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Groundfish Stock Assessments Off the West Coast of Canada in 1981 and Recommended Total Allowable Catches for 1982

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Nanaimo, British Columbia V9R 5K6

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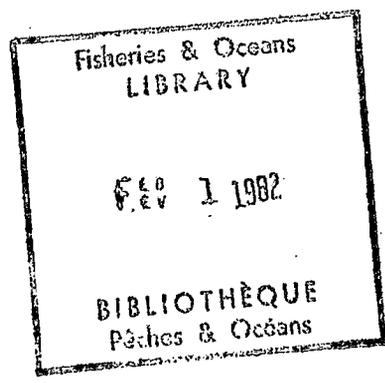
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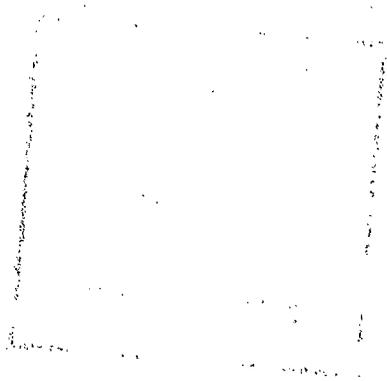
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GROUND FISH STOCK ASSESSMENTS OFF THE WEST COAST OF CANADA IN 1981
AND RECOMMENDED TOTAL ALLOWABLE CATCHES FOR 1982

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(Editor)

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ABSTRACT

Stocker, M., Editor. 1981. Groundfish stock assessments off the west coast of Canada in 1981 and recommended total allowable catches for 1982. Can. MS Rep. Fish. Aquat. Sci. 1626: xxx + 282 p.

Recommended Total Allowable Catches (TACs) for 1982, are included for commercially important groundfish stocks off British Columbia, by statistical area (3C, 3D, 4B, 5A and 5B, 5C and 5D, and 5E). These TACs are based on the best available information but many are not considered to be precise values, due to the limited information available. Total (all species, all areas) recommended TAC for 1982 is 77,160 t, compared to 86,515 t for 1981. TAC estimates for principal species in 1982 (1981 in parentheses) were: Pacific hake, 45,000 t (35,000 t); dogfish, 9,000 t (9,000 t); Pacific ocean perch, 3,900 t (4,400 t); sablefish, 3,500 t (3,500 t); yellowtail rockfish, 2,350 t (3,050 t); and arrowtooth flounder 2,200 t (3,150 t). No TACs are recommended at this time for Pacific cod and walleye pollock (except for Area 5D). However, these should be announced prior to the 1982 fishing season. For all other species, recommended TACs for 1982 were less than 1,850 t each. All-nations all-species landings from B.C. waters totalled 57,084 t in 1980, and 52,483 t in 1979.

RÉSUMÉ

Stocker, M., Editor. 1981. Groundfish stock assessments off the west coast of Canada in 1981 and recommended total allowable catches for 1982. Can. MS Rep. Fish. Aquat. Sci. 1626: xxx + 282 p.

Les totaux des prises admissibles recommandés (TPA) pour 1982 sont indiqués pour les stocks de poisson de fond de grande valeur commerciale au large de la Colombie-Britannique, par zone statistique (3C, 3D, 4B, 5A et 5B, 5C et 5D, et 5E). Ces TPA sont établis à partir des meilleurs renseignements obtenus mais on estime qu'un grand nombre ne sont pas précis, à cause de l'insuffisance des données. Le TPA global (toutes les espèces, toutes les zones) recommandé pour 1982 est de 77 160 t, contre 86 515 t pour 1981. Les TPA pour les principales espèces ont été établis comme suit pour 1982 (chiffres de 1981 entre parenthèses): merlu du Pacifique, 45 000 t (35 000 t); aiguillat, 9 000 t (9 000 t); sébaste du Pacifique, 3 900 t (4 400 t); morue charbonnière, 3 500 t (3 500 t); sébaste à queue jaune, 2 350 t (3 050 t); et flétan du Pacifique, 2 200 t (3 150 t). Aucun TPA n'est recommandé pour le moment pour la morue du Pacifique et la morue du Pacifique occidental (à l'exception de la zone 5D). Cependant, ces TPA devraient être annoncés avant la saison de pêche 1982. Pour toutes les autres espèces, les TPA recommandés pour 1982 étaient tous inférieurs à 1 850 t. En 1979 et 1980, les débarquements pour tous les pays et toutes les espèces des eaux de la C.-B. ont totalisé respectivement 52 483 t et 57 084 t.

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FOREWORD

This report was prepared by the Groundfish Program staff (Resource Services Branch), and contains proposed Total Allowable Catches (TACs) of groundfish for 1982 as recommended by scientists of the Resource Services Branch. The TACs 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

The following is a summary of recommended TACs for the 1982 groundfish fishery by major region of the British Columbia coast. It should be noted, that at this time (May 1981), no TACs have been recommended for Pacific cod.

BRITISH COLUMBIA COAST

For all but two species, 1982 TACs have been recommended for individual major statistical areas, or combinations of no more than two such areas. Sablefish and dogfish shark are the exceptions. No TAC is recommended for albacore tuna.

For sablefish, the recommended TAC for 1982 is 3,500 t, to be applied coastwide. All-nation landings off British Columbia were 3,992 t in 1980, and 3,080 t in 1979.

For dogfish, the recommended TAC for 1982 is 9,000 t coastwide, of which 3,000 t applies to Georgia Strait and vicinity (Area 4B) (Fig. 1; Table 1). Coastwide landings were 4,547 t in 1980 and 4,757 t in 1979. Most of those dogfish were caught in Area 4B in 1979, and in Areas 4B and 3C in 1980.

All-species recommended TAC for 1982 is 77,160 t compared to 86,515 t in 1981. Principal change is due to the fact that no TACs are recommended for Pacific cod and walleye pollock (except Area 5D) at this time. All-species all-nation landings from B.C. waters totalled 57,084 t in 1980, compared to 52,483 t in 1979.

GEORGIA STRAIT AND VICINITY (Area 4B)

Principal species (based on 1980 records) in the Canadian landings from Georgia Strait and vicinity were dogfish (2,108 t), Pacific cod (1,623 t), walleye pollock (1,057 t), and Pacific hake (508 t) (Table 2). Landings in 1980 did not exceed 423 t for any other species.

For Pacific hake, the recommended TAC for 1982 is 10,000 t. Trawl landings of 508 t in 1980 and 516 t in 1979 were recorded from Area 4B.

For Pacific cod, lingcod, and walleye pollock (at this time) no TAC is recommended.

SOUTHWEST VANCOUVER ISLAND (Area 3C)

Important species (based on 1980 landings) in the Canadian portion of Area 3C are Pacific hake (17,662 t), and dogfish (1,739 t) (Table 3). Secondary species are Pacific cod (979 t), lingcod (850 t), and sablefish (762 t).

For Pacific hake, the recommended TAC for 1982 is 35,000 t¹, most of which will probably be harvested by foreign vessels.

For Pacific cod, no TAC is recommended for 1982. However, if low abundance is predicted for the winter spawning stock in Area 3C, an area-time closure will be imposed, as in previous years. A prediction of the winter spawning abundance will be available early in November. Canada-U.S. landings in 1980 were 979 t.

For lingcod the recommended TAC for 1982 is 600 t. Canada-U.S. landings totalled 850 t in 1980.

For secondary species, recommended TACs in 1982 are: 500 t¹ for Pacific ocean perch (unchanged from 1981); 500 t for petrale sole (unchanged from 1981); 150 t for Dover sole (100 t in 1981); and 100 t each for S. pinniger and S. flavidus.

NORTHWEST VANCOUVER ISLAND (Area 3D)

Principal species, based on 1980 landings, were sablefish (1,119 t), rockfish other than Pacific ocean perch (1,010 t), lingcod (218 t), and Pacific cod (183 t) (Table 4). All other species amounted to less than 133 t each.

For Other rockfish, the recommended TACs for 1982 are: S. brevispinis 200 t (same in 1981); S. flavidus 200 t (same in 1981); and S. pinniger 350 t (same in 1981). Total Canada-U.S. landings were 1,010 t in 1980, and 965 t in 1979.

For lingcod, the recommended TAC for 1982 is 200 t (same in 1981). Canada-U.S. landings were 218 t in 1980, and 250 t in 1979.

QUEEN CHARLOTTE SOUND (Areas 5A and 5B)

Principal species based on Canada-U.S. landings in 1980, from Queen Charlotte Sound (Areas 5A and 5B) were Pacific ocean perch (2,104 t), Other rockfish (2,091 t), Pacific cod (1,388 t), and sablefish (771 t) (Table 5). No other species amounted to more than 647 t.

For Other rockfish, recommended TAC for 1982 is 3,850 t (4,400 t in 1981). Canada-U.S. landings were 2,091 t in 1980, and 3,673 t in 1979. Principal species is S. flavidus for which the recommended TAC for 1982 is 1,500 t (2,000 t in 1981). Recommended TACs in 1982 for secondary species are: 600 t for S. brevispinis, 500 t for S. pinniger, and 300 t for S. paucispinis. For Pacific ocean perch, the recommended TAC for 1982 is 1,000 t (1,500 t in 1981). Canada-U.S. landings were 2,104 t in 1980, and 1,549 t in 1979.

For Pacific cod no TAC is recommended for 1982. Canada-U.S. landings in 1980 were 1,388 t, and in 1979, 1,885 t. Recommended TACs in 1982 for associated species are: 400 t each for lingcod and rock sole. Canada-U.S. landings for lingcod were 450 t in 1980, and 386 t in 1979. Comparable values for rock sole were 647 t and 409 t, respectively.

¹Includes Area 3D

HECATE STRAIT AND DIXON ENTRANCE (Areas 5C and 5D)

Principal species, based on Canadian landings in 1980, were Pacific cod (4,555 t), and Pacific ocean perch (2,079 t). Secondary species were Other rockfish (1,175 t), walleye pollock (1,085 t), arrowtooth flounder (1,014 t), English sole (994 t), and rock sole (976 t) (Table 6). No other species amounted to more than 606 t.

No TAC is recommended for Pacific cod in 1982.

For arrowtooth flounder, the recommended TAC for 1982 is 2,200 t (2,100 t in 1981). Canadian landings were 1,014 t in 1980, and 1,527 t in 1979. Arrowtooth flounder are ubiquitous, and hence are associated with all important species.

For Pacific ocean perch, the recommended TAC for 1982 is 1,600 t (unchanged from 1981). Canadian landings were 2,079 t in 1980, and 268 t in 1979. For Other rockfish, recommended TAC for 1982 is 1,500 t (1,725 t in 1981). Canadian landings were 1,175 t in 1980, and 1,466 t in 1979. Recommended TACs in 1982 for individual rockfish species are: 600 t for S. brevispinis; 550 t for S. flavidus; and 350 t for S. pinniger.

For walleye pollock, the recommended TAC for 1982 is 1,000 t. Canadian landings were 1,085 t in 1980, and 1,804 t in 1979.

For secondary species, the recommended TACs for 1982 are 800 t for Dover sole; 750 t for rock sole; and 660 t for English sole. Canadian landings in 1980 (and 1979) were 606 t (633 t) for Dover sole; 976 t (1,314 t) for rock sole; and 994 t (863 t) for English sole. For rock sole, the 1982 TAC is 500 t for the area south of 53°50'N lat., and 250 t north of that latitude.

WEST COAST QUEEN CHARLOTTE ISLANDS (Area 5E)

Principal species, based on 1980 Canadian landings, are Pacific ocean perch (962 t), Other rockfish (881 t), and sablefish (803 t) (Table 7). No other species contributed more than 201 t.

For Pacific ocean perch, recommended TACs in 1982 are 600 t south of 54°N latitude, and 200 t north of 54°N. These TACs are unchanged from 1981. In addition the January-March (inclusive) closure south of 54°N is again recommended for 1982. Canadian trawl landings of Pacific ocean perch in Area 5E were 962 t in 1980, and 1,067 t in 1979.

For other rockfish, recommended TACs for 1982 are: 700 t for S. reedi; 500 t for S. aleutianus; 450 t for S. brevispinis; 400 t for S. pinniger; 300 t for S. ruberrimus; and 250 t for S. proriger.

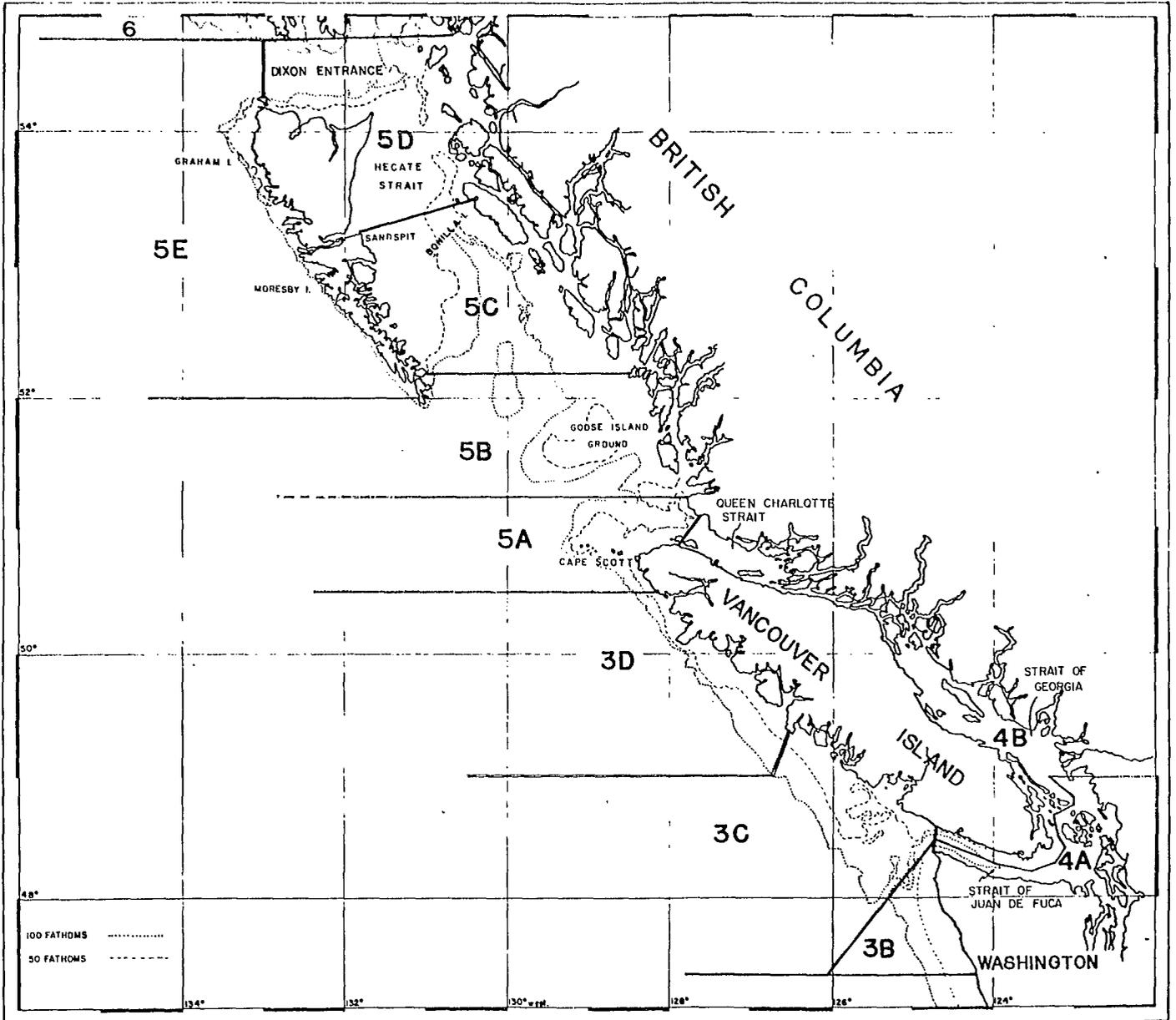


Fig. 1. International (Pacific Marine Fisheries Commission) Statistical Areas along the British Columbia coast.

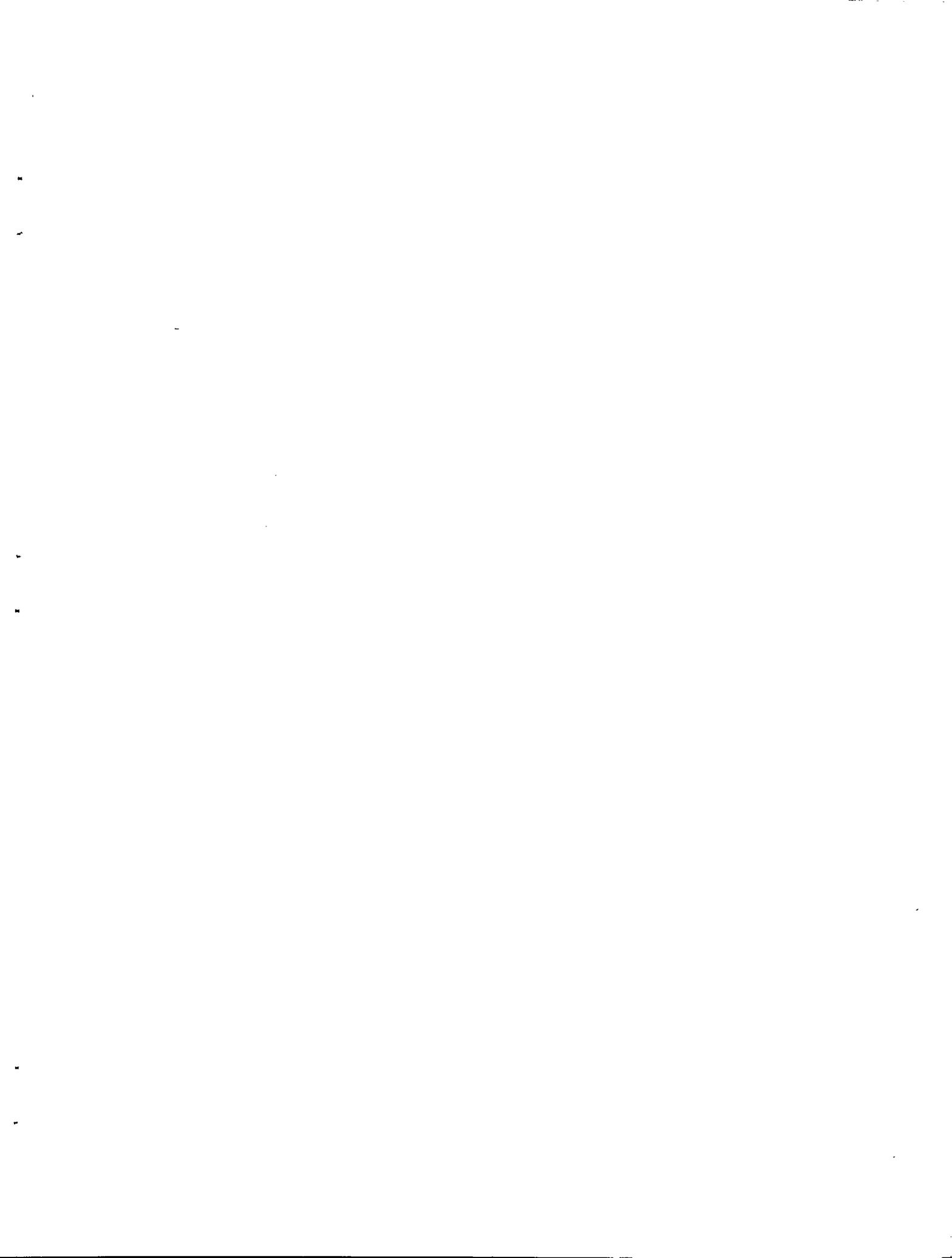


Table 1. Recommended TACs (t) in 1982 and 1981, and total landings (t) in 1980 and 1979, by species, for all areas combined.

Species	Recommended TAC (t)		Canada-U.S. ^a landings (t)	
	1982	1981	1980	1979
Pacific ocean perch	3,900	4,400	5,574.7	3,016.8
Other rockfish	8,900	10,865	5,591.6	7,507.3
<u>S. aleutianus</u>	500	450	82.3	218.0
<u>S. babcocki</u>	200	365	201.4	93.5
<u>S. brevispinis</u>	1,850	1,750	1,639.8	1,677.6
<u>S. entomelas</u>	250	550	21.3	150.1
<u>S. flavidus</u>	2,350	3,050	774.4	2,338.7
<u>S. paucispinis</u>	300	700	272.6	434.2
<u>S. pinniger</u>	1,700	1,650	869.1	912.8
<u>S. proriger</u>	500	650	130.6	89.4
<u>S. reedi</u>	950	1,200	547.3	626.6
<u>S. ruberrimus</u>	300	500	0.7	0.8
Other	-	-	1,052.1	965.6
Dogfish	9,000	9,000	4,547.1	4,757.4
Lingcod	1,200	1,300	2,204.9	2,184.2
Pacific cod	TBA ^b	6,500	8,770.0	9,691.2
Pacific hake	45,000	35,000	18,171.6 ^e	12,953.5 ^e
Sablefish	3,500	3,500	3,992.0 ^e	3,079.6 ^e
Walleye pollock	TBA ^b	9,450	2,201.1	3,391.9
Arrowtooth flounder	2,200	3,150	1,447.9	1,837.8
Butter sole	-	F ^c	0.9	-
Dover sole	1,050	810	1,273.0	880.6
English sole	660	900	1,243.9	1,074.4
Petrale sole	600	600	222.1	225.5
Rock sole	1,150	1,040	1,843.0	1,882.3
Total	77,160	86,515	57,083.8	52,482.5

^aU.S. data not available at this time for all areas and species.

^bTo be announced prior to 1982 season.

^cF = free fishing.

^eAll nations total.

Table 2. Recommended TACs (t) in 1982 and 1981, and Canadian landings (t) in 1980 and 1979, for Area 4B (Georgia Strait and vicinity), by species.

Species	Recommended TAC (t)		Canadian landings (t)	
	1982	1981	1980	1979
Pacific ocean perch	F ^a	F ^a	0.1	0.9
Other rockfish	F ^a	F ^a	200.9	350.1
<u>S. aleutianus</u>	-	-	-	-
<u>S. babcocki</u>	-	-	0.4	-
<u>S. brevispinis</u>	-	-	-	-
<u>S. entomelas</u>	-	-	-	-
<u>S. flavidus</u>	-	-	12.5	83.8
<u>S. paucispinis</u>	-	-	0.1	-
<u>S. pinniger</u>	-	-	-	0.6
<u>S. proriger</u>	-	-	-	-
<u>S. reedi</u>	-	-	-	-
Other	-	-	187.9	265.7
Dogfish	3,000	3,000	2,107.7	4,334.1
Lingcod	F ^a	F ^a	423.2	589.6
Pacific cod	TBA ^b	1,000	1,623.3	1,233.7
Pacific hake	10,000	^c	508.4	516.3
Sablefish	F ^a	F ^a	17.8	51.0
Walleye pollock	TBA ^b	3,400	1,056.5	1,342.4
Arrowtooth flounder	-	50	15.7	9.6
Butter sole	-	F ^a	-	-
Dover sole	-	40	96.5	57.7
English sole	-	90	115.5	114.7
Petrale sole	-	F ^a	2.1	2.5
Rock sole	-	20	81.4	63.6

^aF = free fishing.

^bTo be announced prior to 1982 season.

^cIncluded in coast wide TAC.

Table 3. Recommended TACs (t) in 1982 and 1981, and Canada-U.S. landings (t) in 1980 and 1979 for the Canadian portion of Area 3C (S.W. Vancouver Island), by species.

Species	Recommended TAC (t)		Canada-U.S. ^a landings (t)	
	1982	1981	1980	1979
Pacific ocean perch	500 ^b	500 ^b	285.6	80.6
Other rockfish	200	620	233.1	226.2
<u>S. aleutianus</u>	-	F ^c	5.6	0.5
<u>S. babcocki</u>	-	20	-	1.2
<u>S. brevispinis</u>	-	100	5.4	2.2
<u>S. entomelas</u>	-	100	0.2	1.6
<u>S. flavidus</u>	100	100	37.7	44.1
<u>S. paucispinis</u>	-	50	3.9	6.1
<u>S. pinniger</u>	100	100	31.2	41.6
<u>S. proriger</u>	-	50	0.3	0.9
<u>S. reedi</u>	-	50	-	1.9
<u>S. ruberrimus</u>	-	50	-	0.1
Other	-	-	148.8	126.0
Dogfish	3,000 ^b	3,000 ^b	1,739.4	283.5
Lingcod	600	600	849.8	790.0
Pacific cod	TBA ^f	1,500 ^b	978.8	1,679.3
Pacific hake	35,000	d	17,662.3 ^e	12,437.2 ^e
Sablefish	d	d	762.0	235.6
Walleye pollock	TBA ^f	700 ^b	3.48	30.6
Arrowtooth flounder	-	200	(97.2)	53.0
Butter sole	-	F ^c	(-)	-
Dover sole	150	100	(163.7)	44.5
English sole	-	40	(93.9)	60.6
Petrale sole	500	500	(115.2)	91.6
Rock sole	-	100	(109.1)	83.7

^a1980 all U.S. data not available at this time--Canadian data in parentheses.

