an all-time high of 122,000 m.t. in 1976, but fell to less than one-half that amount in 1977, largely because of a relative failure in the Japanese fishery which is explained in part by the failure of the oceanographic "front" to develop in that year directly to the east of southern Honshu. Preliminary information on the 1978 Japanese fishery indicates a higher production than in 1977 but still far below the 1971-76 average.

In contrast, the North American fishery from 1961 to 1976 showed no trend, averaging about 22,000 m.t., with a peak of 31,000 m.t. in 1973. The catch in 1977 was the lowest since 1961 being less than 12,000 m.t., but preliminary information on the 1978 fishery indicates that production will be near the 22,000 m.t. average. The poor catch of 1977 was attributed to rough seas and unfavourable oceanographic conditions, including poorer than normal upwelling along the Pacific coast.

The Canadian fishery, consisting largely of vessels which do not venture south to more productive latitudes, has been highly erratic, with catches ranging from virtually 0 (from 1953 to 1965) to a peak of 3,600 m.t. in 1972. Since that time production has fallen to very low levels being only 53 m.t. in 1977 and even less in 1978. Again, oceanographic conditions have been the dominant factor in determining the size of the catch in recent years. However, other factors such as poor prices, and the frequently more attractive troll fishery for salmon, have accounted for some of the historical ups and downs in the Canadian fishery.

Statistics of CPUE are provided in Table 15.2. At the 1978 meeting of the international Working Group on Albacore it was apparent that there are many reservations concerning CPUE as a measure of abundance, particularly in the Japanese fishery. There, the major problem is one of defining effective fishing effort because the fishery for albacore is not clearly distinct from those for other tunas such as bonito and skip-jack. Problems which plague interpretation of North American CPUE include year-to-year differences in distribution and size of schools, the presence or absence of upwelling, strengths

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[18] Statistical data contained in the present report have been extracted from the second annual report of an international Working Group on Albacore, represented by Japan, U.S.A. and Canada at its 1978 meeting.

of the frontal system, bad weather, etc.

15.5 State of the albacore resource

Japanese scientists have developed several elaborate schemes to measure effective fishing effort for albacore. Applying these statistics and those of catch to a general production model, they conclude that the present catch is at or near MSY, variously estimated to be between 95,000 and 125,000 m.t. (Fig. 15.1 from Shiohama 1978). This range of estimates reflects uncertainty as to the true shape of the logistic curve, as few if any catch-effort points lie to the right of the dome.

In addition to uncertainty concerning the measure of effective effort and the possibility it is increasing rapidly, there are misgivings that the assumptions implicit in the production model are not satisfied. One is the assumption that there is but one stock. The other, which is much more serious, concerns the stability of age structure. The Japanese fishery which formerly depended on fish of age 4+ to 6+ is now concentrating on fish of age 2+ (ca. 50 cm). Yield-per-recruit analysis has clearly indicated that this shift to younger ages is in the wrong direction for maximizing yield.[19]

The 1978 Albacore Working Group felt that, despite weaknesses in the technique of stock assessment, national governments and fishing industries should be warned of a possible impending disaster if catch and effort continue to rise unchecked.

15.6 Recommendation

Until Japan and the United States, the major exploiters of albacore (accounting for 98.8% of the production) issue an international call for controls, it is recommended that no restraints be placed on Canadian fishing power or catch.

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[19] Continued premature exploitation of juveniles is likely to have substantial impact on the North American fishery north of San Francisco, and may have been felt for the first time in 1978.

Table 15.1. Catches of North Pacific albacore in metric tons, 1961-77.[5]
(dashes indicate no estimate available)

Year	Japan[1]				United States[2]			Canada	Total[3]
	Pole-and-line	Longline	Other gears	Total	Pole-and-line	Jig	Total	Jig	
1961	18,636	15,999	--	34,635	2,837	12,054	14,891	4	49,530
1962	8,729	12,617	--	21,346	1,085	19,753	20,838	1	42,185
1963	26,420	11,445	--	37,865	2,432	25,142	27,574	5	65,444
1964	23,858	11,558	--	35,416	3,411	18,389	21,800	3	57,219
1965	41,491	11,214	121	52,826	417	16,461	16,878	15	69,719
1966	22,830	20,874	585	44,289	1,600	15,169	16,769	44	61,102
1967	30,481	24,374	520	55,375	4,113	17,814	21,927	161	77,463
1968	16,597	19,040	1,109	36,746	4,906	20,441	25,347	1,028	63,121
1969	31,912	18,006	1,480	51,398	2,996	18,826	21,822	1,365	74,585
1970	24,263	15,372	956	40,591	4,416	21,039	25,455	354	66,400
1971	52,957	10,915	1,262	65,134	2,071	22,196	24,267	1,587	90,988
1972	60,591	12,622	922	74,135	3,750	23,600	27,350	3,558	105,043
1973	69,640	16,000	1,922	87,562	2,236	15,652	17,888	1,720	107,170
1974	73,576	12,952	1,289	87,817	4,777	20,177	24,954	1,207	113,978
1975	52,157	9,931	568	62,656	3,243	18,926	22,169	101	84,926
1976	85,336	15,738	2,464	103,538	2,700	16,314	19,014	252	122,804
1977[4]	31,934	10,000	2,500	44,434	1,497	10,012	11,509	53	55,996

[1]Japanese longline catch for 1961-68 excludes minor amount taken by vessels under 20 gross tons. Longline catch in weight is estimated by multiplying annual number of fish caught by an average weight statistic.

[2]United States pole-and-line catch excludes minor amount taken by vessels not submitting logbooks to IATTC; this amount is included in the jig catch.

[3]Omitted are unknown but minor catches by United States sport fishermen and by longline and pole-and-line vessels of the Republic of Korea and Taiwan.

[4]1977 figures are preliminary.

[5]Data from report of the Third North Pacific Albacore Workshop, Honolulu, Hawaii. Feb. 1979.

Table 15.2. Catch per unit of effort (CPUE) of North Pacific albacore by fishery.

Year	U.S.A. Jig[a]	Japan	
		Pole-and-line[b]	Longline[c]
1961	69.17	4.40	0.25
1962	124.59	7.22	0.30
1963	132.09	6.29	0.32
1964	97.61	6.86	0.40
1965	89.07	6.26	0.33
1966	90.45	5.94	0.54
1967	126.83	6.09	0.40
1968	135.23	5.34	0.38
1969	112.57	4.95	0.28
1970	127.39	6.13	0.31
1971	96.68	6.94	0.21
1972	61.08	6.25	0.30
1973	82.89	5.49	0.38
1974	105.17	7.81	0.34
1975	99.81	5.95	0.23
1976	69.22	6.13	0.30
1977	59.90	2.49	

[a] Number of fish per standardized boat-day

[b] Metric tons per standardized fishing day

[c] Number per thousand standardized hooks

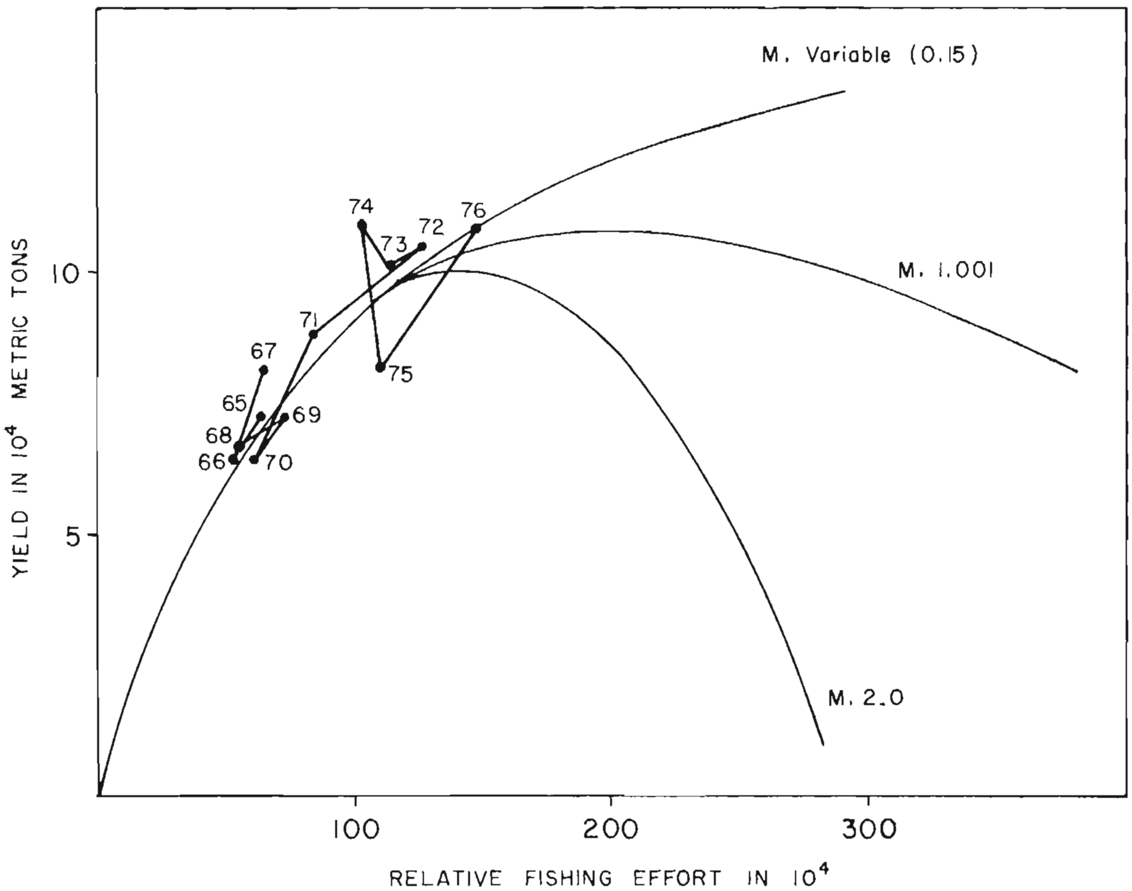

Fig. 15.1. Equilibrium yield curves and observed data for the North Pacific albacore, 1965-1976 (from Shiohama, 1978).

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APPENDIX 1. SPECIAL REGULATIONS FOR PACIFIC COD IN AREA 3C

Introduction

Since 1976, increasing concern has been expressed by trawl captains and processors with respect to the expanding and evolving fishery for spawning Pacific cod on Amphitrite Bank during January-March. They have contended that the new trawling techniques catch an excessive proportion of the spawning cod, and hence jeopardize the stock(s). Since Amphitrite Bank is the only known major spawning area for Pacific cod in Area 3C, the entire cod resource in Area 3C is jeopardized.

Although no proof of this hypothesis is currently available (nor likely to be in the near future), plausibility is evident to those who have observed the new fishing techniques. As a precautionary measure, logic suggests that the January-March fishery be restricted, or closed, during years when Pacific cod abundance is at a cyclic low level of abundance. A predictor of these low-abundance periods is required to provide management and the industry with adequate advance warning.

To satisfy this need, predictors were developed which would give 3-6 months notice as to the abundance of spawning Pacific cod on Amphitrite Bank each year. The predictors were the Canadian landings of Pacific cod during April-June (Quarter II) and July-September (Quarter III), respectively, in the year preceding the spawning season. The general validity of these predictors is based on two facts. First, age composition of Pacific cod landings from Area 3C are principally age-2 fish during Quarters II and III, and age-3 fish (same year-class) in Quarter I of the following year. Age composition of landings during Quarter II are less consistent, perhaps because in some years relatively more age-3 and age-4 fish survive past spawnings. Second, Canada-U.S. landings and Canada catch rates (m.t. landed/hr trawled) were reasonably well correlated as follows:

Ground	Time	r	
Amphitrite Bank	Qtr I	0.911	(Fig. 1)
Big Bank	Qtr II	0.407	(Fig. 2)
	III	0.575	

Both predictors have biases which may affect their accuracy. The predictor based on Quarter II landings will overestimate the Quarter I landings, if the landings contain too many representatives of the older cod which will not be equally abundant during the next spawning season. The predictor based on Qtr III landings will tend to underestimate the Quarter I landings, because dogfish are sometimes sufficiently abundant in Area 3C to inhibit trawling for cod. A counteracting bias in 1978 may have been the abnormally high water temperature (Douglas and Wickett, In Press) which may well have caused a reduction in availability of cod to the trawl fishery.

Prediction and recommendation

Both predictors were employed to estimate the abundance of Pacific cod in Area 3C during January-March 1978, and indicated abundance would be relatively low -- Canadian landings ≅ 476 m.t. (Qtr II predictor) or 856 m.t. (Qtr III predictor) (Fig.3 and 4; Table 1). Accordingly, Area 3C was closed to all trawling for the period February 22-April 3. The estimated Canadian landings for January-March, had there been no closure, totalled 604 m.t. -- slightly less than the mean estimate (666 m.t.). Actual Canadian landings (January 1-February 21) totalled 460 m.t.

For January-March 1979, Canadian landings are estimated to be 840 m.t. (Qtr II predictor) or 432 m.t. (Qtr III predictor) (Fig. 3 and 4 ; Table 1). Mean estimate is 636 m.t., slightly less than the mean estimate for 1978 (666 m.t.).

In summary, the predictors both indicate that Pacific cod abundance in Area 3C during January-March 1979 will be low, and at a similar level to that in 1978.

Therefore, the January-March trawl fishery for Pacific cod should be severely curtailed. A total closure should be seriously considered. For such a closure to be effective, the Canadian portion of Area 3C should be closed to all trawling, as in 1978. The consequences with respect to other fisheries in Area 3C at that time are not serious, but the dispersion of Area 3C trawlers to other areas could be troublesome, if countermeasures are not employed.

Effect of closure on other species in Area 3C

Total (or partial) closure to trawling of the Canadian portion of Area 3C raises the question of its effect on other species. For this analysis the records for 1975 and 1976 have been examined. For Canadian vessels, Pacific cod comprised 96 and 94% respectively, of their 1975 and 1976 landings during January-March (Table 2). The second most important species was rock sole (2 and 4%), a by-catch in the cod fishery. For United States vessels, Pacific cod comprised 85 and 81%, respectively, for January-March 1975-1976. Second most important category was rockfish (including Pacific ocean perch) which comprised 8% in 1975 and 4% in 1976. Rockfish are trawled on the outer shelf and upper slope, in contrast to the inner shelf fishery for cod. Deepwater flatfishes (Dover and petrale sole) amounted to 5% in 1975, and 7% in 1976. Since at least the stocks of Pacific ocean perch and petrale sole are currently at a low level, little real loss, other than cod production, has been imposed on the United States vessels by the closure.

Effects of closure on other areas

A trawl closure of Area 3C during January-March will cause a re-distribution of the Canadian and United States[19] fleets which customarily trawl there at that time. The alternatives for both fleets are either cease trawling (until April) or trawl in other areas.

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[19] Assuming a Canada-U.S. fishing agreement is attained. Currently U.S. vessels cannot trawl in the 200-mile zone of Canada.

For some Canadian trawlers, cessation of trawling might not be objectionable, because the effective closure would be only January-February -- in March, virtually, all groundfish processing ceases to accommodate the more-lucrative herring-roe fishery. However, some trawlers will probably fish elsewhere, and there are three viable alternative locations -- Hecate Strait (Area 5C and 5D), Queen Charlotte Sound (Area 5A and 5B), and Georgia Strait and vicinity (Area 4B). Northwest Vancouver Island (3D) and West Queen Charlotte Islands (Area 5E) have been discounted. Additional vessels might be accommodated during January-March in Hecate Strait and Queen Charlotte Sound, but certainly not in Georgia Strait and vicinity. In fact, if the Canadian portion of Area 3C is closed to trawling during January-March 1979, a vessel-limitation regulation would have to be imposed in Area 4B to prevent the Area 3C fleet of large vessels from competing with the small-vessel fleet which customarily trawls in Area 4B. An analysis of the 1970-77 trawl landings, by vessel, from Area 4B during January-March has yielded a list of 33 trawlers which would be eligible for special permits to trawl in Area 4B during January-March 1979. Details of the analysis are contained in the next section.

For United States vessels, the alternatives are likewise cessation of trawling and trawling in other areas. For them there is no herring-roe fishery. Alternate trawling areas are: Queen Charlotte Sound (Areas 5A and 5B); U.S. portion of Area 3C; Washington-Oregon coast (Areas 3B, 3A and 2C); and Puget Sound and vicinity(Area 4A). Northwest Vancouver Island (Area 3D) has been discounted, and United States vessels have no rights to fish in Hecate Strait or off west Queen Charlotte Islands.

Vessel eligibility in Area 4B

During January-March 1970-77, 81 trawl vessels made one or more groundfish landings from Area 4B (Table 3). Some of the vessels also landed groundfish caught outside Area 4B. Criteria were developed, based on vessel performance, to provide a list of vessels eligible for a special permit to trawl in Area 4B during January-March 1978, _if_ Area 3C is closed during the same time period. The eligible list was obtained by elimination.

First criterion for vessel elimination was vessels making one or more landings in only one year during 1970-75. A total of 42 vessels made one or more landings in only one year (Table 4) and 30 of these qualified for elimination (Table 5). In Table 3, they are indicated by a single asterisk.

Second criterion for elimination was vessels making one or more groundfish landings in two or more years, but none during 1976-77. A total of 39 vessels made one or more groundfish landings in two or more years (Table 4), and 16 of these qualified for elimination (Table 5). These vessels are indicated by a double asterisk in Table 3.

Third criterion for elimination was vessel tonnage class. Vessels in tonnage classes 5 and 6 were eliminated, because they were substantially more efficient than those in tonnage classes 1-4 -- 24.1 m.t./landing for class 5-6 _vs_ 4.7 m.t./landing for class 1-4 (Table 6). On this basis two vessels were eliminated (Table 5), which are identified in Table 3 by triple asterisks.

Thus, the three elimination criteria have reduced the number of eligible vessels to 33 (Table 5).

Table 1. Relationship between Canadian trawl landings (m.t.) of Pacific cod from Area 3C (Canadian portion) during April-June (Qtr. II) and July-September (Qtr. III), and those during January-March (Qtr. I) in the following year (Qtr.I), 1967-76.