^bIncludes Area 3D.

^cF=free fishing

^dIncluded in coastwide TAC. See text.

^eAll nations total

^fTo be announced prior to 1982 season.

^gExcludes 995 t caught during hake joint venture fishery.

Table 4. Recommended TACs (t) in 1982 and 1981, and Canada-U.S. landings (t) in 1980 and 1979 for Area 3D (N.W. Vancouver Island), by species.

Species	Recommended TAC (t)		Canada-U.S. ^a landings (t)	
	1982	1981	1980	1979
Pacific ocean perch	b	b	144.3	51.3
Other rockfish	750	1,170	1,009.9	964.8
<u>S. aleutianus</u>	-	F ^c	21.4	2.5
<u>S. babcocki</u>	-	20	8.0	14.4
<u>S. brevispinis</u>	200	200	416.4	252.6
<u>S. entomelas</u>	-	50	4.7	-
<u>S. flavidus</u>	200	200	48.4	91.8
<u>S. paucispinis</u>	-	200	111.1	79.6
<u>S. pinniger</u>	350	350	263.7	380.7
<u>S. proriger</u>	-	50	-	1.0
<u>S. reedi</u>	-	50	-	-
<u>S. ruberrimus</u>	-	50	-	-
Other	-	-	136.2	142.2
Dogfish	b	b	133.3	15.8
Lingcod	200	200	217.8	250.3
Pacific cod	TBA ^f	b	183.1	191.2
Pacific hake	b	d	-	-
Sablefish	d	d	1,118.5	387.7
Walleye pollock	-	b	3.3	0.3
Arrowtooth flounder	-	200	(9.9)	37.3
Butter sole	-	F ^c	-	-
Dover sole	100	40	(113.4)	25.3
English sole	-	F ^c	(5.4)	5.4
Petrale sole	100 ^e	100 ^e	(31.3)	23.9
Rock sole	-	b	(23.1)	11.7

^aCanada only, in parentheses.

^bIncluded in TAC for Area 3C.

^cF=free fishing

^dIncluded in coastwide TAC. See text.

^eApplies only to January-March.

^fTo be announced prior to 1982 season.

Table 5. Recommended TACs (t) in 1982 and 1981, and Canada-U.S. landings (t) in 1980 and 1979 for Areas 5A and 5B (Queen Charlotte Sound), by species.

Species	Recommended TAC (t)		Canada-U.S. ^a landings (t)	
	1982	1981	1980	1979
Pacific ocean perch	1,000	1,500	2,103.8	1,548.9
Other rockfish	3,850	4,400	2,091.0	3,672.7
<u>S. aleutianus</u>	F ^b	F ^b	1.3	5.0
<u>S. babcocki</u>	200	200	117.6	27.8
<u>S. brevispinis</u>	600	600	761.2	991.2
<u>S. entomelas</u>	250	250	11.1	138.9
<u>S. flavidus</u>	1,500	2,000	510.1	1,527.4
<u>S. paucispinis</u>	300	300	119.9	230.3
<u>S. pinniger</u>	500	500	368.5	364.4
<u>S. proriger</u>	250	250	2.5	9.4
<u>S. reedi</u>	250	250	47.4	219.3
<u>S. ruberrimus</u>	-	50	0.7	-
Other	-	-	150.7	159.0
Dogfish	F ^b	F ^b	161.6	15.4
Lingcod	400	300 ^e	449.8	386.0
Pacific cod	TBA ^h	2,000	1,387.6	1,884.9
Pacific hake	-	d	-	-
Sablefish	d	d	770.8	324.1
Walleye pollock	-	1,300	35.0	147.7
Arrowtooth flounder	-	500	(295.6)	203.1
Butter sole	-	F ^b	(-)	-
Dover sole	-	130 ^f	(92.0)	56.5
English sole	-	20	(31.4)	30.8
Petrale sole	-	F ^b	(40.0)	66.2
Rock sole	400 ^c	300 ^g	(647.3)	408.9

^aCanada only, in parentheses.

^bF=free fishing

^c200 t in 5A 200 t in 5B.

^dIncluded in coastwide TAC. See text.

^e100 t in 5A; 200 t in 5B.

^f300 t in 5A; 100 t in 5B.

^g100 t in 5A; 200 t in 5B.

^hTo be announced prior to 1982 season.

Table 6. Recommended TACs (t) in 1982 and 1981, Canadian landings (t) in 1980 and 1979 for Areas 5C and 5D (Hecate Strait), by species.

Species	Recommended TAC (t)		Canadian landings (t) ^a	
	1982	1981	1980	1979
Pacific ocean perch	1,600 ⁿ	1,600	2,079.4	268.3
Other rockfish	1,500	1,725	1,175.3	1,466.4
<u>S. aleutianus</u>	F ^b	F ^b	-	3.9
<u>S. babcocki</u>	-	75	73.4	47.0
<u>S. brevispinis</u>	600 ^k	500	337.6	379.9
<u>S. entomelas</u>	-	50	-	-
<u>S. flavidus</u>	550 ^m	550	165.7	590.2
<u>S. paucispinis</u>	-	100	37.1	114.6
<u>S. pinniger</u>	350 ^l	300	205.2	125.0
<u>S. proriger</u>	-	50	16.8	0.4
<u>S. reedi</u>	-	50	-	-
<u>S. ruberrimus</u>	-	50	-	-
Other	-	-	339.5	205.4
Dogfish	3,000	3,000	404.5	108.4
Lingcod	-	200	245.7	159.4
Pacific cod	TBA ^o	2,000	4,555.2	4,700.2
Pacific hake	-	d	0.9	-
Sablefish	d	d	320.5	234.6
Walleye pollock	1,000 ^c	3,350	1,084.5	1,804.2
Arrowtooth flounder	2,200 ^g	2,100	1,013.7	1,527.5
Butter sole	-	-	0.9	-
Dover sole	800 ^f	500 ^f	606.2	632.8
English sole	660 ⁱ	750	994.2	862.9
Petrale sole	-	-	32.7	39.2
Rock sole	750 ^h	620 ^e	976.3	1,314.3

^aNo U.S. landings.

^bFree fishing.

^cArea 5D only.

^dIncluded in coast wide TAC. See text.

^e320 t south of 53°50'; 300 t north of 53°50'.

^fIncludes areas 5C, 5D, and 5E.

^g200 t in 5C; 2,000 t in 5D.

^h500 t south of 53°50'; 250 t north of 53°50'.

ⁱ70 t in 5C; 590 t in 5D.

^k400 t in 5C; 200 t in 5D.

^l250 t in 5C; 100 t in 5D.

^m200 t in 5C; 350 t in 5D.

ⁿ1,500 t in 5C; 100 t in 5D.

^oTo be announced prior to 1982 season.

Table 7. Recommended TACs (t) in 1982 and 1981, and Canadian landings (t) in 1980 and 1979 for Area 5E, by species.

Species	Recommended TAC (t)		Canadian landings (t) ^a	
	1982	1981	1980	1979
Pacific ocean perch	800 ^b	800 ^b	961.5	1,066.8
Other rockfish	2,600	2,950	881.4	827.1
<u>S. aleutianus</u>	500 ^h	450 ^c	54.0	206.1
<u>S. babcocki</u>	-	50	2.0	3.1
<u>S. brevispinis</u>	450 ⁱ	350	119.2	51.7
<u>S. entomelas</u>	-	100	5.3	9.6
<u>S. flavidus</u>	-	200	-	1.4
<u>S. paucispinis</u>	-	50	0.5	3.6
<u>S. pinniger</u>	400 ^k	400	0.5	0.5
<u>S. proriger</u>	250 ^k	250	111.0	77.7
<u>S. reedi</u>	700 ^d	800	499.9	405.4
<u>S. ruberrimus</u>	300 ^k	300	-	0.7
Other	-	-	89.0	67.3
Dogfish	-	-	0.6	0.2
Lingcod	-	-	18.6	8.9
Pacific cod	F	F	42.0	1.9
Pacific hake	-	e	-	-
Sablefish	e	e	803.4	817.6
Walleye pollock	-	700 ^f	18.4	66.7
Arrowtooth flounder	-	100 ^f	15.8	7.3
Butter sole	-	-	-	-
Dover sole	g	g	201.2	63.8
English sole	-	-	3.5	-
Petrale sole	-	-	0.8	2.1
Rock sole	-	-	5.8	0.1

^aNo U.S. landings.

^b600 t south of 54°; 200 t north of 54°.

^c250 t south of 54°; 200 t north of 54°.

^d600 t south of 54°; 100 t north of 54°.

^eIncluded in coastwide TAC. See text.

^fAll of Area 5E.

^gIncluded in TAC for Area 5C and 5D.

^h250 t north of 54°; 250 t south of 54°.

ⁱ100 t north of 54°; 350 t south of 54°.

^kSouth of 54°.

ACKNOWLEDGMENTS

This document is the third report containing comprehensive assessments of all commercially important groundfish stocks off the west coast of Canada together with recommendations on catch limits, this time for 1982. It also presents the efforts of the entire Groundfish Section staff (Resource Services Branch). Principal contributors are C.P. Archibald, R.J. Beamish, A.J. Cass, J. Fargo, R.P. Foucher, D. Fournier, C. Houle, K.S. Ketchen, R. Kieser, L. Lapi, B.M. Leaman, G.A. McFarlane, M. Stocker, F.H.C. Taylor, J.M. Thompson, and S.J. Westrheim. 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.

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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.

This report is the third in the new series which provides a comprehensive assessment of almost all commercially important groundfish stocks in Canadian waters. Contained herein are compilations and analyses of available, pertinent data, and recommended Total Allowable Catches (TACs) for the 1982 season.

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,² which on the basis of biological

²The term "catch" is conventionally, but at times inaccurately, used as a synonym for landings. More accurately the term net catch should be used, because in almost all groundfish fisheries, some of the catch is discarded at sea (undersized, or unsaleable at the time), and rarely is accurate information on gross catch available. Hence TAC (Total Allowable Catch) and CPUE (Catch per unit effort) usually would more accurately be referred to as TAL (Total Allowable Landing) and LPUE (Landing Per Unit Effort).

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 species/stocks; 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 greater 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 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 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 mathematical modelling to arrive at TAC recommendations, which is not to say that the conclusions are necessarily any more reliable than those reached by other 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 stocks 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 secondary species in what may appear to be trivial amounts but which, in fact, constitute overfishing. In such cases TACs are fully warranted for both primary and secondary species. For other minor species which perhaps are underfished, our recommended TACs should be merely regarded as an acknowledgment 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, one of the more important species in the Canadian groundfish fishery, is subject to highly variable short-term fluctuations in abundance which are as yet unpredictable (see Fig. 6.1.2). No reasonable estimates of TACs are possible at present. Hence, other measures of control must be imposed when necessary. The absence of recommended TACs does not imply that respective fisheries are uncontrolled. In-season monitoring will be maintained, and anomalous changes in effort and/or landings will be reviewed promptly, and appropriate corrective action taken if necessary. An area-time closure has already been used in Area 3C to prevent overfishing during the current low cycle of abundance.

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 now 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.

Most groundfish species in British Columbia waters comprise relatively isolated regional groups--for example the Pacific cod of Hecate Strait, Queen Charlotte Sound, Strait of Georgia, and Southwest Vancouver Island. Also, regional differences in abundance of most groundfish species cause their relative importance to vary among regions--for example, rock sole which is relatively important only in Hecate Strait and Queen Charlotte Sound. From a biological and management standpoint, it therefore seems appropriate to organize this report by region rather than by species.

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 1982 fishery.

1. GENERAL BIOLOGICAL NOTES ON SPECIES SUPPORTING THE GROUND FISH FISHERY

In this report we shall be dealing with about 20 separate species of groundfish and an even greater number of stocks. To minimize unnecessary repetition and confusion for the reader it has been deemed desirable to summarize here the general biological features of each species or group of species to be discussed and thus clear the way for the stock assessment portion of the report.

1.1 Pacific cod (*Gadus macrocephalus*)

Pacific cod, the long-time mainstay of the domestic trawl fishery is the only true cod in the North Pacific and is similar in appearance to its more famous cousin in the North Atlantic. In Canadian waters it is close to the southern limit of its range and occupies intermediate depths along the continental shelf. It is fast-growing and short-lived. Pacific cod reach commercial size as 2-3-yr-olds and mature at about the same age. Few cod live beyond 5 or 6 years of age as the natural mortality rate is relatively high (possibly as much as 50% per year). With few age groups, cod populations exhibit considerable instability. Large and almost cyclical fluctuations in abundance have a profound effect on the annual success of fishing. As yet these fluctuations cannot be reliably predicted. The largest of at least 6 stocks occurs in Hecate Strait.

1.2 Pacific hake (*Merluccius productus*)

The Pacific hake, long regarded as a nuisance fish of no commercial value, is now sought after by both domestic and foreign fleets. Canadian trawlers handle more of this species than any other but most is transferred to foreign factory ships. What is currently regarded as a single large stock occurs along the open coast from California to British Columbia. There are seasonal north-south migrations with only the larger, older (mostly female) hake moving into the Canadian zone. In 1979 their modal length was 54 cm and most were 9 yr old. Few fish younger than 6 yr were caught.

A separate but smaller stock occurs in the Strait of Georgia. The growth rate there is slower than that in the offshore stock. Juvenile hake reach a length of about 33 cm after 3 yr, and mature and spawn for the first time at age 4 yr. Average size in the 1979 fishery was 44 cm with corresponding average age of 6 yr. Few hake exceed 50 cm in length but some live as long as 21 yr.

The Pacific hake spends most of its life in midwater. It spawns there also in late winter releasing pelagic (floating) eggs. The fishery in the Strait of Georgia takes place on pre-spawning or spawning concentrations, whereas the offshore fishery (in the Canadian zone) takes place mainly in summer when the hake are in a resting condition. Spawning takes place in winter off southern California.

1.3 Walleye pollock (*Theragra chalcogramma*)

Like the hake, the walleye pollock is a new-comer to the trawl fishery for foodfish. It occurs in both midwater and on the bottom at intermediate depths. There appear to be several stocks in the Canadian zone, but as yet their inter-relationships are not fully understood. For example it is possible that one or both of the stocks/populations of adults which spawn

(in midwater) in the Strait of Georgia may make their way out of the Strait to the west coast of Vancouver Island in spring and summer.

Like Pacific cod, pollock off British Columbia are near the southern limit of their range. Life span is relatively short; maturity is reached in 2-4 yr; there are as few as 3-5 year-classes in unexploited stocks; natural mortality rate is relatively high (about 45%) and there are substantial variations in recruitment. These factors produce much instability in the populations and thus make difficult the prediction of abundance and setting of appropriate TACs.

1.4 Rockfishes (Sebastes spp.)

Rockfishes constitute a large and complex portion of west coast bottomfish resources. There are more than 30 species of which at least 7 are of importance to the domestic trawl fishery. As a group they are characterized by slow growth; a prolonged period of immaturity (11-13 yr); an even longer time to become fully recruited to the fishery (13-15 yr); an extended life span in which, depending on species, an age of 50-60 yr is not uncommon, and by a natural mortality rate which in most species is probably less than 5% per annum.

Although composed of many age groups, rockfish stocks are highly vulnerable to over-exploitation. Indeed, many were decimated during the years when uncontrolled foreign fleets were present off British Columbia (1965-76). Particularly hard hit were stocks of Pacific ocean perch off Dixon Entrance, off the west coast of Vancouver Island and in Queen Charlotte Sound.

Rockfishes as a group occupy a wide range of depths but as individual species occupy more restricted ranges from intermediate depths on the continental shelf (73-110 m; 40-60 fm) to the upper continental slope (183-457 m; 100-250 fm). They overlap in their distributions with each other, but more importantly with other species requiring quite different (conflicting) management policies.

For most rockfish species the basic biological parameters are not well known (particularly the relationship between spawning stock and recruitment) because it was not until recent years that rockfishes other than Pacific ocean perch became of economic importance to Canadian fishermen and hence warranted priority for investigation. Such information is needed to determine the level of fishing which can be tolerated while still allowing for a practical rehabilitation schedule.

1.5 Flatfishes (Pleuronectid spp.)

Included in the flatfish group are rock sole, English sole, petrale sole, Dover sole and turbot (halibut is excluded because research and management are in the hands of an international commission). They are bottom dwelling species found in wide depth ranges from shallow (18 m; 10 fm) to very deep (>366 m; >200 fm) water. All spawn during mid-to-late winter months, and, with the exception of rock sole, produce free-floating eggs. The planktonic larvae of these flatfishes undergo metamorphosis, wherein the left eye migrates to the right side of the body before settling to the bottom, blind side down.

As a group, flatfishes are characterized by moderate growth rates: age at first capture is 2-3 yr; age at first maturity is 3-7 yr; natural mortality rate is relatively low and life span is 15-40 yr. Several to many age groups contribute to the catch each year. Thus abundance does not fluctuate as wildly as that of such species as cod and pollock, although fluctuations in individual year-classes are known to occur. Long-term natural fluctuations in abundance affect some species such as the petrale sole which has been virtually absent from Hecate Strait for more than two decades.

1.6 Sablefish (*Anoplopoma fimbria*)

The sablefish or blackcod spends the first 2 or 3 years of its life on the continental shelf often being encountered in shallow or surface waters. It then migrates to deep water along the continental slope where it matures at an age of about 5 yr. It becomes fully recruited to the marketable size range at about 10-13 yr. Results of extensive tagging are still too incomplete to determine the number of stocks inhabiting the B.C. area. Recent improvement in the technique of age determination has revealed a much slower growth rate than previously estimated. Natural mortality rate may be no more than 15% per annum, and fish of up to 50 yr have been found in commercial landings. Like rockfishes, then, the sablefish may be very sensitive to overfishing. Recruitment appears to be highly variable, but lack of a long series of observations prevents interpretation of its year-to-year effect on stock abundance.

1.7 Lingcod (*Ophiodon elongatus*)

The lingcod is widely distributed along the continental shelf from Mexico to the western Gulf of Alaska, but the centre of abundance appears to be off British Columbia. It occurs from the inter-tidal zone to depths of 366 m (200 fm).

Spawning occurs on rocky bottom where eggs are laid in clusters and defended by the male. After a 2-3 month pelagic stage, larval lingcod assume a bottom-dwelling life. Growth rate is relatively rapid in the early years of life and entry into the commercial fishery occurs at 3-5 yr of age. The majority of lingcod mature at 4-5 yr of age, or a length of 65-76 cm. They cease to be of significance in commercial landings beyond the age of 10-12 yr, but may live as long as 18 yr.

Tagging results of adults suggest that the species is relatively non-migratory, thus it is likely that the resource consists of numerous local stocks.

Lingcod are fished commercially in Canadian waters primarily by bottom trawl and handline or troll methods. During 1968-79 lingcod comprised an average of 11% of the total groundfish landings excluding halibut. Over its long history dating from the early years of this century, the commercial fishery has evolved from a traditional handline fishery to a trawl-oriented fishery in most areas. However, the bulk of commercial landings from the Strait of Georgia is still caught by line gear. As well as being of commercial interest lingcod are also landed by recreational fishermen using jig, troll and spear fishing gear.

1.8 Spiny dogfish (*Squalus acanthias*)

The spiny dogfish occurs in the northeastern Pacific from southern California to the Gulf of Alaska, but is most abundant from southern Oregon to Dixon Entrance.

Dogfish have been fished commercially for over 100 years beginning in the 1870s when the liver and body oils were used as a lubricant and fuel for lamps. The major fishery occurred between 1937 and 1949 as a result of a strong market for dogfish livers as a source of Vitamin A. From 1950 to about 1975 the resource remained virtually unexploited. With the development of foodfish markets abroad, dogfish landings increased from 1976 to 1979, but decreased in 1980 as a result of a decline in market conditions.

Dogfish are characterized by slow growth, a low birth rate and a long life-span. The young are born after a uniquely long gestation period of nearly 2 yr. Males mature at a length of 72 cm (16 yr) and age at first maturity for females appears to be about 25 yr (90 cm). During the 1979 fishery in the Strait of Georgia the average size was 84 cm and 102 cm for males and females respectively. The average age was 35 yr, however fish older than 60 yr were not uncommon. Elsewhere along the coast, especially in Hecate Strait, the species remains unexploited and interferes with the prosecution of other commercial fisheries. The impact of dogfish as a predator on other groundfish and herring is not fully understood.

As the dogfish has a low rate of reproduction, it is extremely sensitive to overfishing and a rational approach to exploitation requires careful monitoring of the harvest.

1.9 Albacore (*Thunnus alalunga*)

Although the albacore is far from being a groundfish--indeed it is one of the widest ranging pelagic species of the world--it is included with the groundfish group as a matter of administrative convenience, in consideration of coastal fish stocks other than salmon and herring that require or may soon require management measures.

Albacore which appear in late summer to autumn off the British Columbia coast are believed to be part of a single stock ranging across the Pacific to southern Japan. Migrants along the North American coast are all juveniles of 2-4 years of age and weigh 5-14 kg. They reach maturity at about age 6 and spawn in sub-tropical waters mainly to the west of Hawaii. Mature fish are caught with deep longlines and reach an age of more than 10 yr and a weight of over 40 kg.

2. COASTWIDE STOCK ASSESSMENTS

2.1 Sablefish

2.1.1 Introduction

The changeover from a foreign longline fishery to a domestic trap fishery has created a problem in the assessment of sablefish stocks. The lack of a time-series of catch per unit effort data and age data eliminates the possibilities of general production modelling and cohort analysis. Prior to 1980, there was sufficient Japanese longline information to attempt general production modelling (Ketchen 1980a; Westrheim 1980) and the quota which was obtained using these models has been retained since 1978. There is evidence of a strong-year class being recruited to the fishery which may affect the stock abundance in the near future.

2.1.2 Catch statistics

An increase in domestic trap catches of sablefish was concurrent with the elimination of the Japanese longline fishery. The first year in which the total quota of 3,500 t was taken by Canadian boats was in 1980. The quota was actually exceeded before the end of the year by ~ 500 t due to the difficulty of closely monitoring a trap fishery and the allowance of a 200 t quota to the Japanese longline fishery.

Trap catches increased by 220% from 1979 to 1980 and composed 80% of the 1980 all-nation catch as compared to 42% of the 1979 all-nation catch (Table 2.1.1). Before 1978 the trap catches were taken with a Canadian-style trap and were insignificant compared to the Japanese longline fishery but it appears that the future catches will be taken mostly by Korean traps. Licensing of longline and trap vessels fishing for sablefish began in 1981 and 27 of the 39 vessels licensed before May 30, 1981 use trap gear. CPUE information for Korean trap gear is only available from 1978 (Table 2.1.1).

Japanese catch and effort statistics for the 1968-1980 longline fishery are included (Table 2.1.2) for reference. This fishery was completed at the end of 1979 but 200 t were allocated in 1980 in exchange for experimental work on a potential B.C. squid fishery. Total catches of sablefish by all nations and all gears since 1964 are presented in Table 2.1.3.

2.1.3 CPUE

Accurate catch and effort statistics for the Canadian trap fishery are scanty and until 1977 no concerted attempt was made to collect this information. The change from Canadian rectangular traps to Korean conical traps around 1978 created a situation in which we have at this time only 4 years of catch and effort data for the principal gear type to be used in the future fishery by the domestic fleet. The change-over was so complete that we have very little information to standardize the two types of traps (Table 2.1.1).

The CPUE from 1979-1981 has varied from 15.1-19.4 kg/(Korean) trap (Table 2.1.4). The data for 1978 and 1981 are incomplete and is probably not representative of the annual catch and CPUE for Korean traps. (However, the catch and CPUE for all areas for 1978 and 1981 are included in Fig. 2.1.1 for

comparison). Although there appears to be a change in the CPUE within Areas 5B and 5E between 1979 and 1980, the CPUE for the whole coast is quite similar--16.0 kg/trap for 1979 and 15.1 kg/trap for 1980 (Fig. 2.1.1).