	Canada landings (m.t.)		
Year (i)	Qtr. II (i)	Qtr. III (i)	Qtr. I (i+1)
1967	344	138	420
1968	126	33	344
1969	200	67	343
1970	277	176	516
1971	1,076[a]	468	1,544
1972	2,031[a]	706	1,425
1973	566	369	1,263
1974	692	536	1,463
1975	734	358	1,362
1976	652	326	944
1977	259[a]	268	476/856[b]
1978	453[a]	69	840/432[b]
r	0.934	0.911	
a	-10.419	284.0	
b	1.876	2.134	
Syx	186.0	222.0	

[a]Not included in regression computations.

[b]Estimates. Qtr.II/Qtr.III.

Table 2. Canadian and United States landings of principal trawl-caught groundfish from the Canadian portion of Area 3C, by species, during January-March 1975 and 1976.

Species	1975 m.t.	1975 %	1976 m.t.	1976 %
		Canada		
Pacific cod	1,463	95.9	1,362	93.9
Rock sole	32	2.1	57	3.9
Lingcod	12	0.8	16	1.1
Other rockfish	4	0.3	4	0.3
Pacific ocean perch	0.1	T	-	-
All-species total	1,525		1,450	
		United States		
Pacific cod	677	85.2	347	80.9
Other rockfish	35	4.4	16	3.7
Pacific ocean perch	29	3.6	3	0.6
Petrale sole	21	2.6	24	5.6
Dover sole	15	1.9	21	4.9
Lingcod	8	1.0	10	2.3
All-species total	795		430	

Table 3. Numbers of trawl landings of groundfish from inside (I) and outside (O) Area 4B during January-March 1970-77, by vessel number, vessel tonnage class, and year.

Vessel no.	Tonnage class	1970		1971		1972		1973		1974		1975		1976		1977		No. of years
		I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	
* 1	2	5	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
2	3	-	-	3	0	-	-	1	0	5	0	3	0	4	1	-	-	5
* 3	3	-	-	-	-	-	-	5	0	-	-	-	-	-	-	-	-	1
** 4	2	5	0	6	0	2	0	1	0	6	0	2	0	-	-	-	-	6
** 5	4	-	-	1	3	2	2	2	4	1	3	1	4	-	-	-	-	5
* 6	6	-	-	-	-	2	0	-	-	-	-	-	-	-	-	-	-	1
7	2	-	-	-	-	-	-	-	-	-	-	-	-	4	0	1	0	2
** 8	3	6	0	6	0	6	0	7	0	-	-	-	-	-	-	-	-	4
* 9	3	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
**10	4	-	-	2	0	1	0	4	1	-	-	-	-	-	-	-	-	3
11	3	4	1	5	0	5	0	4	0	4	0	1	0	6	0	5	0	8
12	3	8	0	7	0	6	0	9	0	5	0	6	0	5	0	7	0	8
*13	2	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	-	1
14	2	8	0	9	0	-	-	-	-	-	-	11	0	3	0	-	-	4
*15	4	-	-	-	-	-	-	-	-	-	-	-	-	3	0	-	-	1
**16	3	-	-	6	0	3	0	-	-	-	-	-	-	-	-	-	-	2
17	3	-	-	-	-	-	-	-	-	4	0	3	0	2	0	4	0	4
**18	3	5	0	4	0	2	0	2	1	-	-	-	-	-	-	-	-	4
19	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	1
20	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0	1
21	2	-	-	-	-	-	-	-	-	-	-	4	0	3	0	-	-	2
*22	4	2	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
***23	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0	1
*24	3	-	-	-	-	-	-	-	-	1	0	-	-	-	-	-	-	1
25	2	13	0	13	0	12	0	23	0	10	0	5	0	15	0	-	-	7
26	3	-	-	-	-	-	-	1	4	-	-	-	-	3	0	-	-	2
**27	3	9	1	12	0	6	0	12	0	8	0	15	0	-	-	-	-	6
*28	4	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	1
*29	4	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	1
*30	4	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	1

Table 3 (cont'd)

Vessel no.	Tonnage class	1970		1971		1972		1973		1974		1975		1976		1977		No. of years
		I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	
**31	4	–	–	6	0	1	2	3	1	–	–	–	–	–	–	–	–	3
32	3	7	0	6	1	–	–	3	0	4	0	6	0	3	0	5	0	7
**33	1	7	0	4	0	3	0	2	0	–	–	–	–	–	–	–	–	4
34	3	–	–	–	–	–	–	–	–	–	–	–	–	2	0	1	0	2
*35	4	–	–	–	–	1	0	–	–	–	–	–	–	–	–	–	–	1
*36	6	–	–	–	–	–	–	2	3	–	–	–	–	–	–	–	–	1
37	1	–	–	–	–	–	–	–	–	–	–	2	0	16	0	12	0	3
**38	1	2	0	–	–	–	–	–	–	3	0	–	–	–	–	–	–	2
**39	2	–	–	1	0	2	0	–	–	–	–	–	–	–	–	–	–	2
**40	6	–	–	1	3	–	–	2	4	–	–	–	–	–	–	–	–	2
41	1	9	0	7	0	12	0	11	0	17	0	1	0	5	0	2	0	8
***42	5	–	–	–	–	–	–	–	–	1	1	3	0	1	2	–	–	3
**43	4	3	0	2	0	–	–	8	0	3	0	6	0	–	–	–	–	5
*44	4	–	–	2	0	–	–	–	–	–	–	–	–	–	–	–	–	1
**45	3	4	0	4	0	–	–	–	–	–	–	–	–	–	–	–	–	2
**46	2	22	0	25	0	4	0	12	0	15	0	10	0	–	–	–	–	6
*47	6	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	1
*48	6	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	1
*49	5	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	1
50	3	–	–	5	0	1	0	14	0	2	0	3	0	4	0	2	0	7
*51	1	–	–	2	0	–	–	–	–	–	–	–	–	–	–	–	–	1
*52	3	–	–	–	–	2	0	–	–	–	–	–	–	–	–	–	–	1
53	1	–	–	–	–	6	0	2	0	7	0	8	0	2	0	–	–	5
54	1	–	–	–	–	–	–	9	0	9	0	5	0	9	0	29	0	5
**55	4	–	–	–	–	–	–	7	3	1	3	–	–	–	–	–	–	2
*56	1	–	–	–	–	–	–	7	0	–	–	–	–	–	–	–	–	1
*57	2	–	–	–	–	–	–	–	–	4	0	–	–	–	–	–	–	1
58	3	–	–	–	–	–	–	–	–	4	0	–	–	–	–	6	2	2
*59	3	–	–	–	–	–	–	–	–	–	–	3	2	–	–	–	–	1
60	3	–	–	–	–	–	–	–	–	–	–	1	0	5	0	4	0	3

Table 3 (cont'd)

Vessel no.	Tonnage class	1970		1971		1972		1973		1974		1975		1976		1977		No. of years
		I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	
61	4	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	0	2
*62	6	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	1
*63	1	-	-	-	-	-	-	-	-	-	-	7	0	-	-	-	-	1
64	4	-	-	-	-	-	-	-	-	-	-	10	0	2	2	4	2	3
*65	4	-	-	-	-	-	-	-	-	-	-	1	0	-	-	-	-	1
66	3	-	-	-	-	-	-	-	-	-	-	5	0	9	1	12	0	3
67	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0	1
*68	4	-	-	-	-	-	-	-	-	-	-	-	-	5	1	-	-	1
*69	1	-	-	-	-	-	-	-	-	-	-	-	-	8	0	-	-	1
70	2	-	-	-	-	-	-	-	-	-	-	-	-	1	0	11	0	2
*71	4	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-	-	1
72	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5	1
*73	1	-	-	-	-	-	-	-	-	-	-	-	-	2	0	-	-	1
*74	3	-	-	-	-	-	-	-	-	-	-	-	-	4	0	-	-	1
75	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	0	1
76	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	0	1
77	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	0	1
78	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0	1
79	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	0	1
80	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0	1
81	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	1
Total		121	7	140	10	81	5	161	28	114	7	124	9	130	10	173	9	

No. of asterisks indicate elimination category: I, II, III.

Table 4. Numbers of trawl vessels making one or more groundfish landings from Area 4B during January-March 1970-77, by tonnage class and numbers of years participation.

Tonnage class	Years of Participation								Total
	1[a]	2	3	4	5	6	7	8	
1	11	1	1	1	2	-	-	1	17
2	4	4	-	1	-	2	1	-	12
3	8	5	2	3	1	1	2	2	24
4	12	2	3	-	2	-	-	-	19
5	1	-	1	-	-	-	-	-	2
6	6	1	-	-	-	-	-	-	7
Total	42	13	7	5	5	3	3	3	81

[a] Number of vessels making one or more landings in only one year, by year, were: 1970, 3; 1971, 3; 1972, 4; 1973, 8; 1974, 2; 1975, 4; 1976, 6; 1977, 12.

Table 5. Numbers of rejected and accepted trawl vessels making one or more groundfish landings from Area 4B during January-March 1970-77, by tonnage class.

Tonnage class	Total vessels	Rejected Vessels[a]			Eligible vessels
		I	II	III	
1	17	5	2	-	10
2	12	3	3	-	6
3	24	6	5	-	13
4	19	10	5	-	4
5	2	1	0	1	-
6	7	5	1	1	-
Total	81	30	16	2	33

[a]I = vessels making one or more landings in only one year during 1970-76.
II = vessels making one or more landings in two or more years, but none during 1976-77.
III = vessels making one or more landings in two or more years during 1970-77, but are larger than tonnage class 4.

Table 6. Landing statistics for trawl vessels landing groundfish from Area 4B during January-March 1970-77, by year, by tonnage classes 1-4 and 5-6.

Year	Tonnage class 1-4			Tonnage class 5-6		
	Landings		L/N	Landings		L/N
	(m.t.)	no.	(m.t./no.)	(m.t.)	no.	(m.t./no.)
1970	433.0	121	3.6	-	0	-
1971	685.0	139	4.9	12.2	1	12.2
1972	467.8	79	5.9	22.5	2	11.3
1973	1,194.5	154	7.8	271.8	7	38.8
1974	565.5	113	5.0	6.2	1	6.2
1975	432.0	119	3.6	65.6	5	13.1
1976	453.4	129	3.5	3.5	1	3.5
1977	569.7	170	3.4	99.6	3	33.2
Total	4,800.9	1,024	4.7	481.4	20	24.1

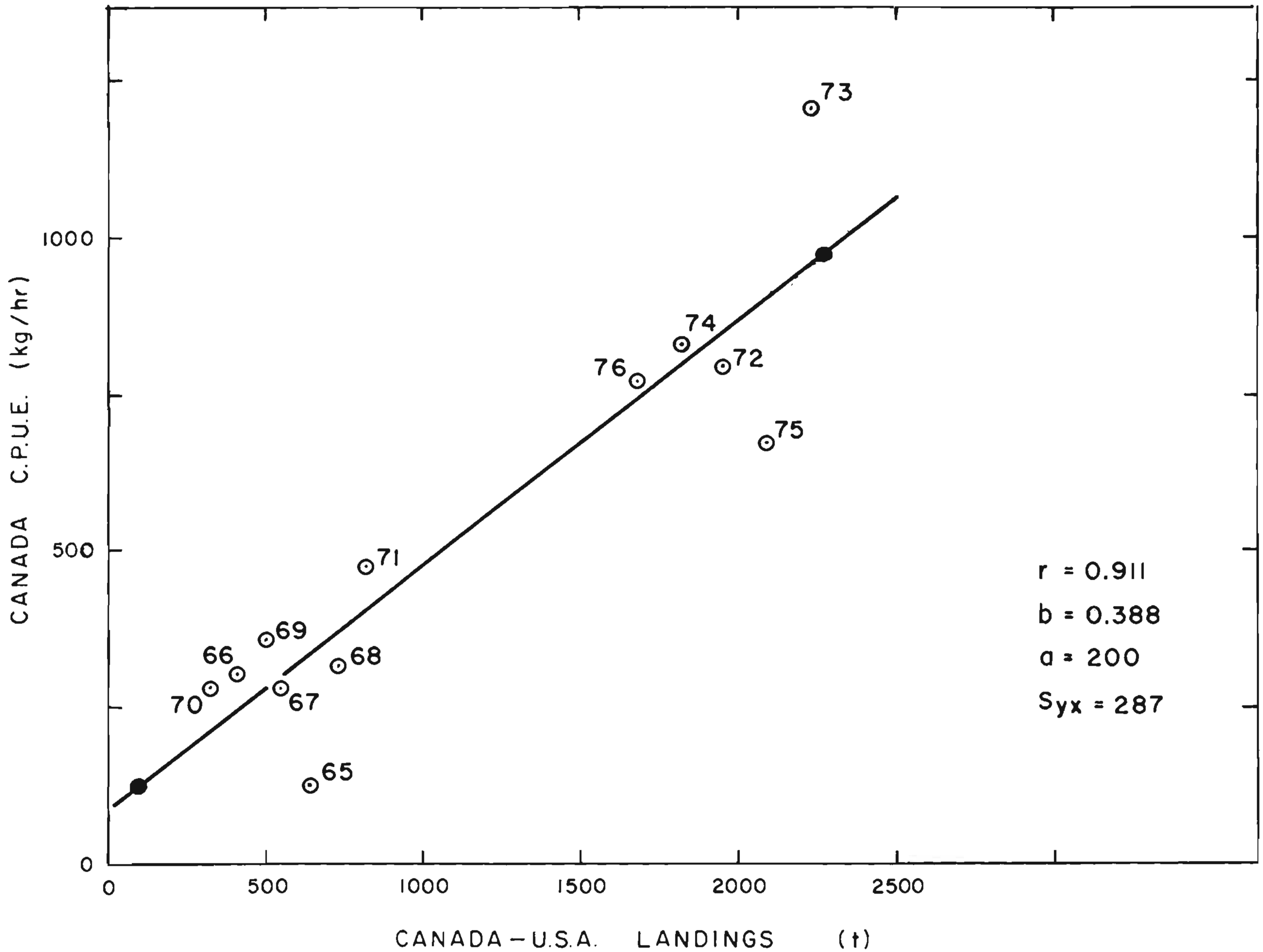

Fig. 1. Relationship between Canada-United States Pacific cod landings and Canada CPUE from Amphitrite Bank during January-March, 1965-76.

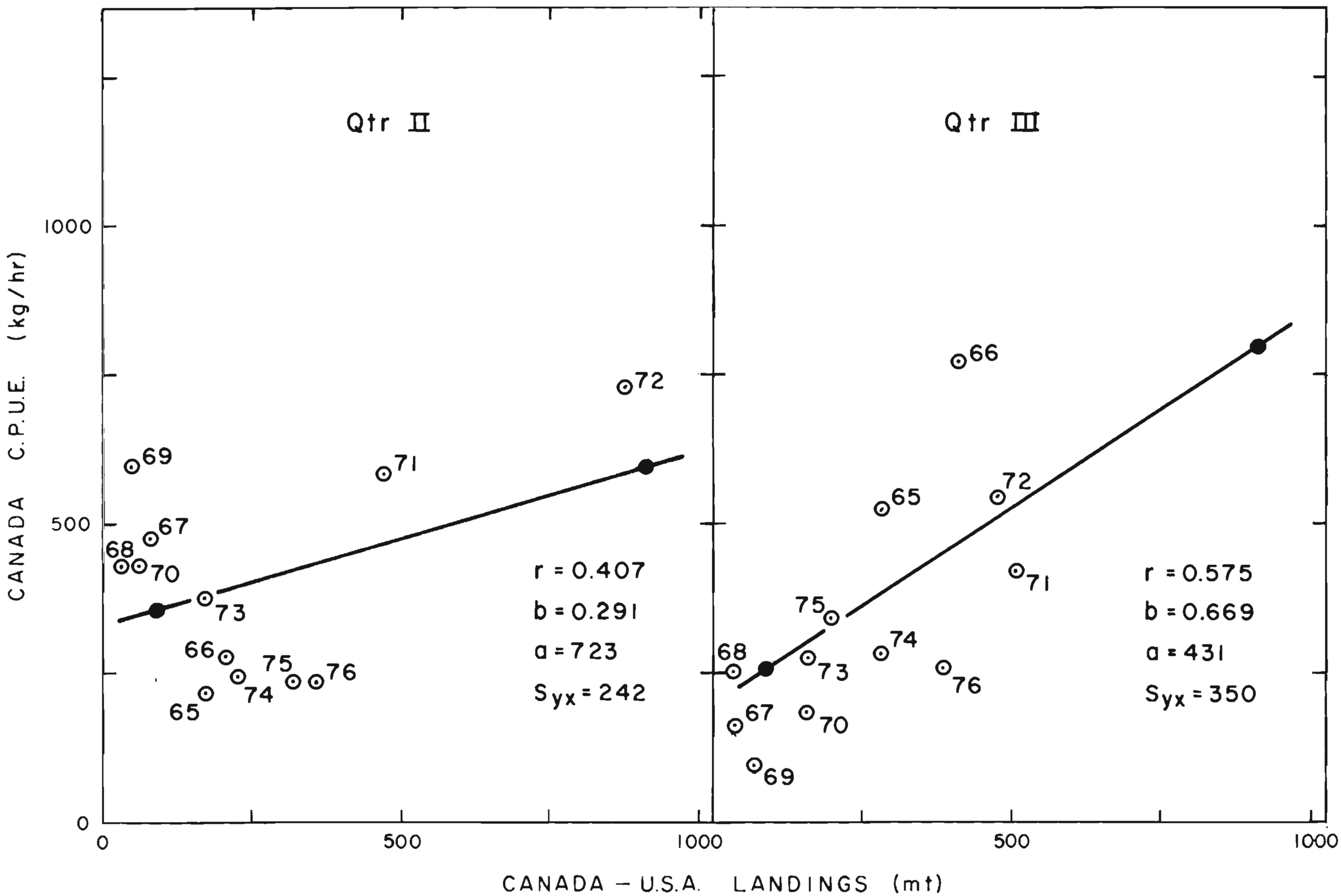

Fig. 2. Relationship between Canada-United States Pacific cod landings and Canada CPUE from Big Bank during April-June and July-September, 1965-76.