2.1.4 Age composition of the sablefish stock

It has been quite evident in the last few years that a strong 1977 year-class is present in Canadian waters (Table 2.1.5). These fish began to appear in 1980 in the offshore trap catches off the Queen Charlotte Islands and off Vancouver Island but not in trap catches in Queen Charlotte Sound (Fig. 2.1.2). Recoveries in 1980 and 1981 of the juveniles tagged and released in Hecate Strait, Queen Charlotte Sound and the central inlets of B.C. indicate that these fish are moving offshore in the Canadian zone and to Alaska and California (Table 2.1.6; Fig. 2.1.3).

Age composition data collected in 1980 indicates that the age of full recruitment was 12-13 yr (Fig. 2.1.4). This may mean that fish are gradually recruited into the fishery over 2-10 yr or that this age group (12-13-yr-olds) is another strong year-class which has dominated the age composition over the last decade. Results from juvenile tagging experiments begun in 1979 should indicate which of the above possibilities is true.

2.1.5 Stock assessment

Prior to 1980, stock assessments and predicted maximum sustainable yields were based on the Japanese longline fishery. General production modelling of the catch and CPUE resulted in a recommended quota of 3,500 t for sablefish (Westrheim 1980, Ketchen 1980a).

The sablefish fishery's statistics are now based on the trap fishery for which there are not enough data available to use general production models. There is no evidence of a strong increase or decrease in the stock as a whole, from the available statistics. The strong 1977 year-class may create a situation of high abundance upon full recruitment, however the stock should not necessarily be fished heavily because of its presence.

2.1.6 Management recommendations

The recommended TAC for sablefish should remain at 3,500 t for 1982 for all areas and all gears. The strategy for the best harvest of the recruiting 1977 year-class has not been developed yet and therefore the quota should not be raised on the assumption that the stock abundance will increase in the next few years. The quota was originally based on the assessment of the Japanese longline fishery from 1968-1978 and a conservative approach was taken at that time. If the decrease in Japanese CPUE in 1979 and 1980 (Table 2.1.2) is real and not a result of misreporting then it would appear that the quota may have been too high. However, until we have more information on Canadian CPUE, the composition of the stock and the biology of the fish, the quota should remain at this best estimate and catch rates should be monitored closely.

Table 2.1.1. Canadian sablefish trap fishery statistics--Canadian rectangular collapsible traps and Korean conical traps, 1971-1981.

Year	All-nation catch		Monitored catch (t)		Monitored Effort (traps)		CPUE (kg/trap)	
	all gear catch (t)	domestic trap catch (t)	Canadian traps	Korean traps	Canadian traps	Korean traps	Canadian traps	Korean traps
1971	3,487	? ^a	15	-	397	-	38	-
1972	5,840	? ^a	34 ^b	-	552	-	61	-
1973	3,976	732	133	-	2,556	-	52	-
1974	4,612	318	124 ^b	-	1,993	-	62	-
1975	6,741	458	79	-	2,185	-	36	-
1976	6,702	334	132 ^b	-	2,379	-	55	-
1977	5,041	215	101 ^b	-	1,916	-	53	-
1978	3,555	635	132	369	2,287	20,060	58	18.4
1979	3,542	1,477	209	945	6,580	59,201	32	16.0
1980	3,992	3,211	-	2,373	-	157,170	-	15.1
1981 ^c	549	538	-	538	-	27,796	-	19.4

^aCatch by trap not separated from other gear in catch statistics.

^bEstimated total.

^cTotals until April 24.

Table 2.1.2. Sablefish catch (t) and effort (10-hachi) statistics for the Japanese longline fishery in Canadian waters (48°00'-54°30'N lat.), 1968-1980.

Calendar year	Reported Catch (t) ^{a, b}	Best estimate of catch (t)	Effort (10-hachi)	Best estimate of CPUE (t/10-hachi)
1968	1,454	1,454	5,573	0.261
1969	4,224	4,224	22,412	0.207
1970	4,919	4,919	22,886	0.215
1971	2,721	2,721	16,774	0.162
1972	3,491	3,491	16,831	0.207
1973	2,585	2,585	12,367	0.209
1974	3,527	3,527	16,765	0.210
1975	4,433	4,433	22,807	0.194
1976	3,209	3,209	16,519	0.194
1977	2,982	3,440 ^c	20,260	0.170
1978	2,091	2,405 ^c	13,396	0.180
1979	1,068	1,112 ^c	8,362	0.133
1980	199	199	1,506	0.132

^a1968-76 statistics from U.S. National Marine Fisheries Service computer printouts.

^b1977-1980 statistics from fishing log books.

^cReported catches increased by using percent recovery rates calculated by observers on board vessels.

Table 2.1.3. Sablefish catch (t) by nation (all fishing gears) in British Columbia waters, 1964-1980.

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	1,189	-	-	1,647
1968	465	65	2,271	-	-	2,801
1969	312	43	4,712	-	-	5,067
1970	257	104	5,119	-	-	5,480
1971	314	161	3,012	-	-	3,487
1972	1,086	582	4,172	-	-	5,840
1973	938	82	2,950	-	-	3,976
1974	482	70	3,866	65	129	4,612
1975	892	126	4,460	0	1,263	6,741
1976	771	217	3,379	0	2,335	6,702
1977	1,088	345 ^e	3,440 ^d	0	168 ^d	5,041
1978	831	319 ^e	2,405 ^d	-	-	3,555
1979	2,031	399 ^e	1,112 ^d	-	-	3,542
1980	3,793	?	199	-	-	3,992

^aCan. Dept. Fish., B.C. Catch Statistics (1965-78) and Fish. Res. Board Canada, Catch and effort statistics of the B.C. trawl fishery, (1967-1978).

^bKetchen (1977).

^cINPFC statistical bulletins including unpublished data for 1975 and 1976.

^dBest estimate of catch using fishing log books from foreign vessels plus observer information. These figures differ from previously published estimates (Ketchen 1980a) as a result of a change in conversion rates.

^ePMFC data series.

Table 2.1.4. Canadian CPUE for Korean trap sablefish catch (t) and effort (traps) in 1979, 1980 and 1981 (incomplete) from monitored landings.

AREA	Catch (t)			Effort (traps)			CPUE (kg/trap)		
	1979	1980	1981	1979	1980	1981	1979	1980	1981
3C	94.5	418.3	53.6	7,862	29,841	3,855	12.0	14.0	13.9
3D	84.6	646.9	81.5	7,703	42,291	8,565	11.0	15.3	9.5
5A	118.4	213.4	62.9	7,774	14,048	3,010	15.2	15.2	20.9
5B	67.2	417.4	111.4	5,221	21,390	3,680	12.9	19.5	30.3
5E	580.7	676.8	228.9	30,641	49,600	8,686	19.0	13.6	26.4
Total	945.4	2,372.7	538.3	59,201	157,170	27,796	16.0	15.1	19.4

Table 2.1.5. Reported Canadian sablefish discards (t), 1977-81.

Year	Area								Total
	4B	3C	3D	5A	5B	5C	5D	5E	
1977	-	-	2.7	-	-	-	9.1	-	11.8
1978	6.8	63.8	-	86.1	101.8	8.6	89.9	.4	357.5
1979	4.2	383.0	24.6	160.6	298.1	271.9	942.1	5.1	2089.6
1980	3.3	281.3	83.7	34.7	307.2	107.0	663.3	22.0	1502.6
1981 ^a	-	0.2	0.5	0.8	0.1	1.4	51.2	2.8	56.9

^a Until April 24.

Table 2.1.6. Recoveries of juvenile sablefish released in 1979 and 1980 in British Columbia waters.

Release Area	Number Released	Number Recovered						
		Hecate Strait	Queen Charlotte Sound	Central Inlets	West Coast of Queen Charlotte Islands	West Coast of Vancouver Island	Gulf of Alaska	California
Hecate								
Strait	21,511	58	3	0	1	0	1	0
Queen								
Charlotte								
Sound	15,109	7	62	0	7	2	1	1
Central								
Inlets	7,019	1	0	473	4	0	0	0

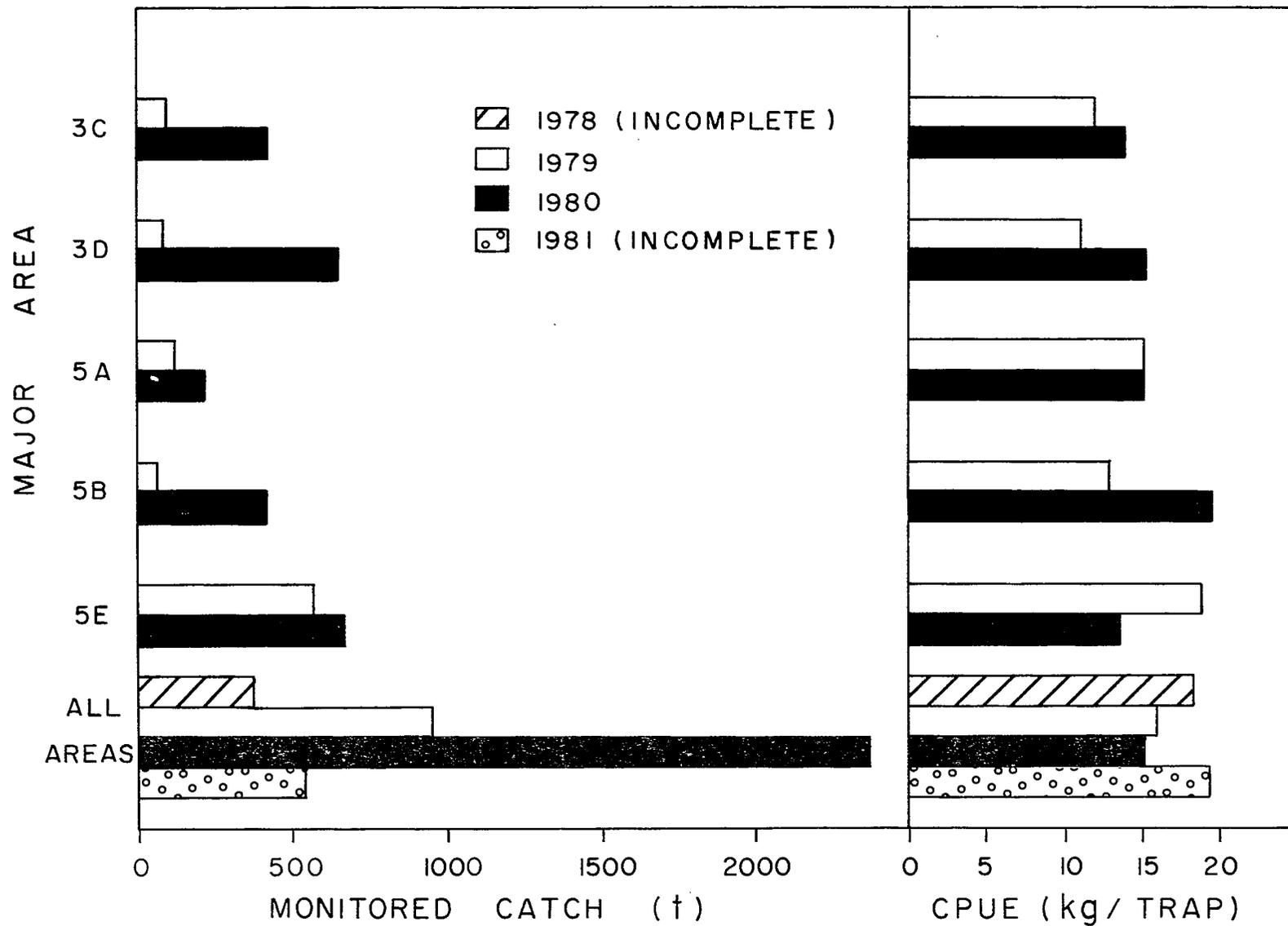


Fig. 2.1.1. Canadian catch (t) and CPUE (kg/trap) for offshore areas of the B.C. coast, monitored landings of Korean trap catch only.



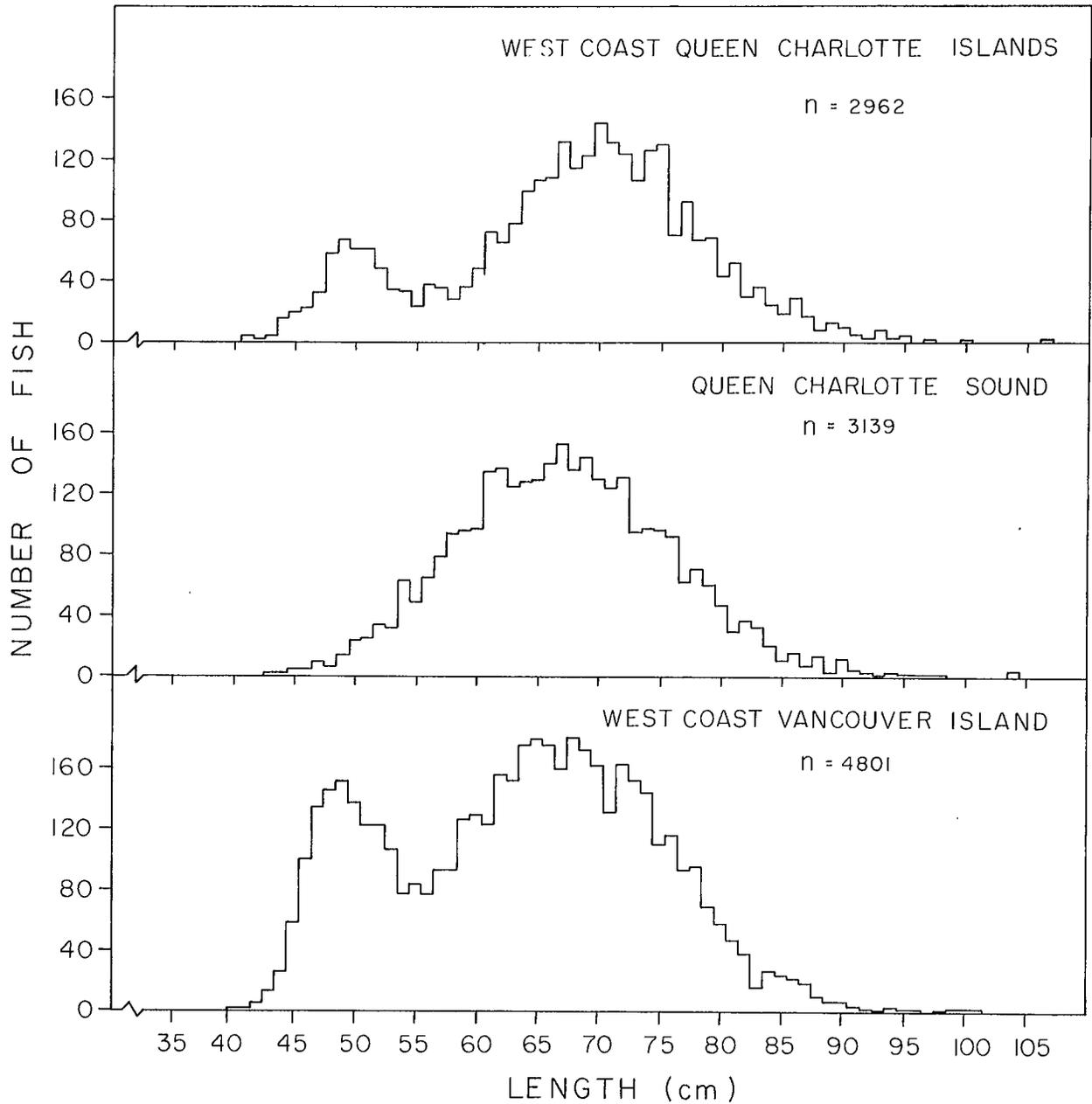
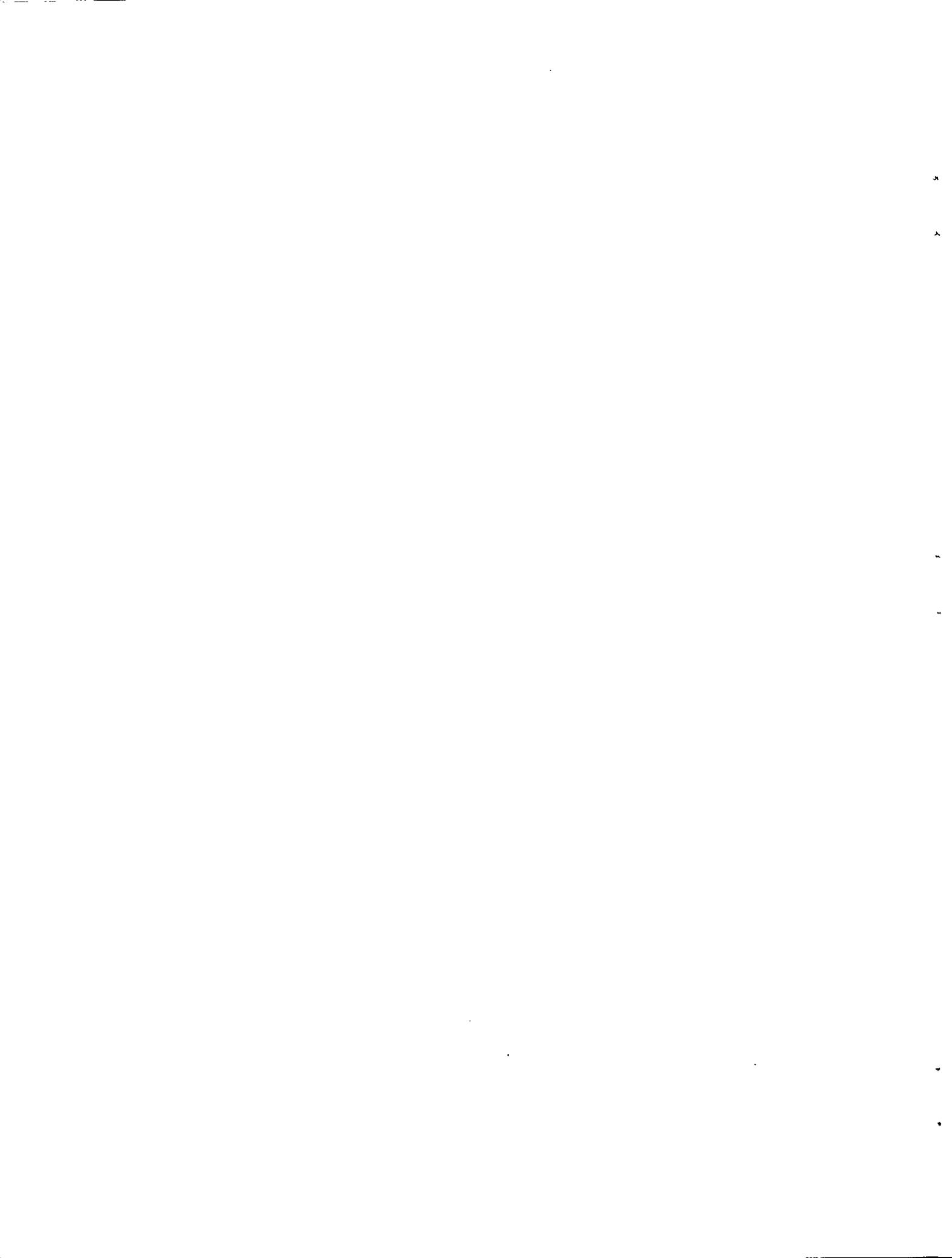


Fig. 2.1.2. Sablefish length frequencies from research cruises illustrating recruitment of 1977 year-class to offshore commercial fishing areas in January to March 1980.



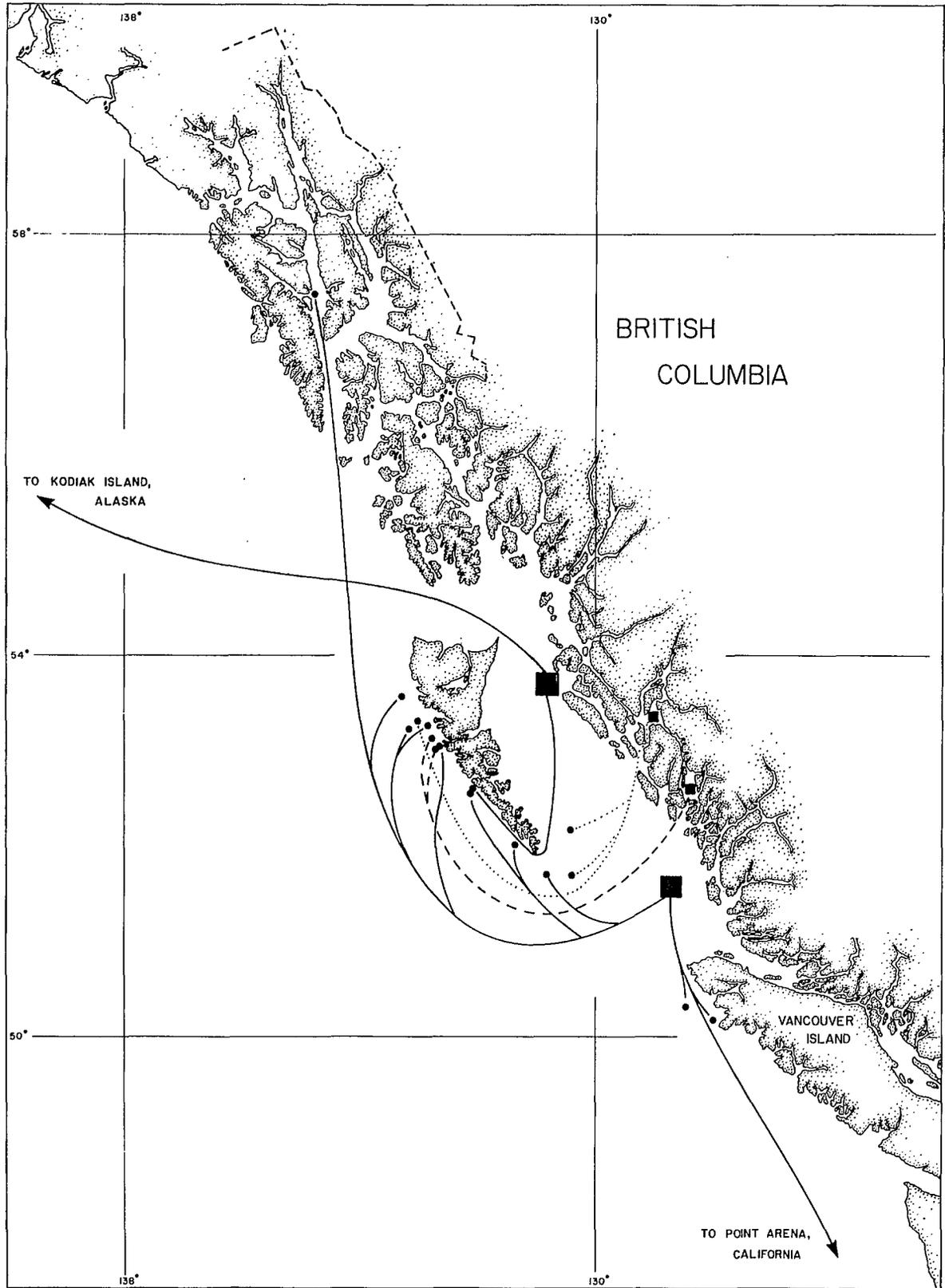
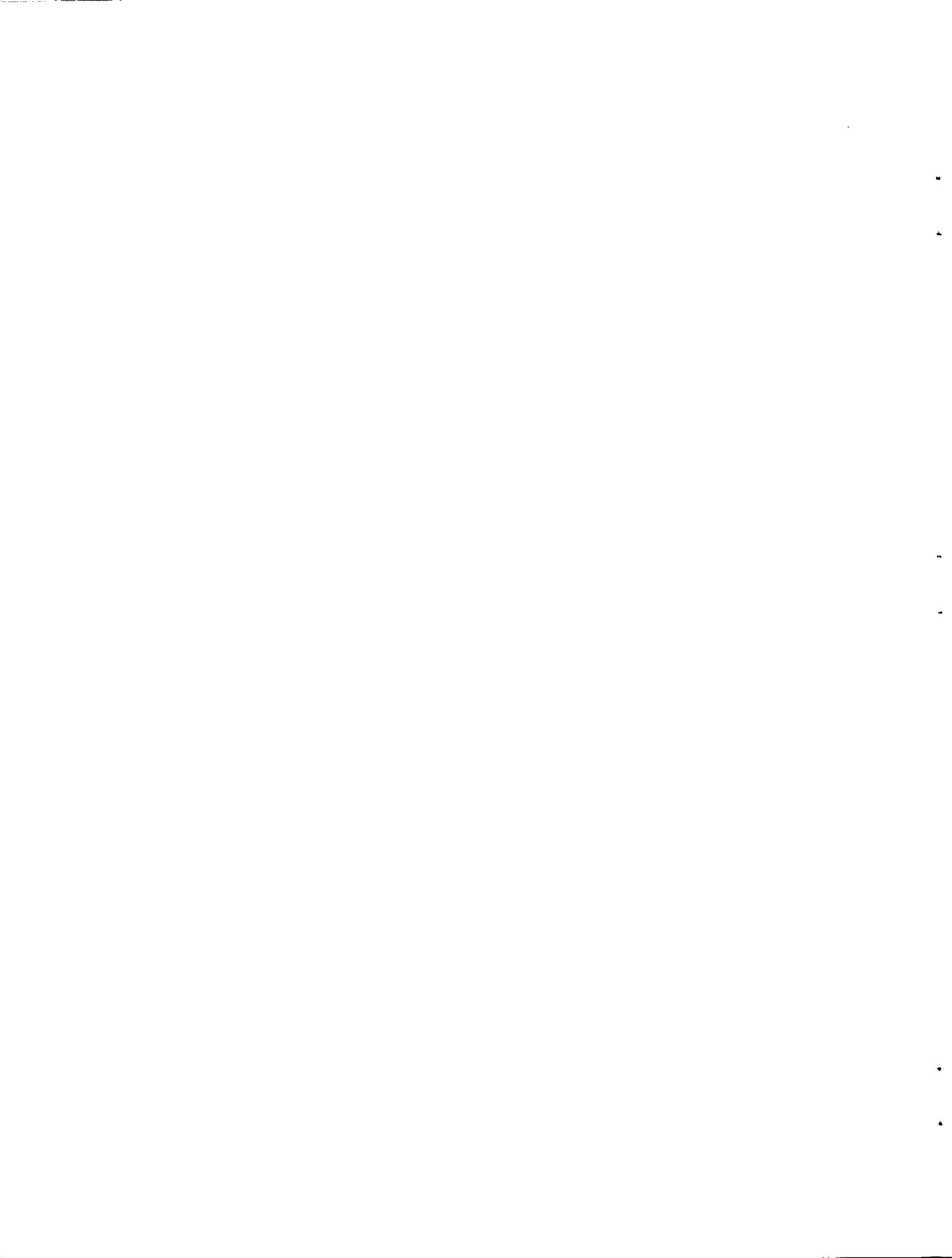


Fig. 2.1.3. Movement of tagged juvenile sablefish within two years of release.