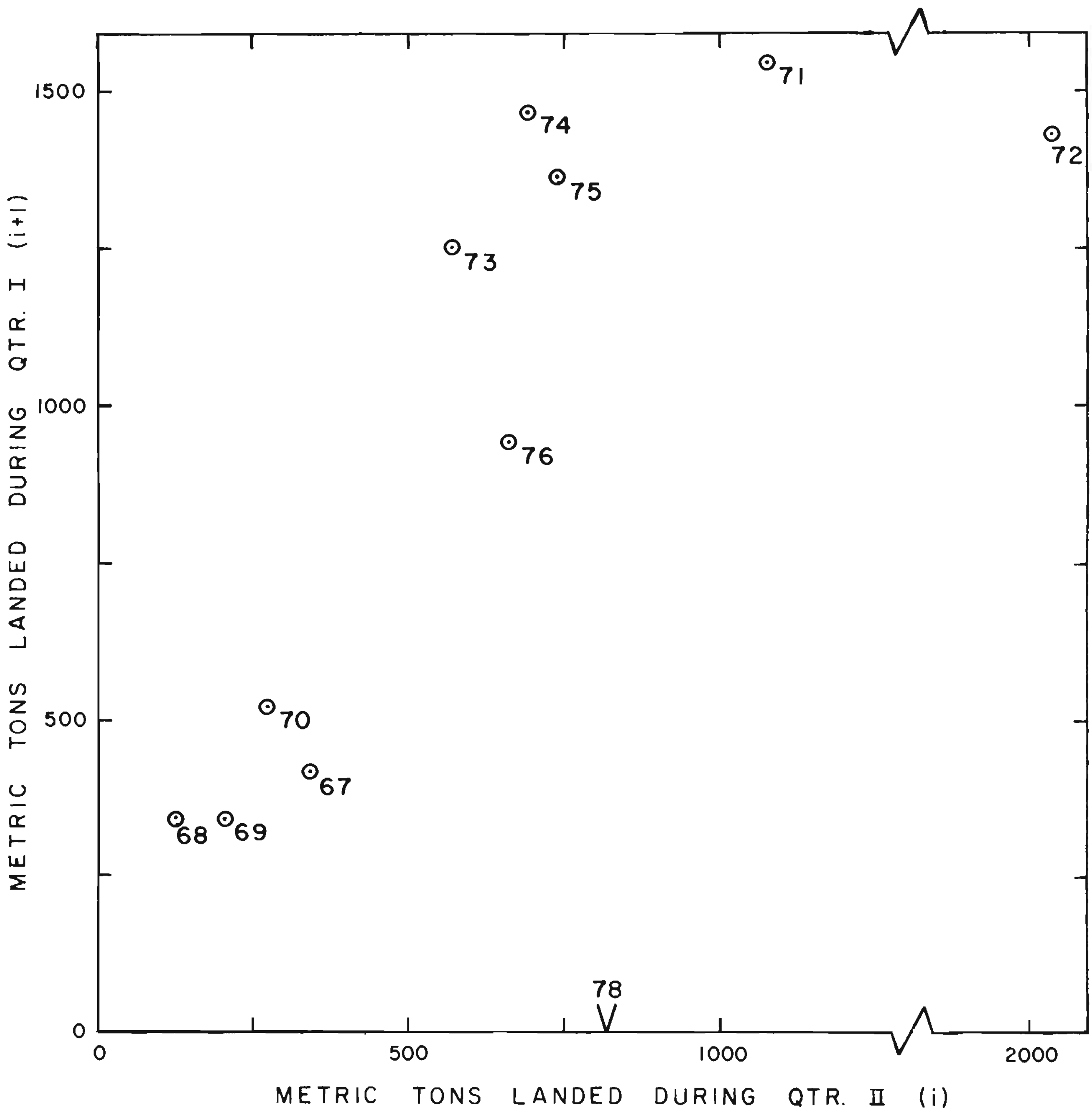

Fig. 3. Relationship between Canadian landings of Pacific cod from Area 3C (Canadian portion) during April-June with those during January-March in the following year, 1965-76.

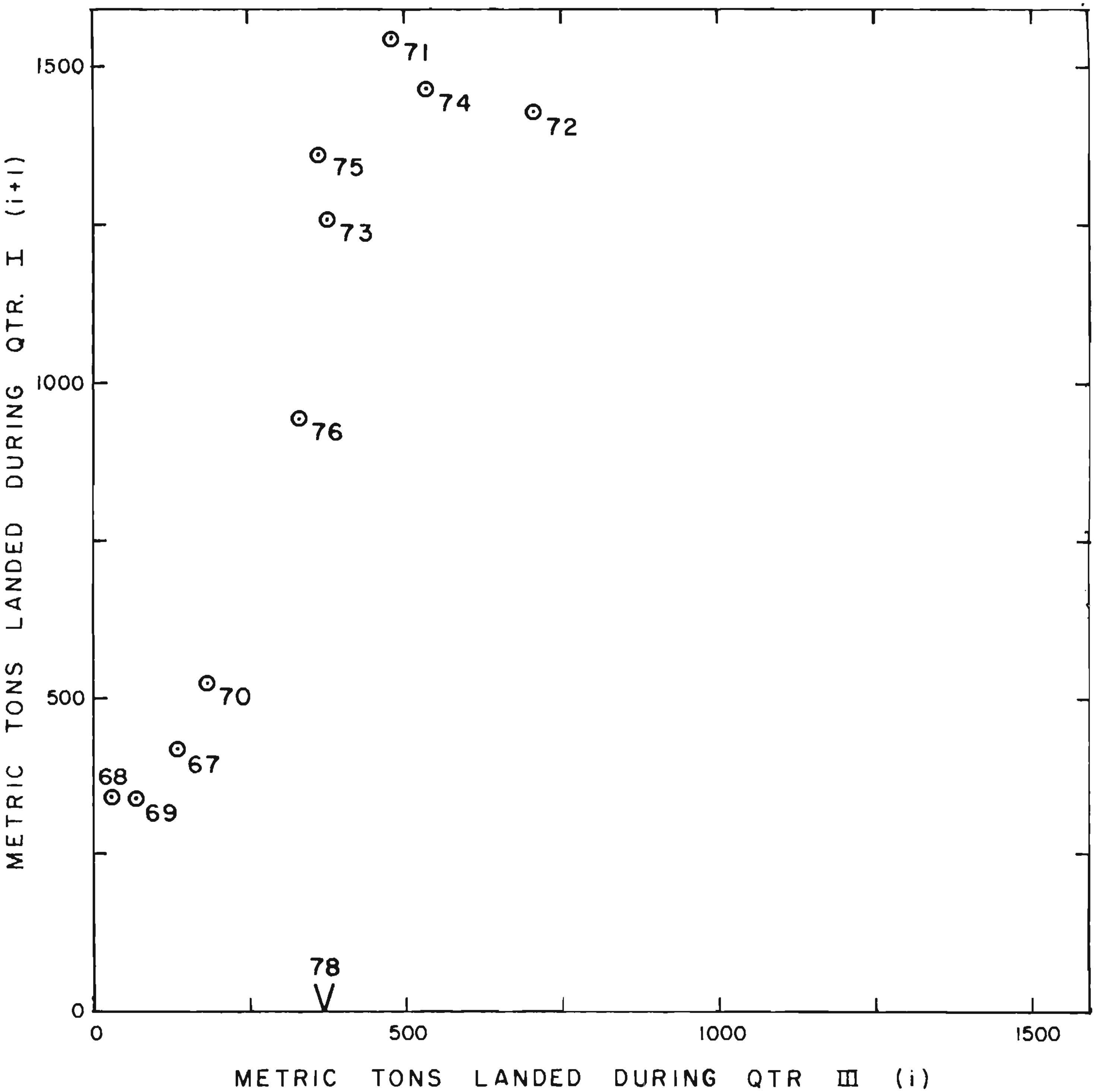

Fig. 4. Relationship between Canadian landings of Pacific cod from Area 3C (Canadian portion) during July-September with those during January-March in the following year, 1965-76.

Appendix 2: ENVIRONMENTAL EFFECT ON THE STOCK-RECRUITMENT RELATION OF NORTHERN HECATE STRAIT ROCK SOLE

Summary

A stock-recruitment model which incorporates the environmental indices, temperature and sunlight, was calculated using the number of 4, 5, 6, 7 year-old male plus female fish caught per 10 days fishing as parental stock and year-class strength in the same units as recruitment for the year-classes 1944 to 1969. (General form of Ricker environment curve). The variables with coefficients significantly different from zero are stock, sunlight squared and stock times sunlight. (Reduced form of Ricker curve).

Computation of model

The General form of the Ricker stock-recruitment curve was calculated using the P.B.S. Computing Centre's MREG multiple regression program. The dependant variable is the natural logarithm of the fraction recruitment divided by stock, and the independant variables are the terms of the full second degree equations for stock, March mean temperatures at Triple Island and annual mean hours of sunlight at Sandspit. The MREG program eliminates those variables that do not meet a t-test at the 5% level. Expected values of recruitment are calculated from the antilogged values of this Reduced form of the Ricker curve. Data were taken from Forrester and Thomson (1969) and current files of the Groundfish Program. This equation for northern Hecate Strait rock sole is

$$R = P \cdot \exp\,(5{,}8473461 \cdot \exp\,[\,P(0.05643167X - 0.892627778)] \cdot \exp\,(0.026289914X^2)$$

where R = year-class strength in 10^4 fish/10 days fishing
P = parental stock 4, 5, 6, 7♂ and♀ fish 10^4/10 days fishing
X = annual hours of bright sunlight at Sandspit observed and regressed from Prince Rupert for early years in 10^2 hours.

The curves for 3 values of X = 04.32, 11.82, 17.62 are plotted in Fig. 1.

Results

Fig. 1 shows the Reduced form (1) for the mean value of sunlight, (2) and (3) for the extreme observed values of sunlight. Curve (1) is almost the same as the geometric mean Ricker curve. With extremely favourable environmental indices the maximum recruitment is obtained with a parental stock (P_m) of 44,000 males and females per 10 days fishing. With the mean value of the index (sunlight), the P_m stock is 118,000 ♂ and ♀/10 d.f. There is no P_m value for curve (3). The coefficient of determination (r^2) between observed recruitment values and values expected from the Reduced Ricker environment equation is 0.41. The observed values are plotted as triangles and the expected values are plotted as circles in Fig. 2D.

An index of the number of eggs calculated to be carried by the parental stock (Fig. 2A) and an index of parental stock, 5 year old females/10 d.f.

(Fig. 2B) and the annual landings (Fig. 2E) are shown for comparison with year-class strengths.

Discussion

Fig. 3 indicates all ages of female fish tend to vary in size together each year. In the 1970's there are anomalies of "negative" growth which may be related to time of year of sampling or perhaps to immigration into the fishing area during a period of low abundance.

Fig. 4 which shows an inverse relation between mean length of female fish and the number of fish in the parental stock confirms the Forrester Thomson (1969) view that competition for food is present in the Hecate Strait stock, i.e. decreased size with increased density. Fig. 1 suggests that such competition is strongly mediated by the environment. Since the number of eggs carried is related to size (Forrester and Thomson 1969), then fecundity appears to be density-dependent.

Fig. 5 indicates why the temperature index is eliminated in this analysis. The recent values, 1965-69, of temperature are not associated with high values of recruitment of year-classes of 4, 5, 6, 7 year-olds that were born in those years. It should be understood that the inclusion of temperature in the General form of the Ricker curve did account for an additional 10% of the sum of squares and with an F-test indicating a less than 1% probability of the result arising by chance.

The location of the replacement line on Fig. 1 is not straightforward since the axes are dissimilar indices. Approximately 80,000 males and females/10 d.f. is the desirable parental level judging by inspection of Fig. 1. Catches of 3 million pounds (Canada and U.S.) from 1966 to 1969 were followed by lowered parental stock. A gradual increase in year class strength is predicted for 1973-1976 following low catches in 1973-1975. Therefore, considering the above, catches of less than 800,000 lb seem desirable so as to raise the index of parental abundance from 20,000-30,000 male plus females for 10 days fishing to the 80,000 index level.

Table 1. Biological Indices

	Estimation of year-class strengths	Estimation of Parental Stock: (4, 5, 6, 7 yr females per 10 days fishing	Estimation of Parental Stock: (5 yr females per 10 days)	#4, 5, 6, 7 yr ♂ + ♀ per 10 days	Average number of eggs (x 10^3) per fish weighted mean
39	26,298				
40	17,343				
41	22,533				
42	77,324				
43	129,374				
44	71,694		6,298		
45	44,217		4,278	28,580	766
46	75,990	29,388	5,729	46,994	554
47	136,269	55,985	21,384	91,598	463
48	108,342	50,602	28,546	73,136	564
49	87,481	38,608	13,704	61,731	656
50	65,745	37,359	6,787	61,739	704
51	38,605	79,563	27,697	122,444	445
52	37,642	60,578	27,080	10,845	504
53	134,982	38,721	9,224	62,822	655
54	196,288	41,036	18,802	65,791	563
55	190,115	56,757	14,991	81,592	625
56	65,503	30,908	5,372	56,948	690
57	25,071	28,553	4,651	46,105	669
58	32,645	77,728	57,122	96,826	505
59	80,582	98,408	52,122	113,304	419
60	127,748	130,855	45,063	160,269	397
61	104,858	118,546	5,927	127,504	456
62	56,384	55,294	926	82,495	639
63	44,450	37,870	5,010	57,900	736
64	53,910	33,866	10,632	45,253	660
65	55,333	117,560	45,110	154,231	N/A
66	23,128	93,815	38,755	100,547	532
67	9,243	67,748	24,150	80,741	667
68	14,533	28,276	7,454	39,098	641
69	40,249	49,373	15,076	85,276	582
70		27,187	4,973	31,773	627
71		17,195	4,939	24,997	747
72		10,252	1,162	25,187	N/A
73		9,655	2,319	16,241	606
74		37,250	19,381	49,641	599
75		10,455	2,203	16,740	638
76		12,711	3,314	26,842	829
77					

Table 1. (cont'd)

	Number of eggs (x 10^{10}) per 10 days fishing	Weighted average day-of- year of sampling females	Annual Sandspit hr bright sun x 100
39			
40			
41			
42			
43			
44			
45			13.47
46	1.63	165	13.52
47	2.59	N/A	13.10
48	2.85	209	14.79
49	2.53	?	12.89
50	2.63		13.84
51	3.62	153	14.13
52	3.05	223	12.82
53	2.54	215	11.82
54	2.31	213	13.00
55	3.55	189	12.64
56	2.13	210	13.94
57	1.91	?	15.92
58	3.93	234	17.45
59	4.12	176	13.49
60	5.20	229	14.19
61	5.41	180	16.06
62	3.53	274	13.82
63	2.79	238	15.28
64	2.24	211	12.91
65	N/A	N/A	15.61
66	4.99	135	14.44
67	4.52	289	17.62
68	1.81	154	16.69
69	2.87	?	14.48
70	1.71	124	13.67
71	1.28	163	16.04
72	N/A	N/A	15.75
73	0.59	232	13.74
74	2.23	198	15.41
75	0.67	323	13.43
76	1.05	314	12.90
77			

Table 1. (cont'd)

	Total annual Canadian and U.S. rocksole catch		
	Two Pks, B.W. Warrior (lbs)	Two Pks, B.W. Warrior Pks. (lbs x 10^3)	Pacific Marine Fisheries Commission (lbs x 10^3)
39			
40			
41			
42			
43			
44			
45	254,070		
46	788,483		
47	2,264,935		
48	1,851,087		
49	1,229,699		
50	1,452,458		
51	2,401,402		
52	4,688,537		
53	1,066,243		
54	1,869,971		
55	2,643,728		
56	742,880		1,683.0
57	371,610		938.0
58	1,626,903		1,957.5
59	338,368		368.5
60	1,351,767		1,446.5
61	1,339,955		1,398.0
62	1,081,679		1,118.0
63	1,565,837	1,487	1,997.0
64	965,138	1,031	1,101.0
65		444	749.0
66		2,792	3,375.0
67		2,230	2,632.0
68		2,904	3,429.0
69		2,583	2,982.0
70		820	1,475.0
71		1,911	1,475.0
72		277	2,451.0
73		267	758.0
74		163	660.0
75		1,129	740.0
76		2,176	1,828.0
77	797,182		2,559.0