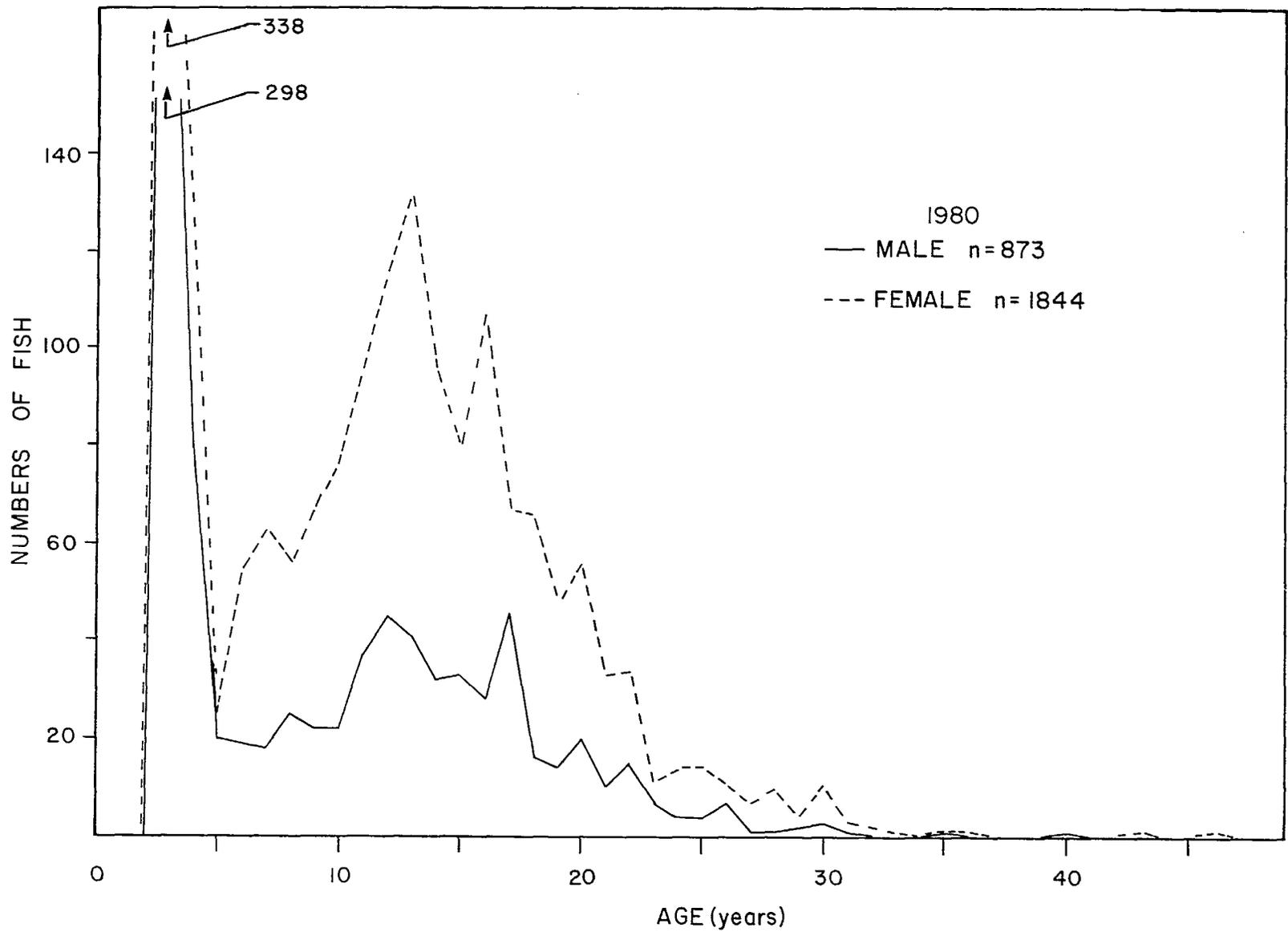
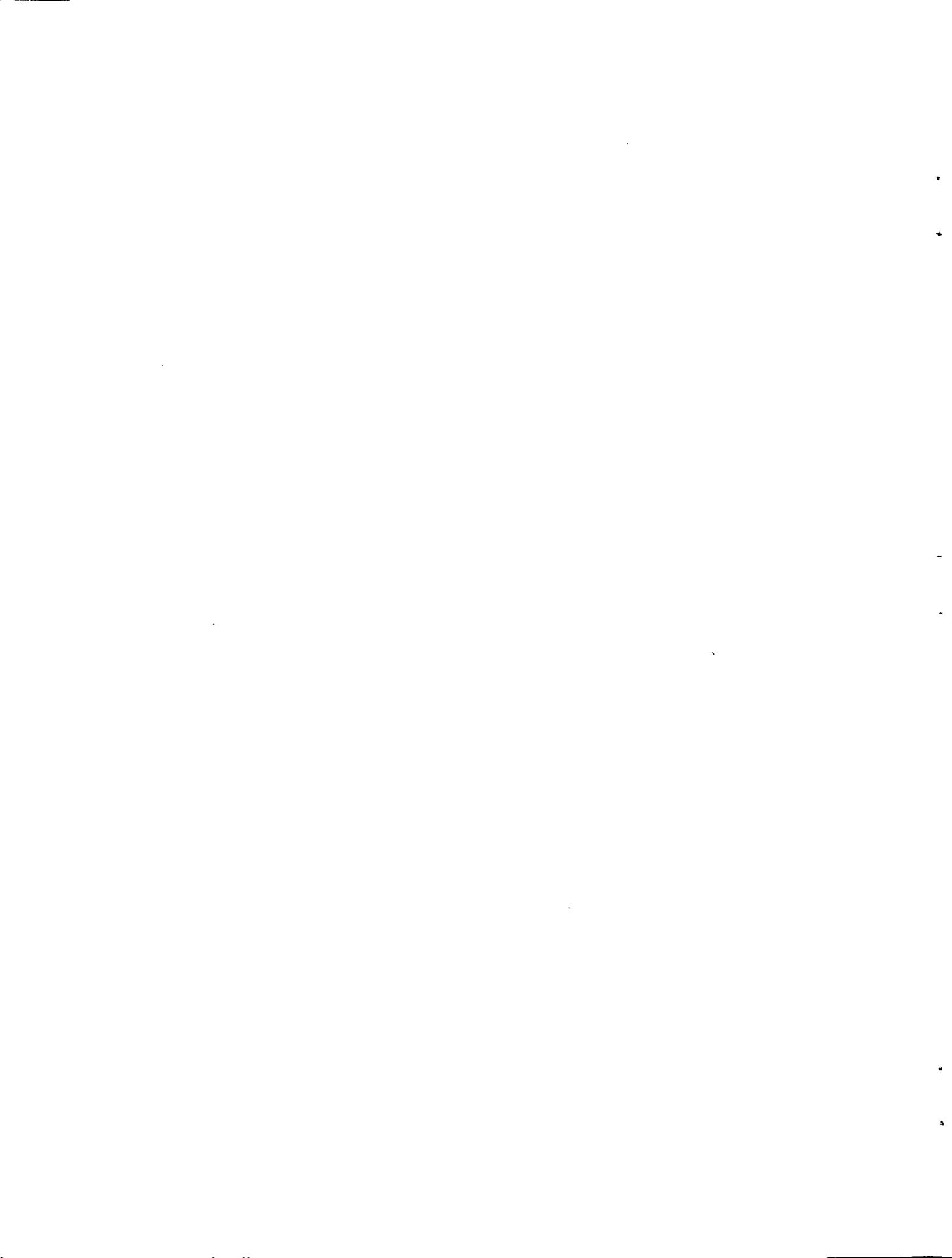


Fig. 2.1.4. Sablefish age composition from samples collected in 1980 illustrating the recruitment of 1977 year-class and the apparent age of recruitment (12-13 yr).



2.2 Dogfish

2.2.1 Introduction

In the early 1900s, dogfish were caught for the production of fish meal and fertilizer and from 1930 to 1950, dogfish were fished mostly for their liver and the oil they contained. In the last few years, with the decline in the supply of European dogfish, it was possible to establish a commercial food fishery.

2.2.2 Landing Statistics

During 1940-49, dogfish (Squalus acanthias) were the object of an intensive liver fishery along the British Columbia coast which reached a peak production level of about 35,000 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. Catch statistics for the 1940-49 period cannot be separated by area.

During 1959-75, a total of eleven subsidy programs resulted in a small dogfish fishery that took place mainly in the Strait of Georgia. The sole aim of the subsidy during 1959-62 was to reduce dogfish abundance below what was considered a nuisance level. The last three subsidies, starting in 1973, established potential foodfish markets but economic and processing difficulties kept production at low levels.

Since the development of foodfish markets abroad, dogfish landings from the Strait of Georgia increased steadily from 170.4 t in 1976 to 4,321.8 t in 1979. Production declined in 1980 to 2,104 t as a result of a decline in market conditions. During 1976-80 an average of 74% of Strait of Georgia dogfish landings were taken by longline gear. The remaining 26% were trawl-caught.

2.2.3 Stock Assessment

Delineation of dogfish stocks is not clearly understood. Preliminary results from tagging studies indicates there is extensive movement within the Strait of Georgia. Movement of tagged dogfish from the west coast of Vancouver Island into the Strait of Georgia is noted, however, the extent of exchange between offshore waters and the Strait of Georgia is not known but doesn't appear to be of any short-term significance. Since early catch statistics are not separated by area and, in the absence of a continued fishery during most years since the 1940s analysis of stocks have been conducted for British Columbia waters as a whole. Catch and effort statistics from the 1940s liver fishery indicate the virgin biomass of marketable stocks (approximately >75 cm) in British Columbia waters was in the order of 200,000 t. These statistics also suggest the marketable stock was reduced to perhaps as little as one quarter of its primitive abundance by a fishery which averaged about 15,000 t/yr between 1937 and 1949--a period of 13 years (Ketchen 1969).

A discrete-time, deterministic 'age-structure' model incorporating 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. 1979). The 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. 2.2.1). The model predicted that the liver fishery reduced the marketable biomass to at least half of its

primitive abundance by 1949, the model also predicted that the stock would recover as early as 1960, due to the considerable biomass of juveniles, inhabiting mid-water 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 1950s which led to the introduction of the subsidized 'eradication fishery' of 1959-62. But while the marketable stock appeared to recover quickly, it is likely that the entire population is only now approaching its historic levels. The present biomass of marketable stock is probably in the order of 120,000-150,000 t (Fig. 2.2.1).

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 dogfish, it is extremely sensitive to overfishing. If the stock(s) were to be fished with the object of obtaining a maximum sustainable yield of large fish (>75 cm), the yield would be only about 8,000-10,000 t coast-wide. There is no way of accurately proportioning a coast-wide estimate of MSY by area without separate estimates of biomass. However, by assuming stock size in the Strait of Georgia to be roughly one-third of the coast-wide estimate, the MSY assigned would be 3,000 t, with the remaining two-thirds (6,000 t) assigned to all other areas.

Presently, it is not possible to assess the impact of the recently intensified longline fishery on the abundance of marketable stock in the Strait of Georgia because of an absence of an adequate time series of fishing effort prior to September 1978. However, there was no substantial change in CPUEs between 1979 and 1980. In 1979 and 1980 the CPUE was 0.608 t/1,000 hooks and 0.643 t/1,000 hooks, respectively. It is important to note that production in 1978 utilized 94% of the 3,000 t quota assigned to the Strait of Georgia. An experimental approach was initiated in 1979 whereby the quota was allowed to exceed the 3,000 t MSY estimate by 2,000 t. However, only 86% of the 5,000 t quota was utilized during 1979. Because of the decline in market condition only 42% of the 5,000 t quota was taken in 1980.

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. The model indicates a periodic fishery which attempts to fish dogfish intensively for short periods may reduce abundance below some "nuisance" level. If our calculations of stock size are correct, then the stocks in the Strait of Georgia could not sustain a fishery of 5,000 t of marketable size dogfish per year for more than 10-15 yr without being 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 commercially fished and begin to recruit 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 (Figs. 2.2.2, 2.2.3). A sustained fishery will also produce oscillations in abundance, but these oscillations will dampen with time (Fig. 2.2.2). Any type of periodic fishery will perpetuate these cycles of

abundance (Fig. 2.2.3). Furthermore, the greater the intensity or larger 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.

2.2.4 Recommendations

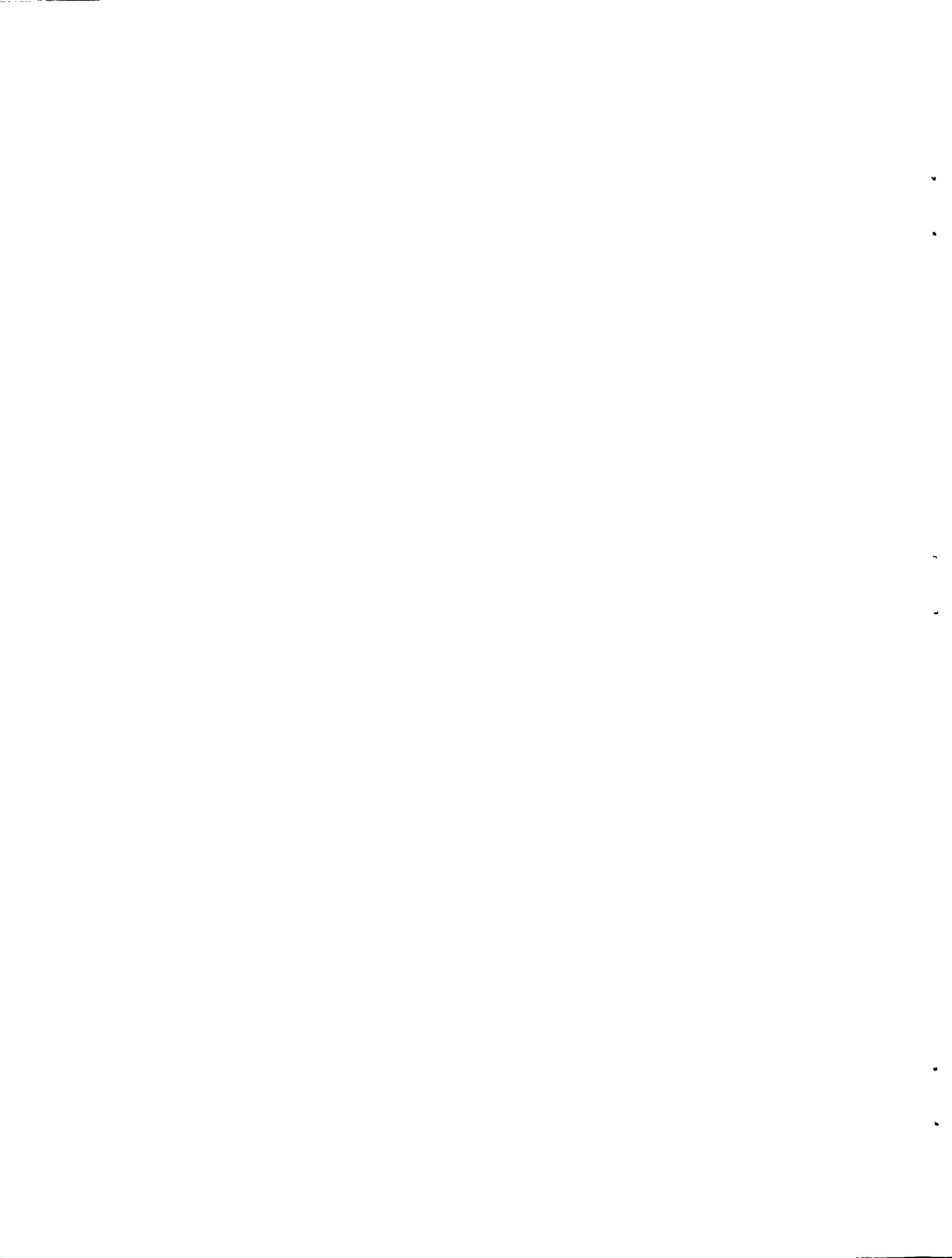
It is recommended that a TAC for dogfish of 3,000 t be assigned for the Strait of Georgia and a TAC of 6,000 t be assigned to cover other areas (3,000 t for Hecate Strait and 3,000 t for West Coast Vancouver Island).

In 1979 it was recommended that the MSY of 3,000 t for the Strait of Georgia be exceeded by 2,000 t for a period of 2 yr. Since that period, declining market conditions were prohibitive to full utilization of the quota. It is therefore recommended that during 1981-82 the MSY for the Strait of Georgia be exceeded by 2,000 t. This is an experimental approach and not to be interpreted as an estimate of sustainable yield.

In conformance to management policies of 1979 we also recommend that the quota be divided into 3 areas:

Area	Statistical Area Equivalent	Quota
1	Minor Statistical Areas 12, 13, 15	1,000 t
2	Minor Statistical Areas 14, 16, 17, 18, 28, 29	3,000 t
3	Minor Statistical Areas 19, 20	1,000 t

The quota is based on a fishing period of October 1, 1981-September 30, 1982. The three-area system is designed to minimize achieving the quota quickly and interrupting the supply to plants. Therefore, Areas 1 and 3 remain closed until Area 2 quota is reached at which time Area 2 is closed and Area 3 opened. When Area 3 quota is reached it will be closed and Area 1 opened. When Area 1 quota is reached the fishery must be closed until October 1, 1982.



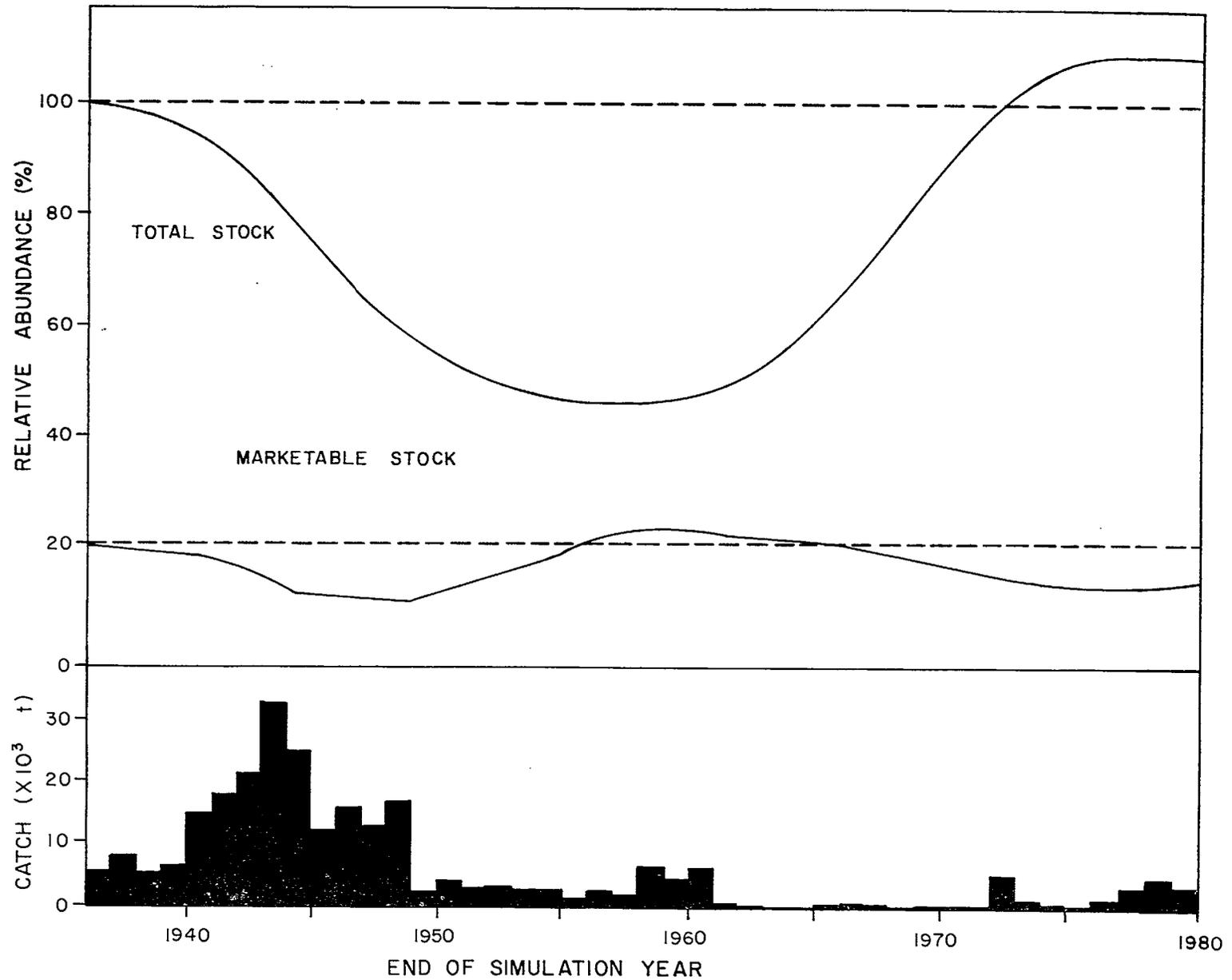


Fig. 2.2.1. Simulation of total and marketable stocks of dogfish following the intensive liver fishery and recorded production during 1937-80 in Canadian waters.