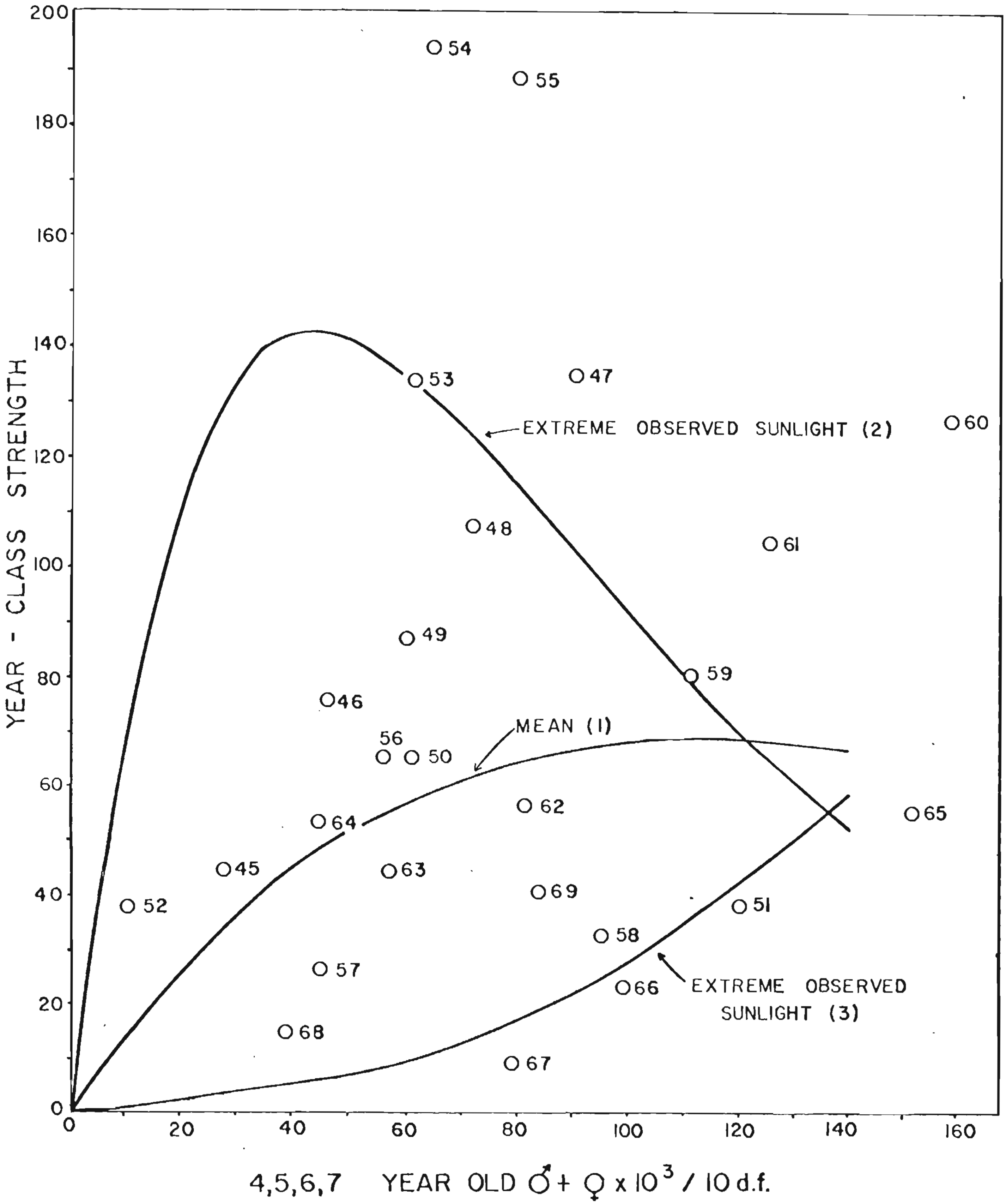

Fig 1. Reduced form of Ricker-Environment curve for northern Hecate Strait rock sole for 3 levels of annual hours of bright sunlight at Sandspit. Curve (1) for the mean hours of sunlight very nearly coincides with a Standard Ricker curve. The index of parental stock is numbers of males plus females caught per 10 days fishing.

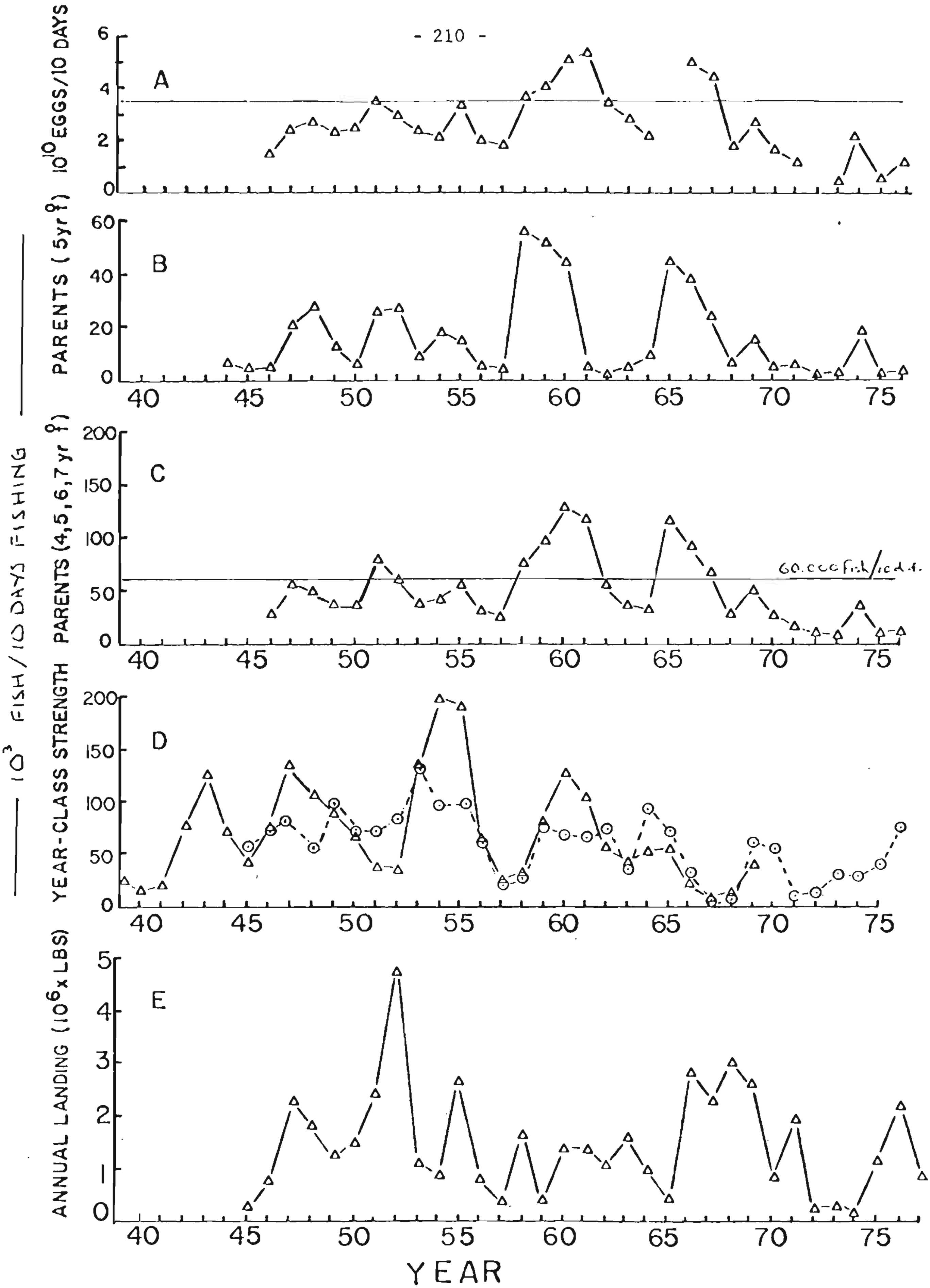

Fig 2. Time series of indices of eggs carried by the parental stock, 5 year-old females, 4, 5, 6, 7 year-old feamles, year-class strength and annual landings of northern Hecate Strait rock sole.

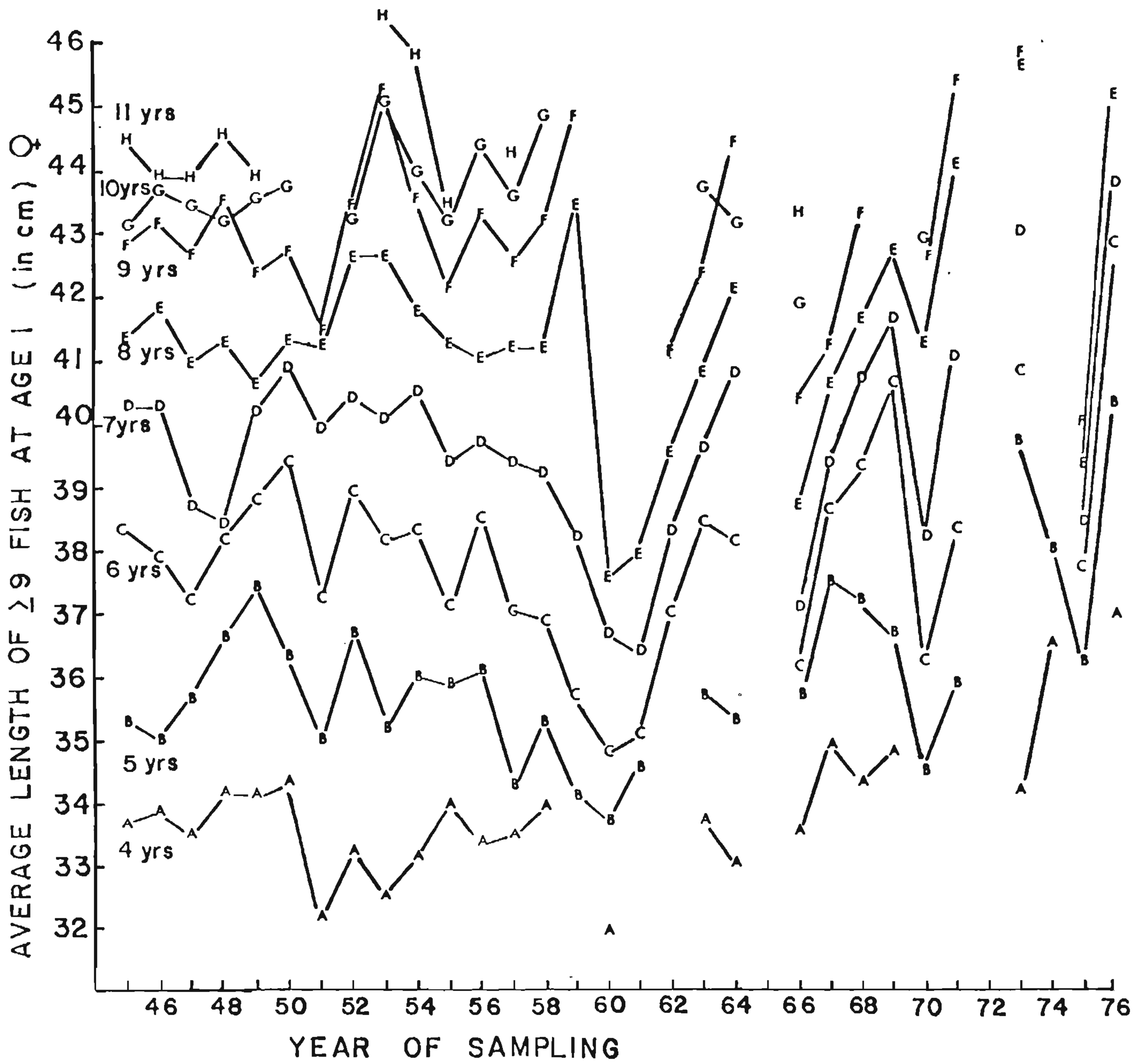

Fig 3. Plot of average length of samples of 9 or more female rock sole at ages 4 to 11 years from 1945 to 1976.

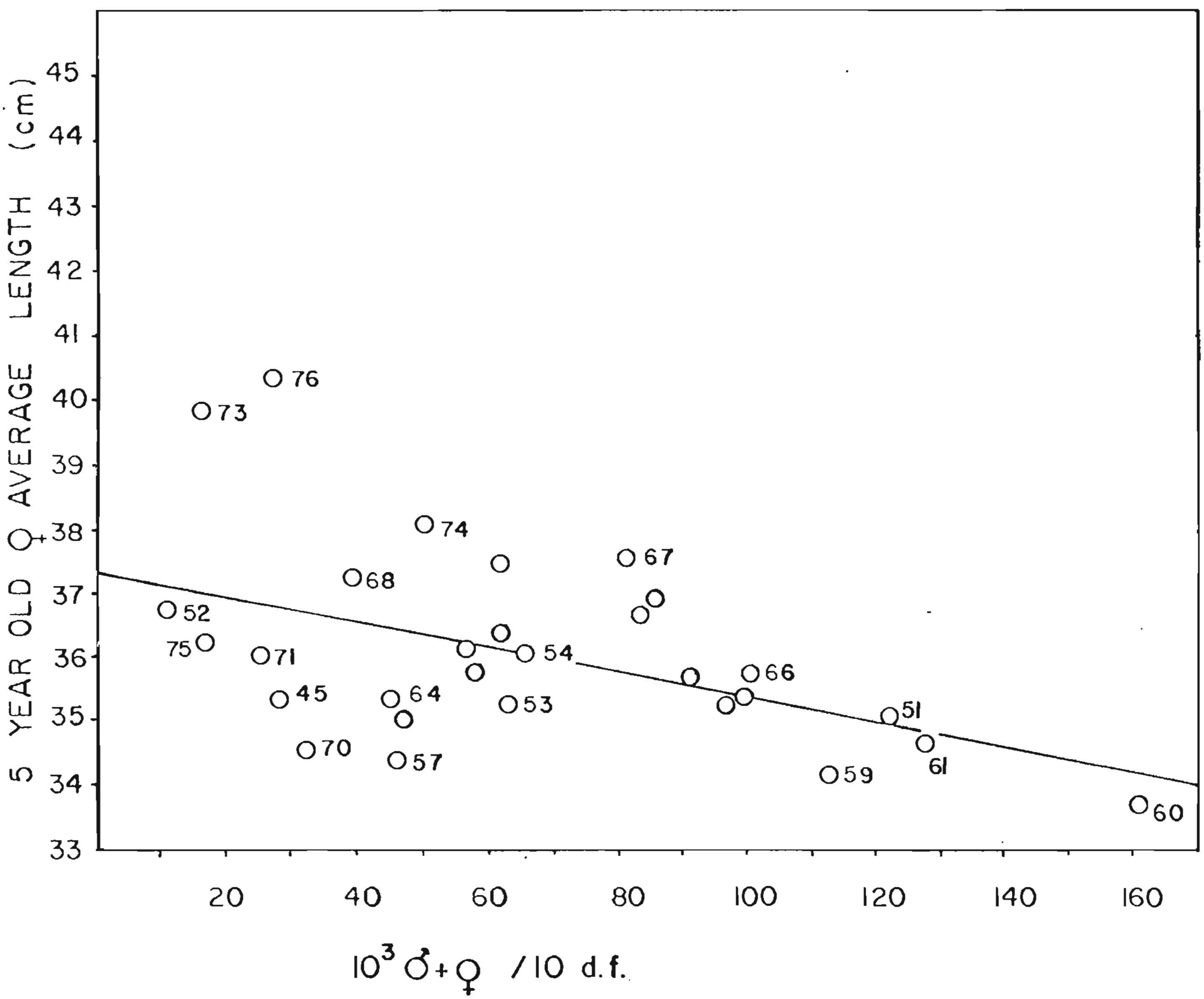

Fig 4. Plot of the average length of female rock sole against the index of abundance of 4, 5, 6, 7 year-old male and female rock sole in the same year. A quarter of the variance of length is associated with density.

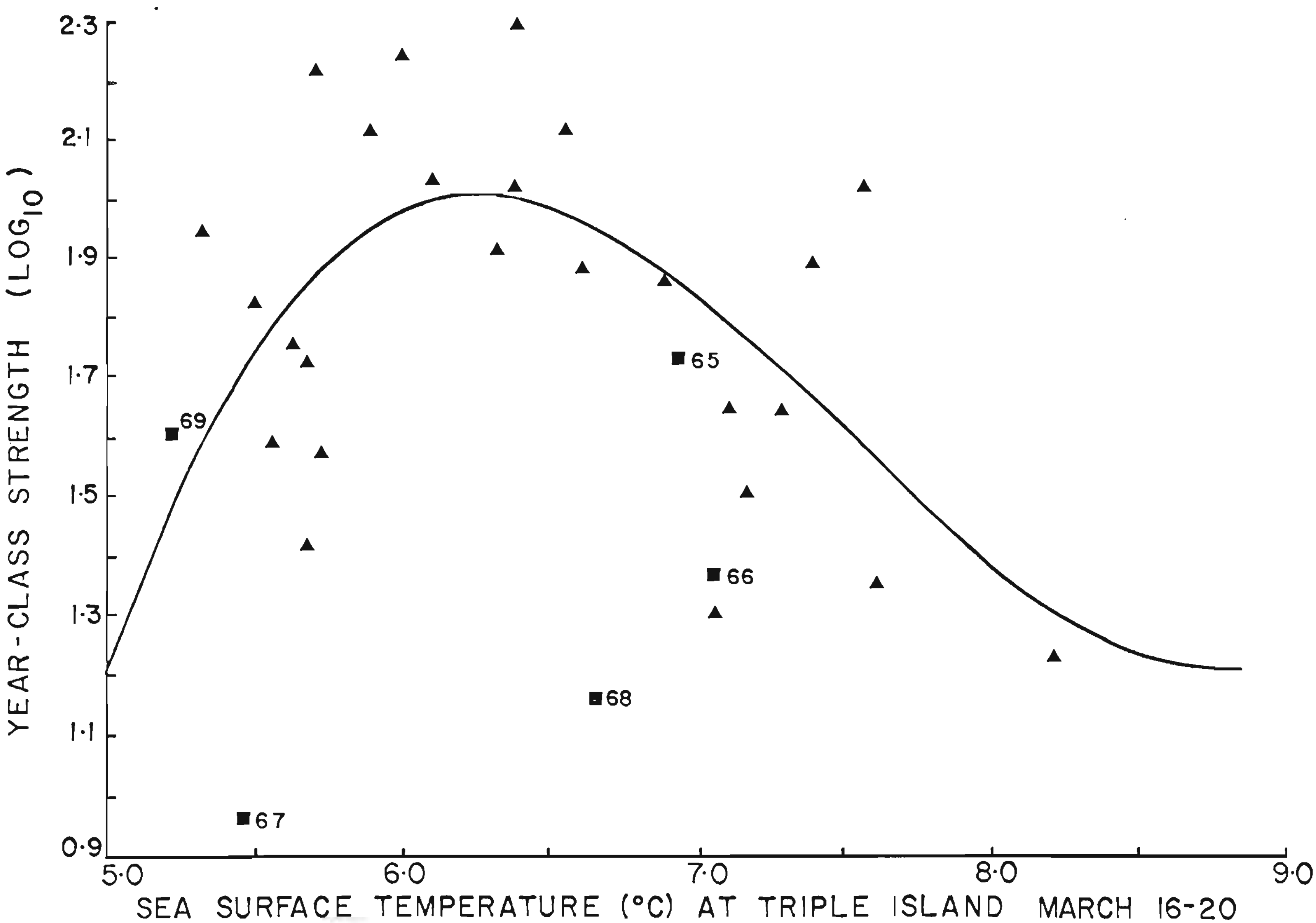

Fig 5. Plot of northern Hecate Strait rock sole year-class strength against March 16-20 mean surface seawater temperature at Triple Island.