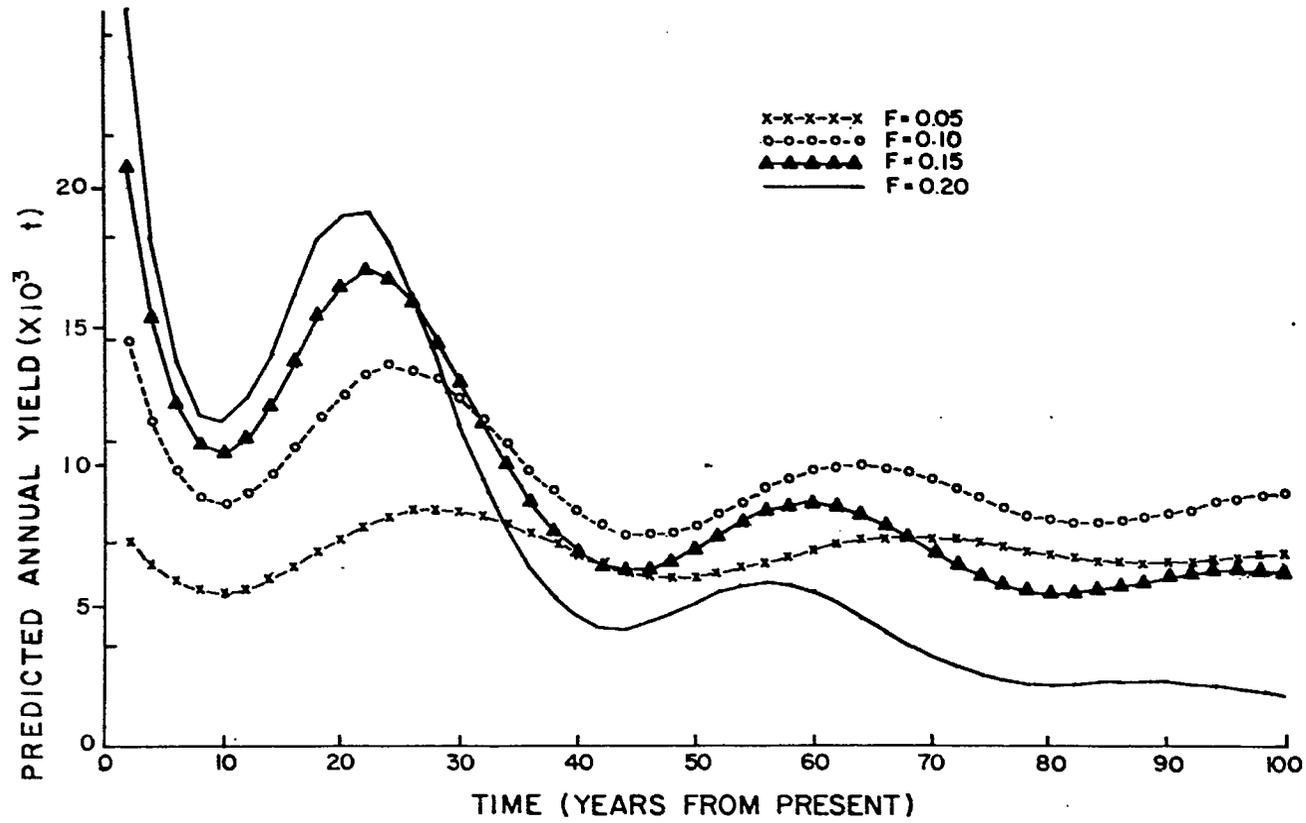


Fig. 2.2.2. Predicted yield of hypothetical dogfish fishery at four sustained fishing rates. (F = instantaneous rate of fishing mortality.)



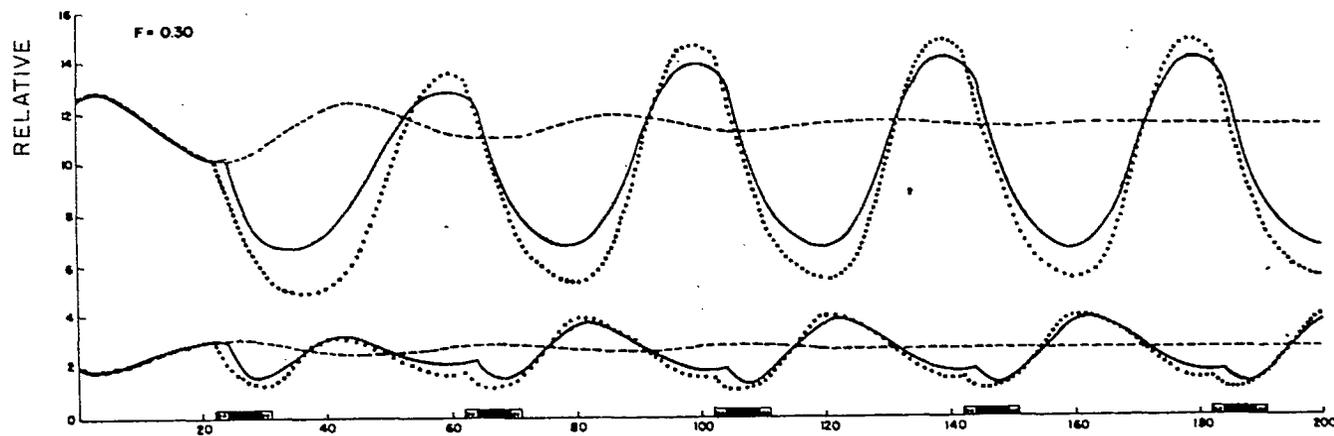
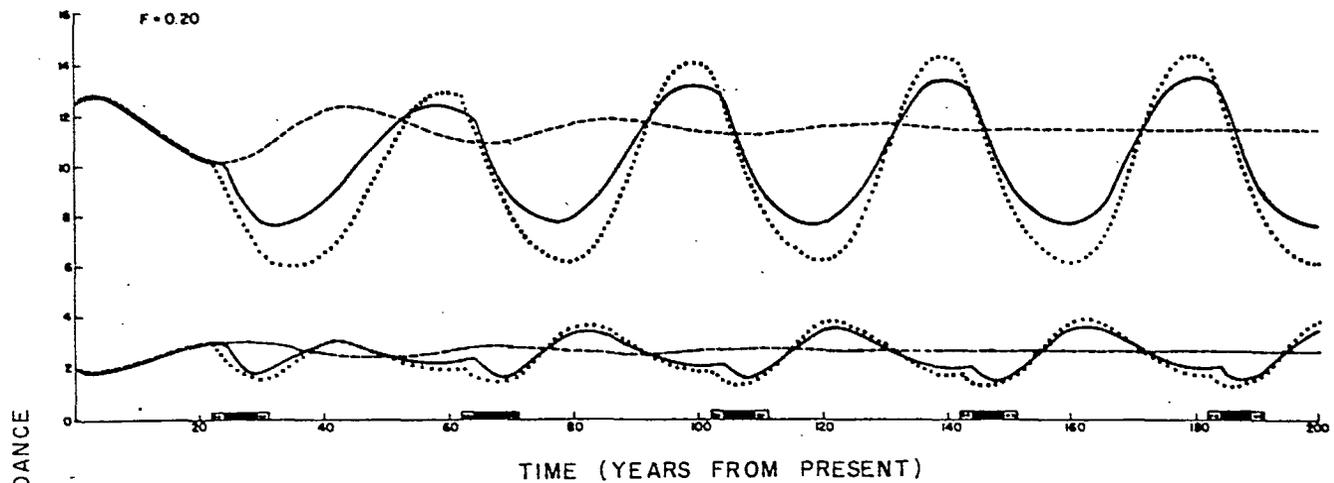


Fig. 2.2.3. Abundance of dogfish predicted by model when exploited by a periodic fishery commencing every 40 yr. The upper lines in each diagram represent the total stock (i.e., all age groups) whereas the lower lines represent only the marketable-sized stock. Dashed lines predict the abundance with 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.

2.3 Albacore

2.3.1 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 migrations at various stages of its life-history into the 200-mile zones of Japan, Mexico, U.S.A., and Canada.

2.3.2 Summary of life history

Albacore spawn 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 reveals itself by the annual arrival of juveniles off the North American coast in late spring to early autumn.

Albacore which make their landfall south of San Francisco to Baja California remain throughout the summer and then move southwestward to areas unknown. Those making their landfall north of San Francisco tend to 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.

2.3.3 Definition of stocks

There is still some doubt as to the number of stocks present in the North Pacific. The current view, as suggested above, is that there are two components, one in an area roughly defined by a triangle joining San Francisco, Graham Island and southern Honshu, the other in the eastern Pacific south of Lat. 38°N. 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. Under the two-stock theory then, one stock is vulnerable to exploitation by both the North American and Japanese fisheries and the other is vulnerable as juveniles only to the North American (United States) fishery. This description is perhaps over-simplified, but it is the best that can be developed on the basis of existing information. Much more tagging is required.

2.3.4 Catch and effort statistics

Table 2.3.1 shows the 1961-78 distribution of albacore catch by country and gear³. From an average of 55,000 t in 1961-65, total production rose fairly sharply surpassing the 100,000 t level during the early 1970s. The catch reached an all-time high of 124,000 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. A sharp improvement occurred in 1978 in both the Japanese and North American fisheries. However, preliminary indications are that 1979 was another bad year, perhaps the poorest in two decades.

The North American fishery has been in general decline since 1973 when the catch was nearly 28,000 t. By 1979 it was only 7,000 t, the poorest since 1941. Various explanations have been given for this decline--all related to the problem of availability (late arrival in the eastern Pacific, reduced formation of fronts to provide conditions which encourage albacore to concentrate and feed, reluctance of fish to bite, unfavourable fishing conditions, etc.). The trend in CPUE in the North American fishery is much more erratic than that of catch (Table 2.3.2) but the figures for 1979 in both cases were the lowest for many years.

The Canadian fishery, occurring at the northern boundary of albacore distribution in the northeast Pacific, usually late in the year, has been much more unstable than the U.S. fishery farther to the south. Albacore do not appear regularly in Canadian waters, but marketing problems including poor prices relative to those paid for troll-caught salmon have also played a part in the instability of the fishery. In 1979 a U.S. embargo on tuna imports from Canada was a major deterrent to the development of a fishery.

2.3.5 State of the albacore resource

The latest in a series of attempts to estimate maximum yield (MSY) with generalized production models produces figures ranging from 104,000 t to as much as 236,000 t. A mid-point value of 170,000 t has been accepted provisionally for sake of convenience and this is 40% greater than the maximum recorded catch (in 1976).

Estimates based on cohort and yield-per-recruit analyses suggest that MSY is near 113,000 t, which is below the recent catch maximum. Yet such analyses are based on very imprecise information on the age and growth of albacore. Thus the current state of the stock(s) remains uncertain.

2.3.6 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.

³ Statistical data contained in the present report have been extracted from the fifth annual report of an international Working Group on Albacore, represented by Japan, U.S.A., Canada and Taiwan at its 1980 meeting.

Table 2.3.1. Catches of North Pacific albacore (t) 1961-1979^e.

Year	Japan ^a			Taiwan	United States ^b			Canada		
	Pole-and -line	Longline	Other Gears	Total	Longline	Pole-and -line	Jig	Total ^c	Jig	Total ^d
1961	18,636	17,437	268	36,341	-	2,837	12,054	16,246	4	52,591
1962	8,729	15,764	191	24,684	-	1,085	19,753	23,519	1	47,204
1963	26,420	13,464	218	40,102	-	2,432	25,142	28,735	5	68,812
1964	23,858	15,458	319	39,635	26	3,411	18,389	22,624	3	62,283
1965	41,491	13,701	121	55,313	16	417	16,461	17,609	15	72,953
1966	22,830	25,050	585	48,465	16	1,600	15,169	17,357	44	65,882
1967	30,481	28,869	520	59,870	17	4,113	17,814	22,634	161	82,682
1968	16,597	23,961	1,109	41,667	15	4,906	20,441	26,298	1,028	69,008
1969	31,912	18,006	1,675	51,593	21	2,996	18,826	21,180	1,365	75,157
1970	24,263	15,372	1,069	40,704	23	4,416	21,039	26,277	354	67,358

(cont'd.)

Table 2.3.1. (cont'd.)

Year	Japan ^a				Taiwan	United States ^b			Canada	
	Pole-and -line	Longline	Other Gears	Total	Longline	Pole-and -line	Jig	Total ^c	Jig	Total ^d
1971	52,957	10,915	1,623	65,495	24	2,071	22,196	25,442	1,587	92,548
1972	60,591	12,622	1,120	74,333	25	3,750	23,600	27,987	3,558	105,903
1973	69,640	16,000	2,152	87,792	35	2,236	15,652	17,960	1,720	107,057
1974	73,576	12,952	1,390	87,918	40	4,777	20,177	25,693	1,207	114,858
1975	52,157	9,931	697	62,785	28	3,243	18,926	23,412	101	86,326
1976	85,336	15,738	2,622	103,696	37	2,700	16,314	19,780	252	123,765
1977	31,934	15,512	1,952	49,398	37	1,497	10,012	12,128	53	62,140
1978	59,817	12,888	7,411	80,176	47	950	15,700	16,650	23	96,842
1979 ^f	43,000	-	-	-	46	-	-	6,632	521	-

^a 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.

^b 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.

^c Includes catch by U.S. sport fishery.

^d Omitted are unknown but minor catches by longline and pole-and-line vessels of the Republic of Korea.

^e Data from report of the Fifth North Pacific Albacore Workshop, La Jolla, California. March 1981.

^f 1979 figures are preliminary.

Table 2.3.2. Catch per unit of effort (CPUE) of North Pacific albacore by major fishery^a.

Year	U.S.A. Jig ^b	Japan	
		Pole-and-line ^c	Longline ^d
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	5.98	0.23
1976	69.22	6.13	0.30
1977	59.90	3.01	0.26
1978	86.80	3.58	0.23
1979	45.41	3.50	-

^a Data from report to the Fifth North Pacific Albacore Workshop, La Jolla, California, March 1981.

^b Number of fish per standardized boat-day.

^c Metric tons per standardized fishing day.

^d Number per thousand standardized hooks.

3. STRAIT OF GEORGIA (4B) STOCK ASSESSMENTS

Principal species (based on a 5-yr average) in the Canadian landings from Georgia Strait and vicinity are dogfish (1,800 t), Pacific cod (1,250 t), walleye pollock (570 t), Pacific hake (512 t; 2-yr average only), and lingcod (423 t) (Table 3.1).

In the following sections stock assessments are presented for Pacific hake, walleye pollock, Pacific cod, and lingcod. Assessment for dogfish shark is presented for the entire coast in section 2.2 of this report.

Table 3.1. British Columbia groundfish landings (t) by main species in the Strait of Georgia (Area 4B), 1976-80.

Species	Landings ^a (t)					5-yr average
	1976	1977	1978	1979	1980 ^c	
Dogfish	170.4	1,638.8	2,827.2	4,339.8	2,104.4	1,799.5
Pacific cod	927.1	1,147.4	1,372.3	1,196.4	1,606.3	1,249.9
Walleye pollock	25.8	50.7	379.6	1,339.7	1,055.8	570.3
Pacific hake	-	-	-	516.3	508.4	512.4 ^b
Lingcod	403.5	501.7	588.6	589.6	33.4	423.4

^a Included are landings by trawl, trap, longline, handline, and troll.

^b Average for 2-yr only.

^c 1980 handline and troll landings not available.

3.1 Pacific hake

3.1.1 Introduction

The recent Pacific hake (Merluccius productus) fishery in the Strait of Georgia takes place from February to May as the hake aggregate to spawn in the deeper waters between Halibut Bank and Gabriola Island. As the market expands for less expensive white-fleshed fish, and handling and processing problems are solved, Pacific hake is becoming an important commercial fishery.

3.1.2 Landing statistics

The Pacific hake fishery in the Strait of Georgia began in 1979. Catches during 1979 and 1980 were 516.3 t and 508.1 t, respectively. In 1981, an estimated 1,068 t of Pacific hake were caught in the Strait of Georgia as of May 1, 1981.

3.1.3 Stock assessment

Commercial fishery statistics and results from hydroacoustic surveys conducted in 1979 indicate stocks in the Strait of Georgia are large and capable of sustaining a commercial fishery. From preliminary estimates of virgin biomass (B_0), MSY based on Gulland's (1970) formula ($MSY = 0.5 \times M \times B_0$) ranged from 10,000-38,000 t (Westrheim 1980). However, studies of the biology and abundance of Pacific hake using ichthyoplankton, hydroacoustic and swept-volume techniques are currently in progress in the Strait of Georgia. Biomass estimates from these methods are needed to increase the confidence in estimates of maximum sustainable yield.

3.1.4 Recommendations

A provisional TAC of 10,000 t is recommended for the Strait of Georgia. This will be re-evaluated following completion of the Strait of Georgia Pacific hake studies in late 1981.

3.2 Walleye pollock

3.2.1 Introduction

The Strait of Georgia fishery for walleye pollock (Theragra chalcogramma) began in the 1950s to supply an animal food market. All of the early catches were made by bottom trawl, and most were made among the Gulf Islands. Landings started to increase sharply in 1978 when a demand for roe and fillets developed, and midwater concentrations were exploited for the first time in the open Strait. The industry continued processing- and fishing-experiments into 1981, the most recent year covered by this report.

3.2.2 Landing statistics

Midwater trawlers and shore-based processors first attempted to develop a fishery for pollock roe in the Strait of Georgia in 1978 (177 t; Tables 3.2.1, 3.2.2). Roe fishery landings peaked the following year, in 1979 (1,085 t), then declined through 1980 (959 t) to 1981 (381 t). First quarter landings from among the Gulf Islands and Strait of Juan de Fuca have also declined since 1979. Very little pollock (<60 t/yr) was landed after the first quarters of 1978-80 because the roe fishery was the major motivation for exploiting pollock in the Strait. Some pollock was caught incidentally in the midwater hake fishery, which is still in an early stage of development. Pollock catches could increase after March if the hake fishery expands.

Canadian landings from Minor Area 18 east of Mayne Island, where a Canada-U.S. parallel management scheme is in effect, dropped to 1t in 1981 from the 1980 high of 454 t. United States landings from Washington State Department of Fisheries Statistical Area 20A reached an all-time high of 580 t in 1981, up from 315 t in 1980, and 500 t in 1979.

3.2.3 Stock assessment

The basic assumption that two demographically discrete stocks are being exploited in the Strait, one east of Mayne Island and the other in Minor Area 29, is being re-examined with data collected during a series of research cruises conducted in January-May 1981. Ageing by fin-ray sections indicates that pollock catches east of Mayne Island in March and April (Minor Area 18E) contain relatively more older males and females than midwater trawl catches in Minor Area 29 during January-February (Fig. 3.2.1). The difference in age composition between the two areas is apparent in length frequencies for all 3 years of the study (Fig. 3.2.2). Samples collected from spawners deep in the midwater during March 1980 showed similar age composition between spawners caught near Halibut Bank and ripening pollock taken for roe at shallower depths in February (predominantly 3-yr-olds), but spawners caught near Sand Heads were more similar to samples from the fishery east of Mayne Island (predominantly 4-6-yr-olds).

These ageing results lead to the suggestion that only one stock is exploited from Texada Island to Point Roberts, but it is evident that different age groups are fished in each area. Evidence for one stock comes from ichthyoplankton surveys conducted in 1978-80, which showed that pollock eggs and larvae were primarily concentrated in the Sand Heads-Halibut Bank area, were relatively much less dense east of Mayne Island, and were continuously distributed throughout the Strait south of Texada Island.

We recommend that the two areas continue to be managed separately, since there is still a possibility that the east Mayne Island-Point Roberts fishery operates on a separate stock. In any case, the fishery selectively captures older females, which produce many more eggs than younger females (Fig. 3.2.3). If only one stock exists then it may be desirable to control removals of these more fecund individuals from the population to prevent recruitment overfishing. The possibility is being investigated.

The steady decline in roe fishery landings since 1978 occurred because pollock were less available to midwater trawlers, as indicated by a considerable drop in midwater trawl nominal LPUE for Minor Area 29:

Year	Pollock landing (all gears,t)	Pollock LPUE (t/hr) (Midwater)	Number of Midwater Trawlers
1978	152	2.19	2
1979	1,063	1.72	9
1980	504	1.43	4
1981a	150	0.61	6
1981a,b	213	1.43	1

^apreliminary estimate.

^bStatistical Areas 14, 16.

It cannot be assumed that these LPUE statistics represent a decline in abundance however, because the catches were made high in the midwater on younger adults and it is known from research fishing that some proportion of the stock was mixed with hake deeper in the midwater. Pollock were caught in most of the shallower sets made during 1980-81 research fishing, so it is possible that some unidentified feature of the environment caused pollock to disperse at lower concentrations in 1980-81. Densities were so low that it became marginally economical to continue fishing in Minor Area 29 in the 1981 season.

Recruitment fluctuations seem to occur in the Strait. Three-yr-olds dominated Minor Area 29 catches in 1978 and 1980, but 4-yr-olds dominated in 1979, which could indicate poor recruitment of 3-yr-olds in 1979 (1976 year-class).

3.2.4 Recommendation

The 1982 TAC will be recommended when estimates of biomass are available from the surveys conducted early in 1981.

Table 3.2.1. Walleye pollock landings (round wt, t) by Canadian vessels for the first quarter and whole year during 1978-81.

Region	1978			1979			1980			1981 ^a		
	QI	Year	TAC	QI	Year	TAC	QI	Year	TAC	QI	Year	TAC
Minor Areas 14,16,17E, 29, (North and Central Strait of Georgia)	176	177	-	1,063	1,063	-	505	505	-	381	-	-
Minor Area 18E (East Mayne I.)	1	11	-	22	22	-	454	454	900 ^b	4	-	900 ^b
Minor Areas 17W,18W,19, 20 (Gulf Islands and Juan de Fuca)	116	183	-	192	206	-	42	63	300	72	-	300
Major Area 4B	319	380	-	1,317	1,341	4,000	1,030	1,056	3,400 ^b	458	-	3,400 ^b
Major Area 5D	532	1,700	-	712	1,566	2,300	317	1,104	2,550	44	-	2,550
All others	23	339	-	45	528	-	35	177 ^c	Z	2	-	-
Total	869	2,410	-	2,033	3,385	-	1,353	2,303	-	506	-	-

^a preliminary estimates

^b includes U.S. catch in WDF 20A of 315 t in 1980 and 580 t in 1981

^c does not include 1,800 t caught in the hake fishery off Vancouver Island

Table 3.2.2. First quarter walleye pollock landings (round wt, t) by gear type from major Area 4B, 1978-1981.

<u>Statistical areas</u>	1978				1979				1980				1981 ^a	
	<u>MWT</u>	<u>BT</u>	<u>UK</u>	<u>TOT</u>	<u>MWT</u>	<u>BT</u>	<u>UK</u>	<u>TOT</u>	<u>MWT</u>	<u>BT</u>	<u>UK</u>	<u>TOT</u>	<u>MWT</u>	<u>BT</u>
14,16,17E,29	176	0	0	176	924	138	0	1063	504	1	1	506	380	1
18E	0	1	0	1	1	21	0	22	322	131	0	454	1	3
17W,18W,19,20	0	98	18	116	108	79	5	192	14	8	20	42	4	68
Coastwide (first quarter)	627	201	41	870	1697	326	10	2033	1042	286	25	1353	429	77

^a preliminary estimates
MWT = midwater trawl
BT = bottom trawl
UK = unknown gear

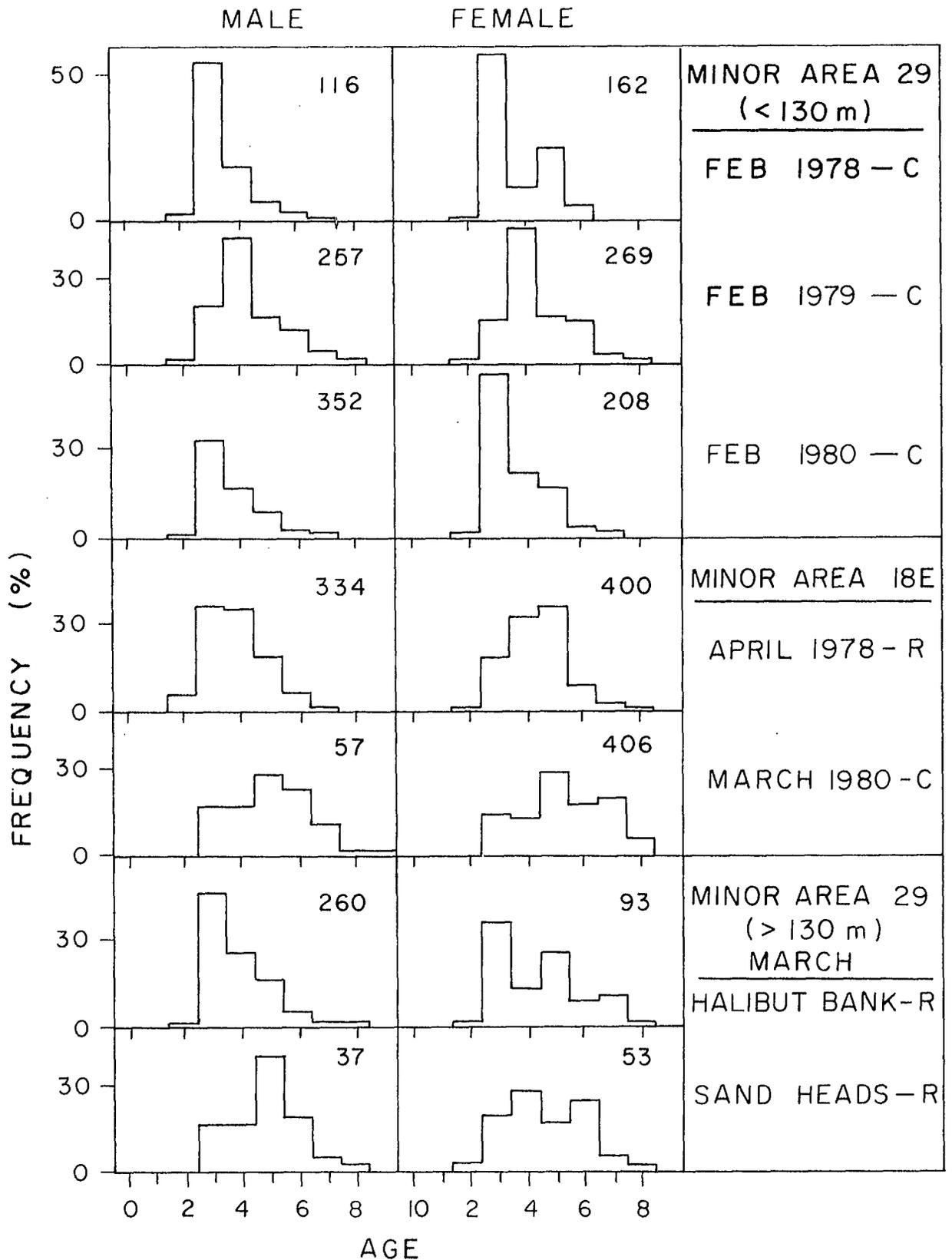


Fig. 3.2.1. Age frequencies of walleye pollock in the Strait of Georgia from the commercial fishery (C) and research cruises (R).



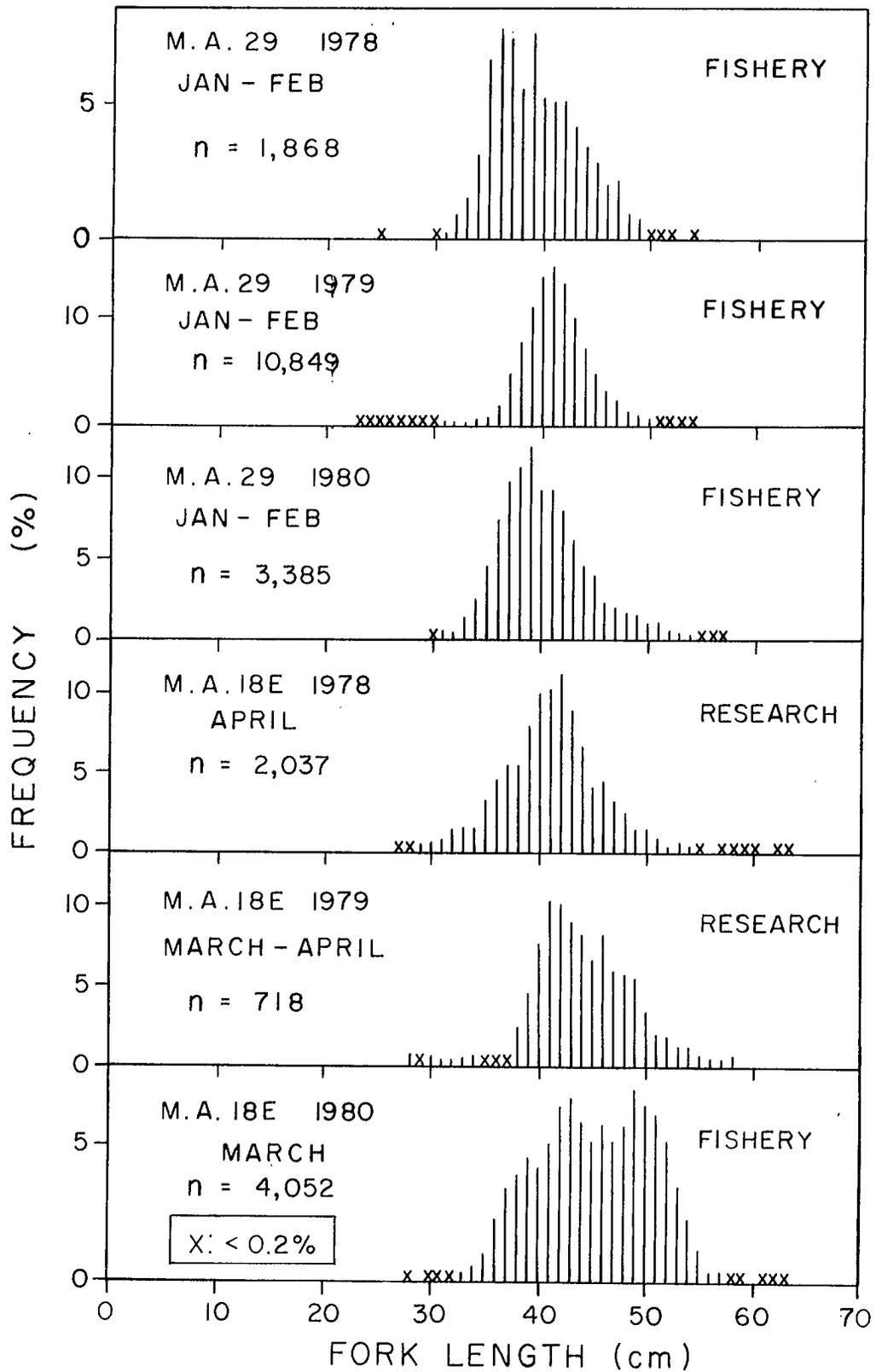
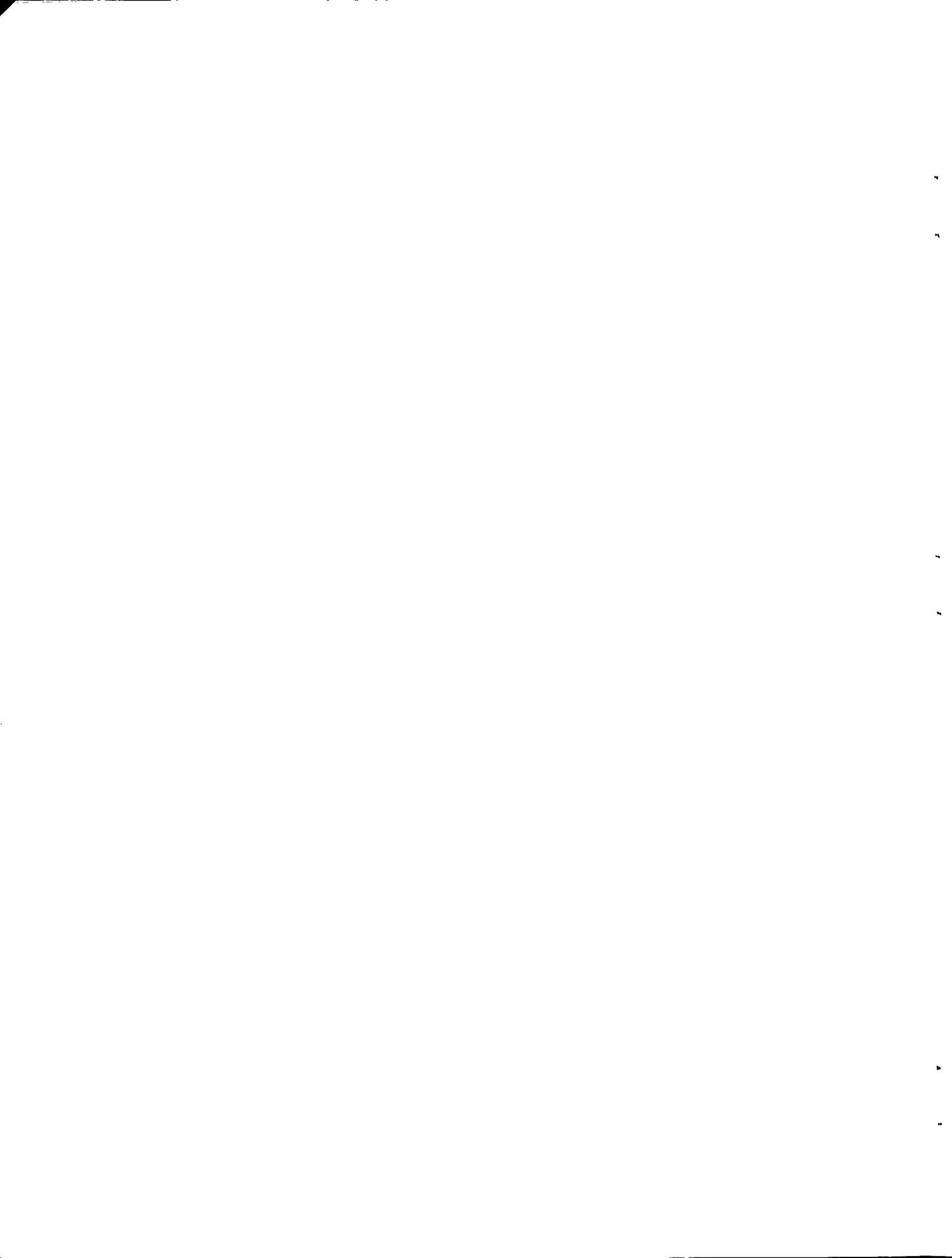


Fig. 3.2.2. Pollock length frequencies from Minor Area 29 (mid-water trawl shallower than 130 m) and Minor Area 18E (east of Mayne Island, combined gears).



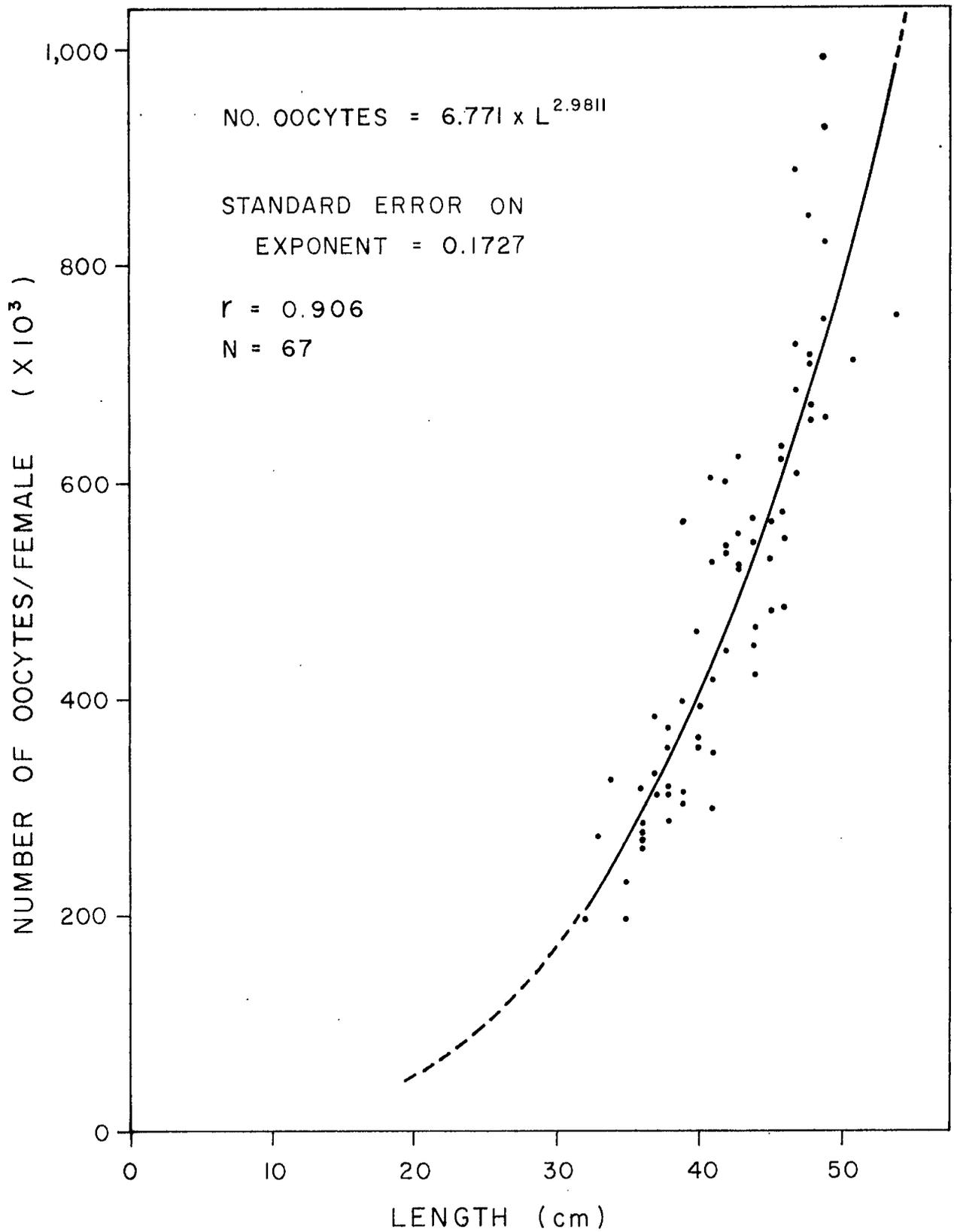
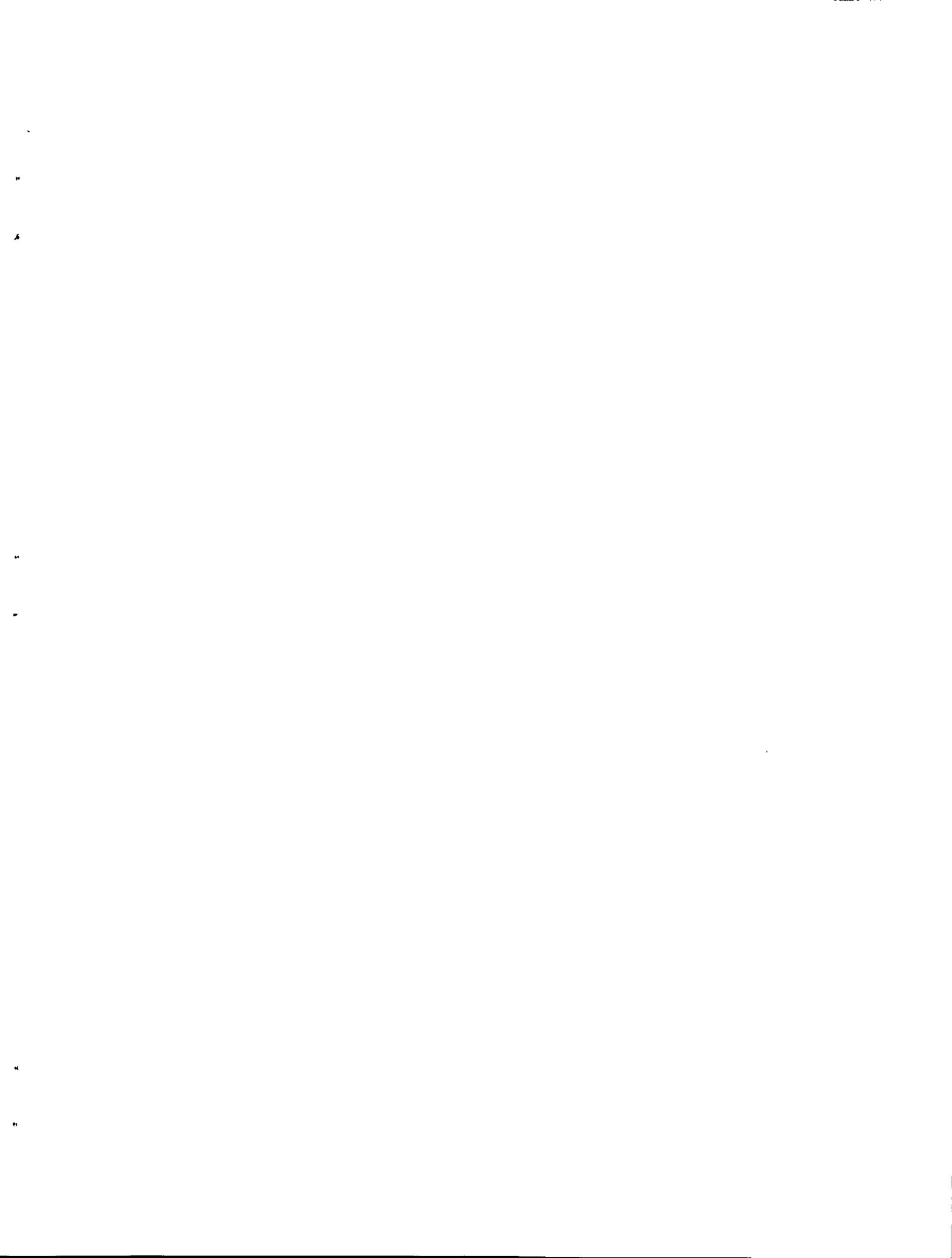


Fig. 3.2.3. Fork length-fecundity relationship for walleye pollock in the Strait of Georgia during February 1979.





3.3 Pacific cod

3.3.1 Introduction

During 1976-80, Pacific cod comprised 23%, by weight, of the Canadian landings of groundfish from Georgia Strait and vicinity (Area 4B), and ranked second in importance to dogfish (Table 3.1). No detailed analysis of landing statistics has been undertaken at this time. See Westrheim (1980) for details through 1977. No age composition data have been calculated for Pacific cod in this region.

3.3.2 Landing statistics

For Area 4B as a whole, Pacific cod trawl landings increased substantially after 1974 (Figs. 6.1.2, 3.3.1; Table 3.3.1). During 1960-74, landings ranged around 500 t/yr, compared to 1,000 t/yr during 1975-80.

Among minor statistical areas (SAs), trends in annual landings differed considerably. No trend was evident in SAs 12+13+15+16, 14 and 29. SA 17 (primarily Nanoose Bay Ground) exhibited a steady decline after 1974, while concurrently a sharp increase was exhibited by SAs 18, 19, and 20. No explanation is available at this time for this phenomenon.

3.3.3 Stock assessment

Pacific cod landings from Area 4B continue to fluctuate substantially among years, and no evidence has arisen to refute previous assessments (Forrester and Ketchen 1963; Ketchen 1967; Forrester and Smith 1974; and Westrheim 1980). That is, these fluctuations are caused by factors other than fishing. However, recent increases in landings from SAs 18-20 deserve more attention. Possibly they may be due only to increased effort rather than increased abundance.

3.3.4 Recommendations

No TAC is recommended for Area 4B, nor any increase in current area-time closures.

Table 3.3.1. Trawl landings (t) of Pacific cod from Georgia Strait and vicinity (Area 4B), and associated minor areas, October-September, 1960-80.

Year	4B	Minor Area						
		12+13+ 15+16	14	17	18	19	20	29
1960-61	486	12	78	100	156	103	29	8
1961-62	434	10	55	69	161	49	78	12
1962-63	561	14	48	151	227	37	71	12
1963-64	772	16	111	138	349	74	54	28
1964-65	502	18	37	45	214	81	88	20
1965-66	326	13	18	16	77	117	76	8
1966-67	464	52	28	151	154	22	52	4
1967-68	381	16	22	126	96	49	58	13
1968-69	326	16	17	59	124	20	82	7
1969-70	509	11	25	93	192	80	95	12
1970-71	743	8	81	340	178	48	86	4
1971-72	665	3	69	302	169	20	98	2
1972-73	513	11	150	133	188	12	11	8
1973-74	526	16	58	144	247	51	8	Tr ^a
1974-75	740	26	74	75	218	258	83	6
1975-76	1,096	25	83	89	418	467	14	2
1976-77	895	53	98	60	385	244	55	Tr
1977-78	1,444	39	130	85	421	696	73	1
1978-79	1,193	17	49	48	283	554	230	12
1979-80	1,512	64	105	42	316	729	243	2

Source: 1960-77; Westrheim (1980. Can. MS Rep. Fish. Aquat Sci. 1563: 130 p.)
 1978-79; Smith (1979, 1980)
 1980; Unpublished data PBS

^aTr=trace



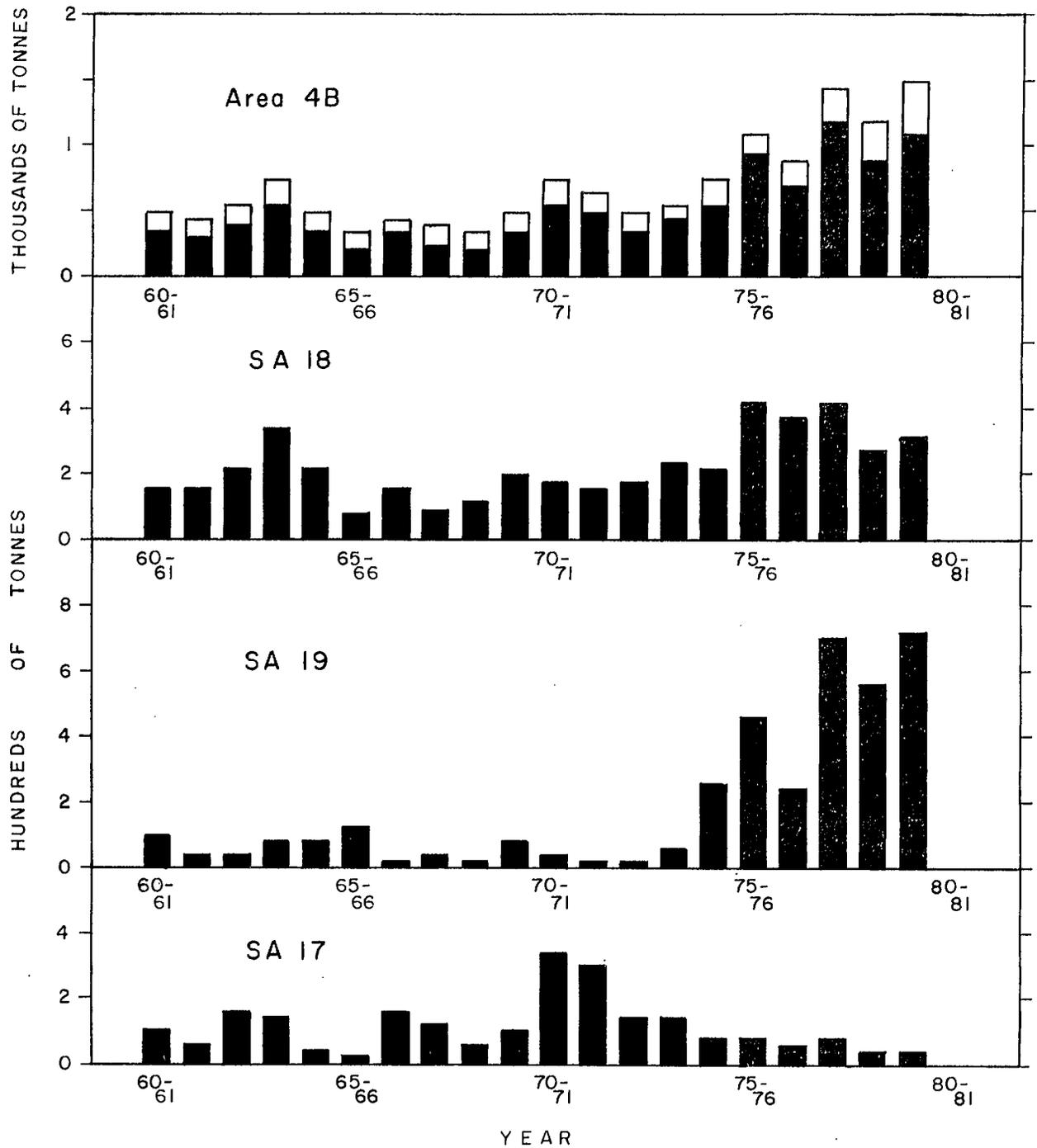
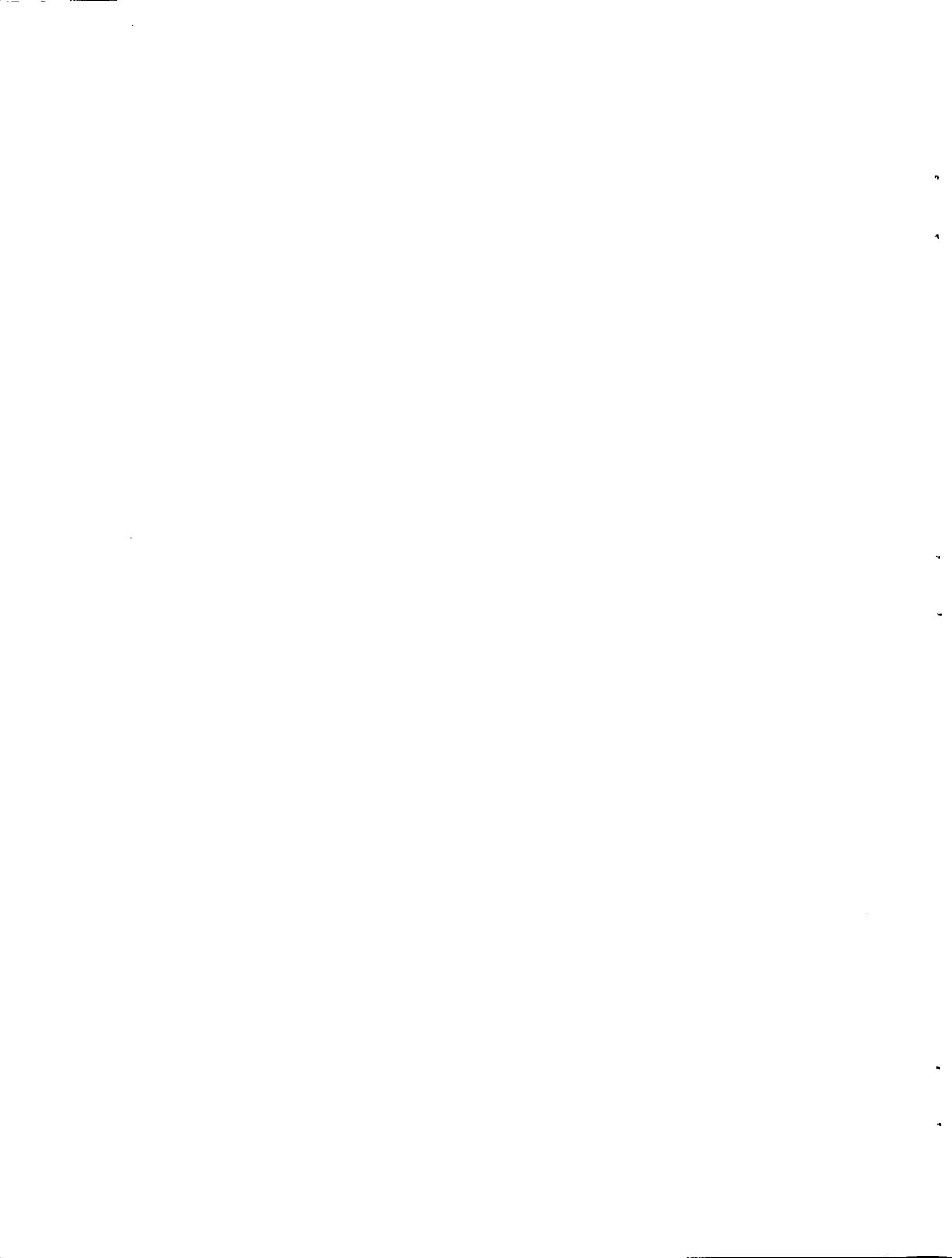


Fig. 3.3.1. Pacific cod trawl landings (t) from Georgia Strait and vicinity (Area 4B), and important minor areas, October-September, 1960-80. (Shaded areas = minor areas 17 + 18 + 19.)



3.4 Lingcod

3.4.1 Introduction

Lingcod are fished commercially in the Strait of Georgia by handline, troll and, to a lesser extent, by bottom trawl, longline, sunken gill nets, traps, beach seines and spear-fishing methods. As well as being of commercial interest, lingcod are landed by recreational fishermen using jig, troll and spear-fishing methods.

Delineation of lingcod stocks in the Strait of Georgia is not clearly understood. Tagging studies (Hart 1943; Chatwin 1956, 1958) indicate adult lingcod do not migrate extensively. The limited number of tag recoveries from juvenile lingcod indicates they may move more than adults. For present purposes, lingcod in the Strait of Georgia will be treated as a single stock, on the assumption that negligible exchange occurs with other areas.

3.4.2 Abundance indices

The trawl fishery in the Strait of Georgia has accounted for only about 10% of the annual commercial production from the Strait of Georgia during 1965-80. For this reason trawl catch and effort statistics are of little value in assessing state of stocks. Production from the commercial handline and troll fisheries, on the other hand, have accounted for about 88% of the total annual commercial production since 1965. Landing records for the line fisheries are only reported on sales slips that do not permit the separation of handline landings from troll landings.⁴ Since 1967 handline/troll effort (boat-days) has been partitioned between that directed at salmonids and that directed primarily at groundfish. Although it is not possible to separate lingcod directed effort from other groundfish species, lingcod has been the principal target species. The catch-per-unit-effort (CPUE) is estimated by dividing the recorded annual handline/troll landings of lingcod by the corresponding number of boat days (Table 3.4.1).

3.4.3 Landing statistics

Landings from the commercial handline/troll fisheries have declined substantially from an average of 1,330 t/yr during 1951-62 to little more than 400 t/yr during 1975-80 (Table 3.4.1; Fig. 3.4.1A). During 1967-75 the decline in handline troll landings was closely paralleled by a decline in effort (Fig. 3.4.1B). CPUE remained fairly constant during this period. After 1975 handline/troll effort increased substantially, however landings remained at low levels. CPUE subsequently declined, reaching a record low in 1980. During 1951-80 trawl production has shown little or no trend (Fig. 3.4.1A) except for a brief flurry of activity associated with the discovery and fishing down of a stock inhabiting waters near Victoria (Ketchen 1980). At this time we do not have an accurate estimate of lingcod landings by the recreational fisheries in the Strait of Georgia. However, in July 1980 a recreational fishery survey was initiated. Preliminary estimates suggest removals by recreational fishermen, excluding SCUBA divers, may equal that of the commercial line fisheries. The quantity of lingcod taken by spear fishermen is unknown. However, lingcod are considered the primary species caught by spear fishermen.

⁴Source: British Columbia Catch Statistics, Department of Fisheries and Environment, Annual Reports 1951-79; 1980 provisional.

3.4.4 Stock assessment

Of primary concern is the pronounced 70% decline in the average handline/troll landings of lingcod from the 1951-62 period to the 1975-80 period. The decline in lingcod handline/troll landings and corresponding effort during 1967-75 indicates the drop in landings may have resulted from a reduction in the amount of fishing effort, a decline in stock abundance, or both. The decline in CPUE after 1975 to a record low in 1980 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 problems associated with determining the amount of effort directed for lingcod. In an attempt to provide additional information on the condition of stocks, a survey of commercial line and recreational fishermen, including SCUBA divers was conducted in 1979. Results support evidence from handline/troll catch and effort analysis indicating stocks have declined.

Recent studies (Low and Beamish 1978) indicate the pre-spawning aggregation, spawning, and incubation period of lingcod extends throughout the November-April period. Starting with pre-spawning aggregation and lasting until hatching is completed, male lingcod assume a territorial behavior pattern that makes them highly vulnerable to exploitation. The presence of the male during incubation is absolutely essential to the survival of the nest and consequently may form a primary requirement for maintaining lingcod stocks.

3.4.5 Recommendations

The declining production of the commercial line fishery, particularly, in the presence of increasing fishing pressure since 1975 are indicative of a decline in lingcod abundance. Therefore it is recommended that the existing November 15-April 15 all-gear lingcod fishing closure be continued in 1982. This is considered necessary to provide greater protection during the reproductive phase in order to ensure a higher survival rate during the egg stage and to reduce the catch at a period of high vulnerability. A TAC during the open fishing period is not recommended.

In 1980 the first year of a 2-yr study, to be concluded in 1981, was implemented to monitor the effect of the extended winter fishing closure on lingcod production. In earlier studies (Phillips and Barraclough 1977) densities of pelagic post-larval lingcod were estimated from purse seine catch data from surveys conducted in 1975 and 1976. These estimates are used in the 1980-81 study as a basis for comparing levels of post-larval production before and following the closure extension.

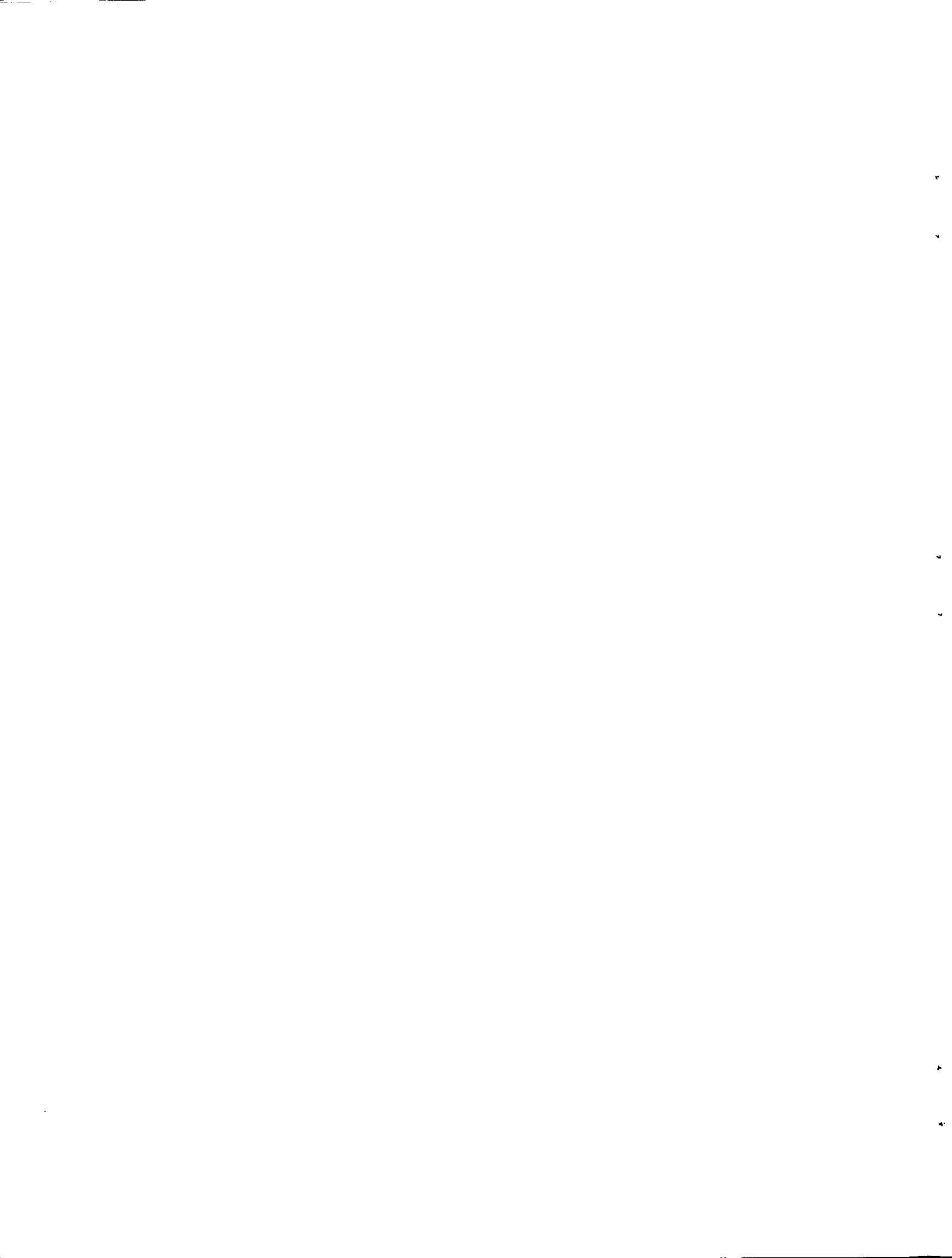
In addition to the larval survey, logbook and biological sampling programs have been initiated in order to provide more adequate coverage of the commercial line fishery.

Table 3.4.1. Handline/troll statistics for the commercial lingcod fishery, from coastal waters of the Strait of Georgia and vicinity (Area 4B), 1951-80^a.

Year	Landings (t) ^a	Effort (boat-days)	CPUE (t/boat-day)
1951	1,279.4	-	-
1952	1,488.7	-	-
1953	1,178.8	-	-
1954	1,449.3	-	-
1955	1,157.4	-	-
1956	1,510.7	-	-
1957	1,539.6	-	-
1958	1,445.7	-	-
1959	1,182.9	-	-
1960	1,250.5	-	-
1961	1,157.5	-	-
1962	1,272.8	-	-
1963	989.2	-	-
1964	870.3	-	-
1965	779.7	-	-
1966	771.3	-	-
1967	778.5	4,776	0.163
1968	728.0	4,758	0.153
1969	875.5	4,974	0.176
1970	788.7	4,065	0.194
1971	564.1	3,973	0.142
1972	513.3	3,693	0.139
1973	371.9	2,353	0.158
1974	363.7	2,393	0.152
1975	330.5	1,933	0.171
1976	315.5	2,607	0.121
1977	410.2	4,508	0.091
1978	451.8	5,372	0.084
1979	505.6	6,456	0.078
1980 ^b	328.4	5,707	0.058

^aBritish Columbia Catch Statistics, Department of Fisheries and Environment, Annual Reports 1951-79.

^bprovisional



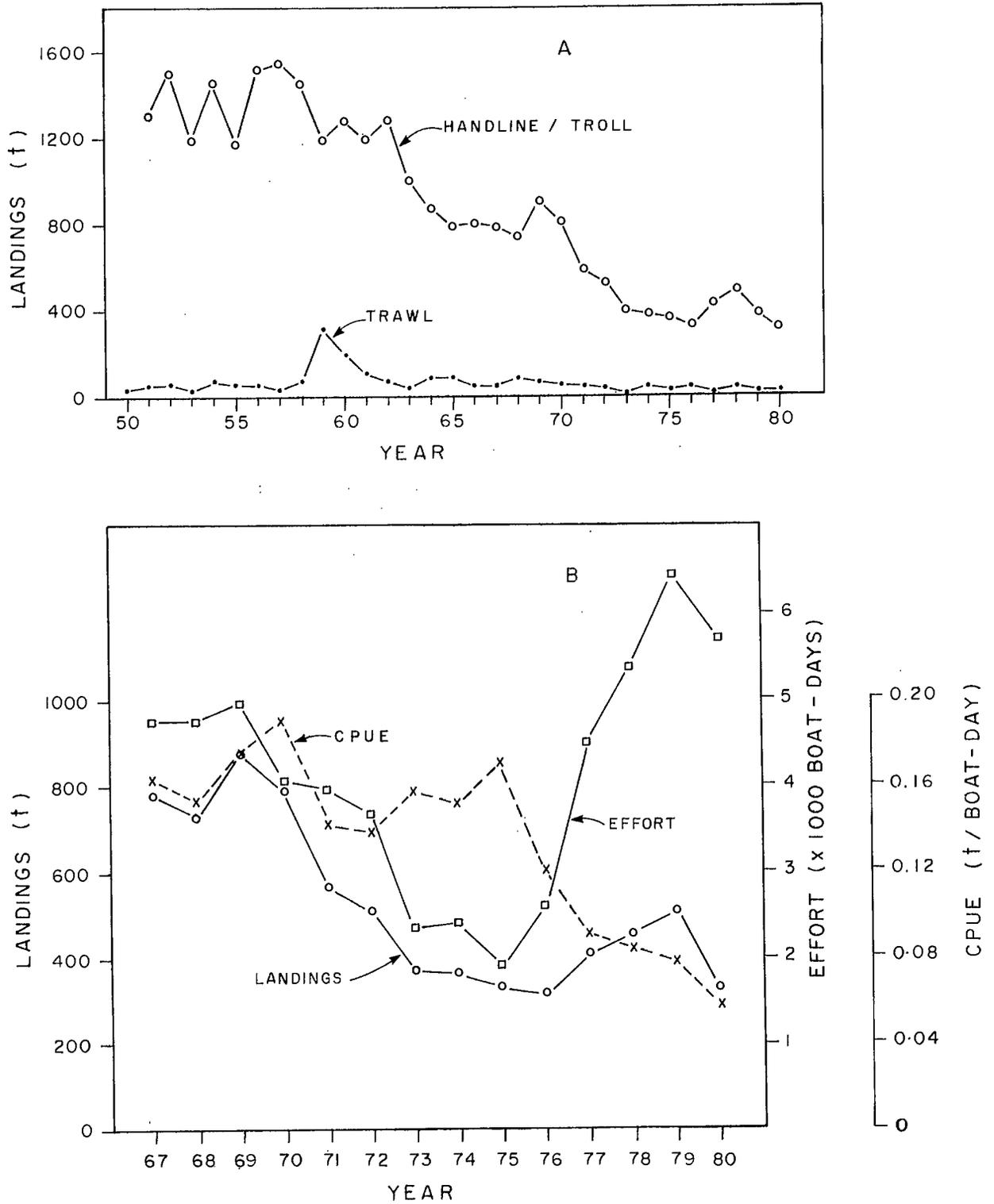
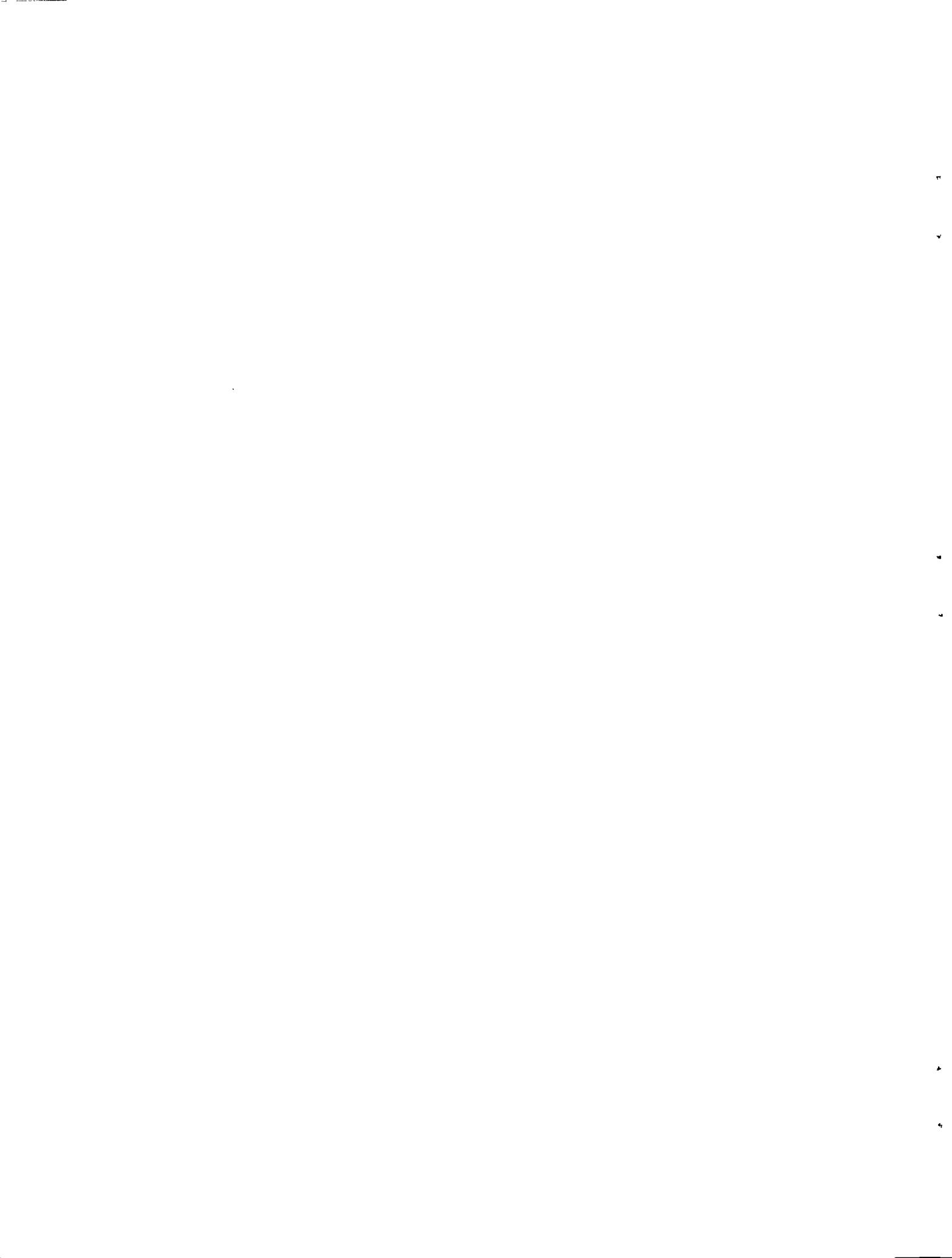


Fig. 3.4.1. Commercial landing statistics for lingcod from the Canadian portion of the inside waters of Vancouver Island (Area 4B): A. Handline/troll and trawl landings (t), 1950-80. B. Handline/troll landings (t), effort (boat-days) and CPUE (t/boat-day), 1967-80.



4. WEST COAST OF VANCOUVER ISLAND (3C AND 3D) STOCK ASSESSMENT

Principal species (based on a 5-yr average) in the Canada-U.S. landings from the west coast of Vancouver Island are Pacific cod (2,510 t), lingcod (1,292 t), rockfish (1,077 t), dogfish (454 t), sablefish (386 t), and petrale sole (303 t) (Table 4.1).

Pacific hake stocks off the west coast of Vancouver Island have become a prominent target of Canadian fishermen since 1978. Catches by the Canadian fleet are mainly part of cooperative ventures with foreign processor vessels. Catches have averaged 6,419 t for the period 1978-80.

In the following section stock assessments are presented for Pacific hake, Pacific cod, lingcod, rockfish, petrale sole, Dover sole, and walleye pollock. Assessments for sablefish, and dogfish are presented for the entire coast in Sections 2.1 and 2.2, respectively.

Table 4.1. Canada-US. groundfish landings (t) by main species for the west coast of Vancouver Island (Areas 3C and 3D), 1976-80.

Species	Canada-U.S. Landings ^a (t)					5-yr average
	1976	1977	1978	1979	1980 ^b	
Pacific cod	3,797.0	2,945.7	2,790.1	1,861.7	1,156.2	2,510.1
Lingcod	1,819.6	1,405.6	1,449.5	1,034.2	749.2	1,291.6
Rockfish	1,311.1	1,249.1	548.3	1,096.8	1,180.2	1,077.1
Dogfish	-	75.6	47.8	299.3	1,848.3	454.2
Sablefish	289.3	784.6	136.3	620.3	99.2	385.9
Petrale sole	605.3	368.6	292.5	101.4	146.5	302.9

^a Included are landings by trawl, trap, longline, handline, and troll.

^b 1980 handline and troll landings not available.

4.1 Pacific hake

4.1.1 Introduction

The major fishery for Pacific hake (Merluccius productus) has occurred by foreign nations on offshore stocks. The average annual catch by all nations for the period 1966-80 was approximately 23,500 t. However, there has been an increasing interest by Canadians in the Pacific hake fishery off the west coast of Vancouver Island and landings by the Canadian fleet have increased dramatically since 1978.

4.1.2 Landing statistics

The reported catch by all nations in the Canadian zone (Sub-zones 5-1 and 5-2) has fluctuated from a high of 64,959 t in 1969 to a low of 5,191 t in 1977 (Fig. 4.1.1). Fluctuations in catch are undoubtedly related to both abundance and migratory habits of hake and to the fishing pattern and strategies of the fleet.

Pacific hake stocks off the west coast of Vancouver Island (Sub-zone 5-1) have been fished by Canadian fishermen since 1978. Most of the catch is sold directly to foreign processor vessels. Catches by the Canadian fleet, as part of a cooperative venture with foreign fishermen, have increased from 1,814 t in 1978 to 4,233 t and 12,215 t in 1979 and 1980, respectively.

4.1.3 Stock assessment

Commercial concentrations of Pacific hake migrate from the U.S. to the Canadian zone. A survey of Sub-zones 5-1 and 5-2 in early May 1979 did not locate significant concentrations of hake indicating movement into the Canadian zone had not begun. By mid-June concentrations of hake were observed in Sub-zone 5-1 indicating the movement into the Canadian zone probably occurred early in June. Catches as large as 4,700 t have been reported for foreign vessels fishing in the Canadian zone in May and hake have been observed in the Canadian zone as late as mid-October. There is good evidence to indicate the timing in and out of the Canadian zone is variable, but it does appear that a commercial fishery for 4-6 months could be sustained annually.

Biological studies in 1979 indicate larger hake of any particular year-class undergo more extensive migrations and tend to migrate into the Canadian zone (Beamish 1981). During 1979, offshore Pacific hake ranged in age from 3-19 yr, however few fish younger than age 6 were found. The population consisted of approximately 70% females that averaged 55 cm compared to an average size of 53 cm for males. The predominance of females in the population and the presence, in general, of larger members of any cohort in the Canadian zone (Fig. 4.1.2) suggest the extent of migration is size dependent.

The 1970 year-class, as 6-yr-olds in 1976 and 9-yr-olds in 1979, have dominated the age distribution of Pacific hake in the Canadian zone in recent years (Fig. 4.1.2). There is little doubt that strong year-classes are important to the fishery and that these year-classes can be fished longer in the Canadian zone.

The effect of over-harvesting of older and predominantly female fish, on recruitment is unknown. However, older individuals within a population may be needed to sustain recruitment during periods of unfavourable environmental conditions.

The size of the offshore Pacific hake stocks and the allowable catch are presently determined by United States scientists. A TAC for the Canadian zone is established based on the U.S. biomass estimate, and an estimate of the proportion of Pacific hake that move into the Canadian zone.

4.1.4 Recommendations

Until more reliable estimates of the biomass in the Canadian zone are made and until the value of the older and larger female hake to recruitment can be determined, the recommended TAC for Pacific hake in the Canadian zone is 35,000 t.

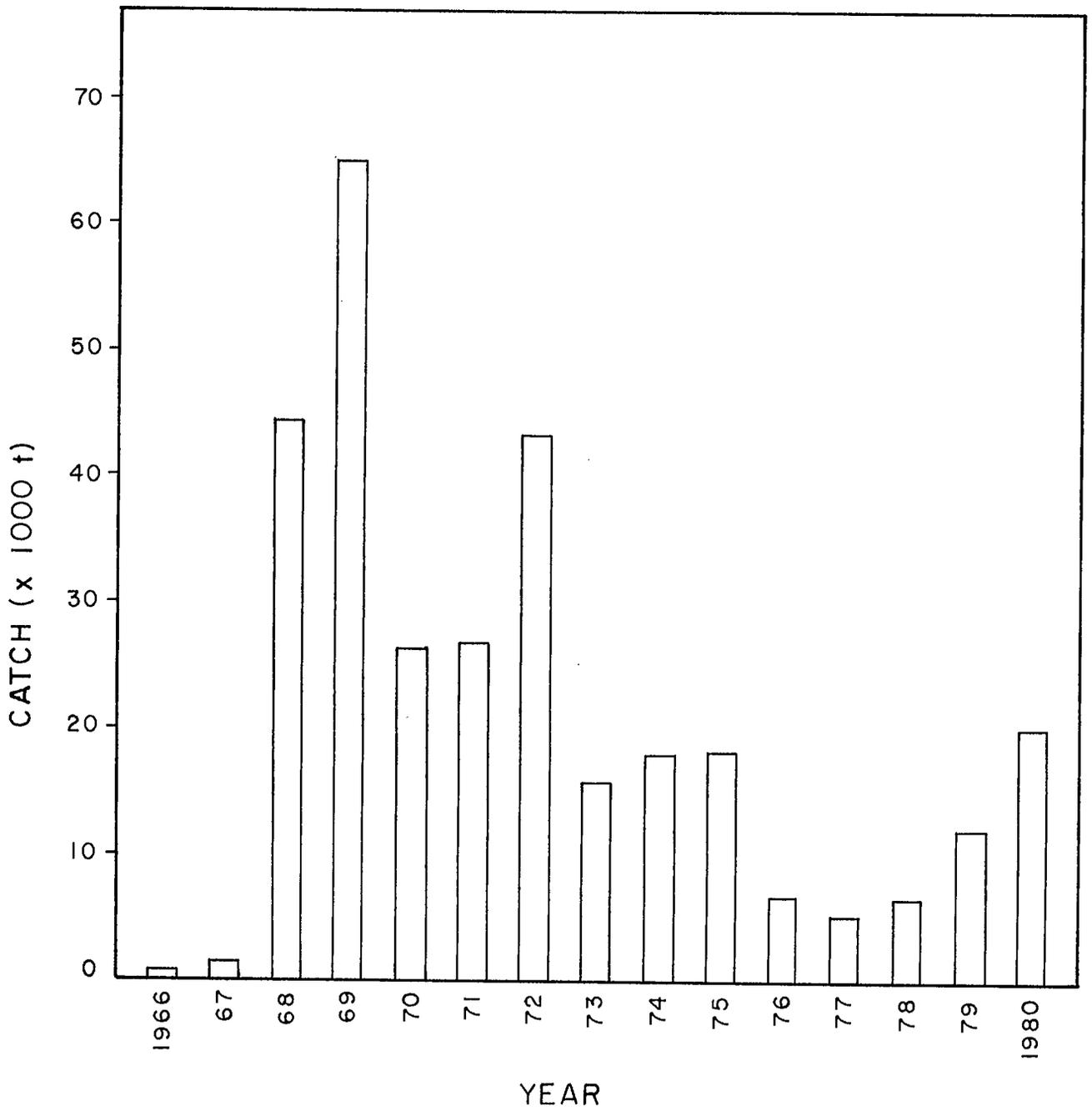


Fig. 4.1.1. Pacific hake catch in INPFC areas Vancouver and Charlotte 1966-1980.



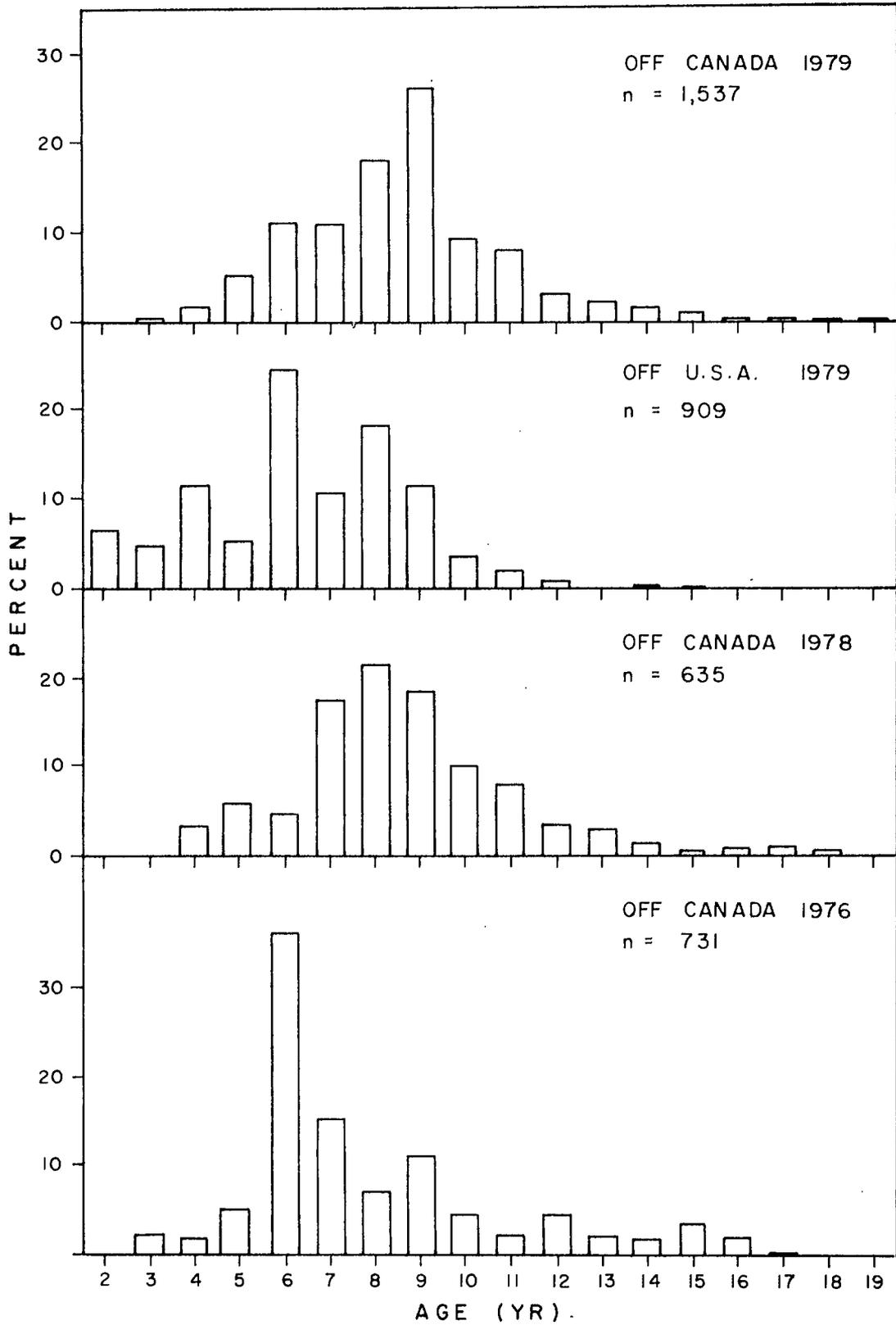
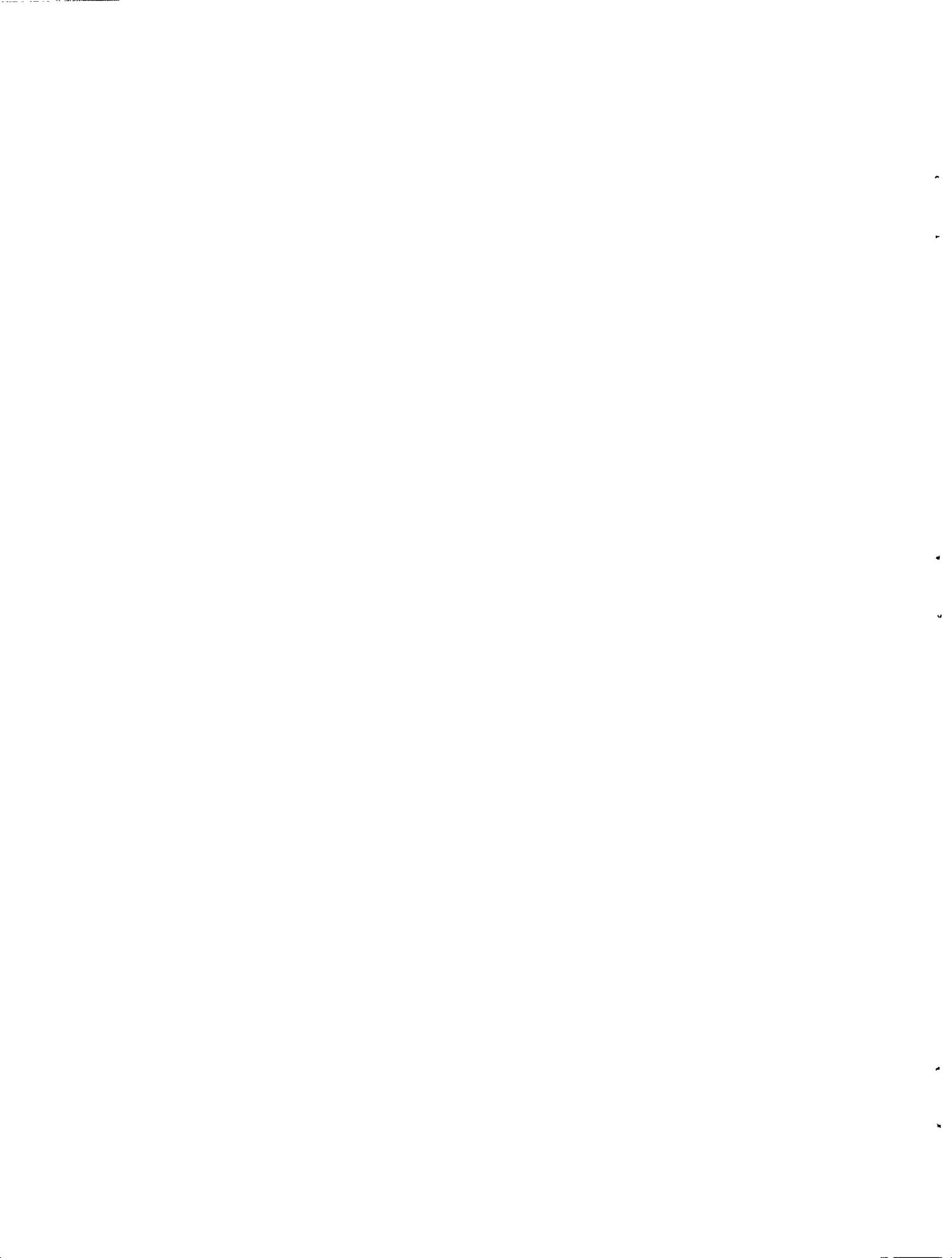


Fig. 4.1.2. Age compositions of Pacific hake catches.



4.2 Pacific cod

4.2.1 Introduction

During 1976-80, Pacific cod comprised approximately 35%, by weight, of the Canada-U.S. landings from Area 3C and 3D, and ranked first (Table 4.1). Negligible landings originated from Area 3D. Several grounds are important in Area 3C, but detailed analysis of landing statistics by ground are incomplete at this time (May 1981), hence Area 3C has been treated as a whole, albeit on a seasonal basis.

4.2.2 Landing statistics

Detailed U.S. landing statistics are not available at this time and the Option-2 method (see description below) was employed using only Canadian data. Approximately 90% of the Canadian landings were interviewed.

Analysis of landing statistics employs a new technique called the Option-2 method (a descriptive report is in preparation), which was developed for allotting effort to individual species in multi-species trawl fisheries. Pacific cod are commonly associated on various B.C. trawling grounds with one to three of the following commercially-important species: English sole (Parophrys vetulus), lingcod (Ophiodon elongatus), petrale sole (Eopsetta jordani), rock sole (Lepidopsetta bilineata), and turbot (Atheresthes stomias). Briefly described, the method involves arranging all-species effort and individual species' landings by depth interval in area-time cells. In each area-time cell, each species is allotted the all-species effort expended in the depth intervals containing the rank-1 (largest) and rank-2 (second largest) landings of that species. For Pacific cod, and co-habitants, depth intervals were in 10-fm units, and area-time cells were fishing ground-quarter-year. LPUE (landing/h trawled) was calculated by dividing Option-2 landings by Option-2 effort. Estimated total effort (\hat{E}) is:

$$\hat{E} = \frac{L}{\ell} e,$$

where L = total landings,
 ℓ = option-2 landings,
e = option-2 effort.

For April-September, Canada-U.S. trawling effort was relatively stable during 1956-74 at 2,248-6,680 h; increased sharply to 8,253-12,890 h during 1975-78; then subsided to 3,429 and 3,736 h in 1979 and 1980, respectively (Fig. 4.2.1; Table 4.2.1). Canada-U.S. landings have fluctuated substantially during 1956-80. In general, landings ranged around 500 t during 1956-70, and around 1,000 t during 1971-80. Landings per trawling hour (LPUEs) fluctuated somewhat synchronously with Canadian interviewed landings. Peaks occurred in 1957, 1964-66, 1971-74 and 1979. There is a slight upward trend evident. The relatively high LPUEs in 1979 and 1980 were due in part to the closure of the cod fishery in Area 3C during February-March and January-March, respectively. That is, more cod survived to be caught, after spawning, during April-June.

During October-March 1956-80, Canada-U.S. effort ranged from 478-3,750 h, without evident trend (Fig. 4.2.2; Table 4.2.1). October-December is a minor factor. The sharp decline in effort after 1974-75 was accentuated by progressively longer closures to trawling in Area 3C beginning in 1978, as follows:

1978 February 22-April 3
1979 February 1-March 31
1980 January 1-March 31

Canada-U.S. landings from Area 3C during October-March were negligible during 1956-64 (133-327 t), moderate during 1964-71 (419-976 t), and substantial during 1971-76 (1,540-2,669 t). This phenomenon reflects the development of the fishery for spawning cod on Amphitrite Bank during January-March, which began in 1972, peaked in 1971-73, and is now closed until recruitment improves. LPUEs exhibited a step-like increase, except for the unusually high values during 1973-74. In general, October-March LPUE does not reflect Pacific cod abundance as does LPUE during April-September. Primary cause is the short time series for the winter fishery, but a partial explanation for later years may lie in the behaviour of cod during their spawning season. A similar phenomenon was noted in Hecate Strait (see Section 6.1).

An overall summary of Pacific cod landing statistics for Area 3C during April-March is shown in Fig. 4.2.3. Total effort (April-March landings ÷ April-September LPUE) rose steadily to a peak of 15,840-19,046 h during 1975-78, and declined sharply thereafter. Landings peaked for the last time in 1975-76, then declined steadily. LPUE peaked in 1972-73 and declined sharply thereafter except for an increase during 1978-80. The sustained high production of Pacific cod was achieved by a substantial increase in effort rather than an increase in abundance. This phenomenon suggests that overfishing might well have occurred after 1974.

4.2.3 Mortality rates

No new information on mortality rates is available at this time (May 1981). Analysis is under way to convert the long time-series of length-frequency data into age-frequencies for analysis.

4.2.4 Recommendations

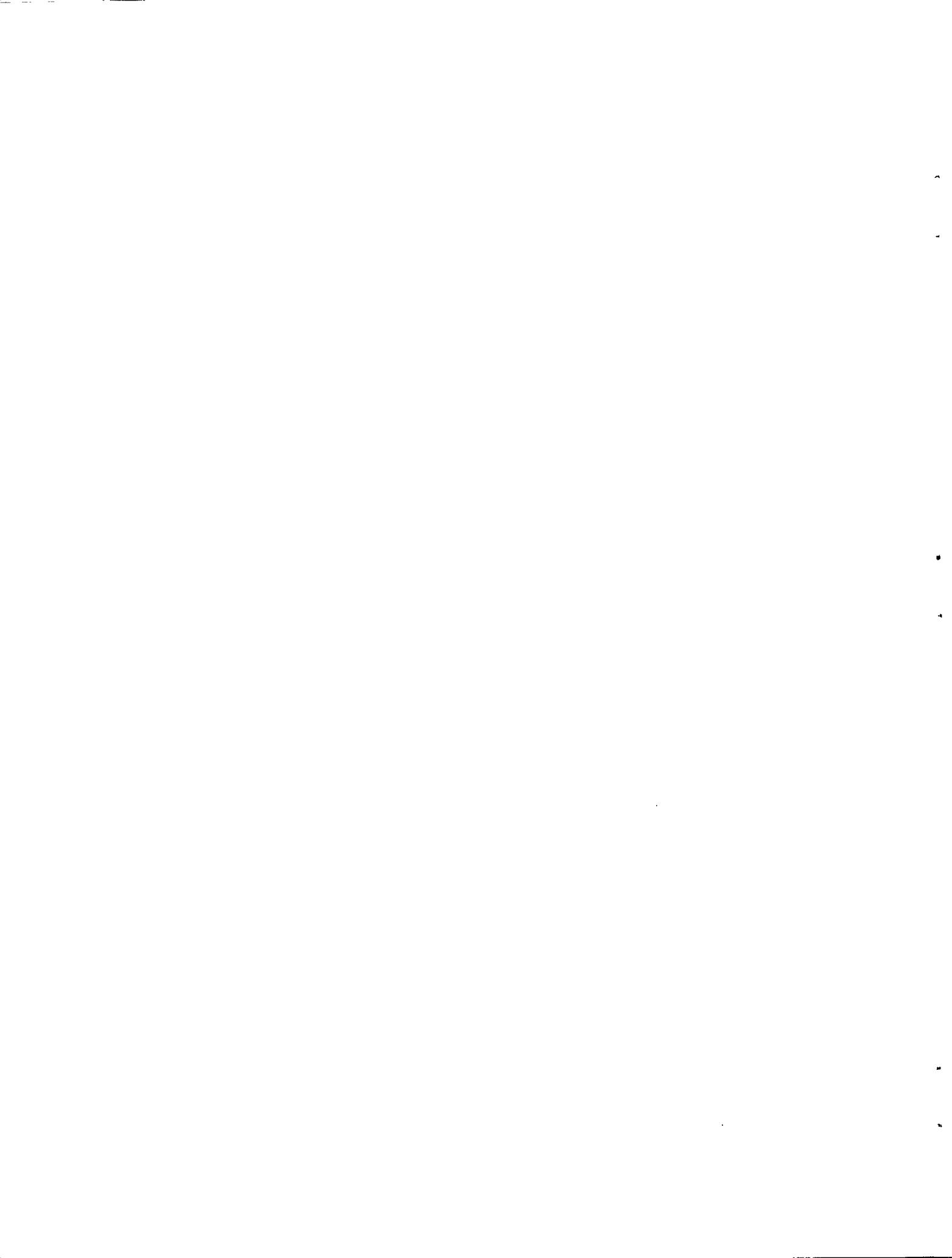
No TAC is recommended for Area 3C. However, a closure of Area 3C during January-March will be recommended once more if the April-September fishery indicates weak to average abundance of the 1979 year-class. A decision will be made in early November. This year, the predictor (see Appendix 1 in Westrheim 1980) will be refined by the inclusion of age-frequency data to better estimate the abundance of the 1979 year-class.

Table 4.2.1. Canada-U.S. landing statistics of Pacific cod for Area 3C, April-September and October-March, 1956-80.

Year	Effort (h)		Landings (t)				LPUE (kg/h)	
	Apr-Sep	Oct-Mar	Apr-Sept		Oct-Mar		Apr-Sept	Oct-Mar
			Can-US	Can Int	Can-US	Can Int		
1956-57	5,542	(1,402) ^a	901	376	(228) ^a	75	163	(163) ^a
1957-58	6,680	924	1,466	603	133	47	219	144
1958-59	4,000	478	573	208	147	114	143	308
1959-60	2,939	3,014	523	207	154	36	178	51
1960-61	6,116	(1,700) ^a	487	139	(84) ^a	18	80	(48) ^a
1961-62	4,972	1,608	345	146	140	36	69	87
1962-63	3,995	655	442	168	327	87	111	499
1963-64	4,162	756	874	429	259	242	210	343
1964-65	2,774	3,405	860	573	974	267	310	286
1965-66	6,188	2,120	1,492	511	939	495	241	443
1966-67	4,914	1,973	1,767	992	976	372	360	495
1967-68	3,764	3,043	649	439	880	406	172	289
1968-69	2,248	2,631	302	106	586	352	134	223
1969-70	3,812	1,364	382	202	419	363	100	307
1970-71	4,218	1,913	545	389	902	486	129	472
1971-72	5,503	1,269	1,989	1,371	2,629	1,673	361	2,072
1972-73	6,272	2,784	2,912	2,429	2,669	1,361	464	959
1973-74	3,422	2,594	1,025	759	1,913	1,239	300	737
1974-75	4,181	3,750	1,395	937	2,310	1,509	334	616
1975-76	9,301	3,140	1,968	873	2,066	1,505	212	658
1976-77	9,115	2,661	2,090	712	1,540	1,034	229	579
1977-78	12,890	1,841	2,077	806	783	589	161	425
1978-79	8,253	884	1,662	561	446	330	201	505
1979-80	3,429	(409) ^a	1,269	943	(158) ^a	99	370	(386) ^a
1980-81	3,736	-	918	682	-	-	246	-

Source: 1956-78 Canada-U.S. landings from PMFC Groundfish Data Series
 1979-80 Canada-U.S. landings from unpublished data
 1956-80 Canada interviewed landings and effort from PBS computer files

^a Canada landings only for Jan-Mar 1980.



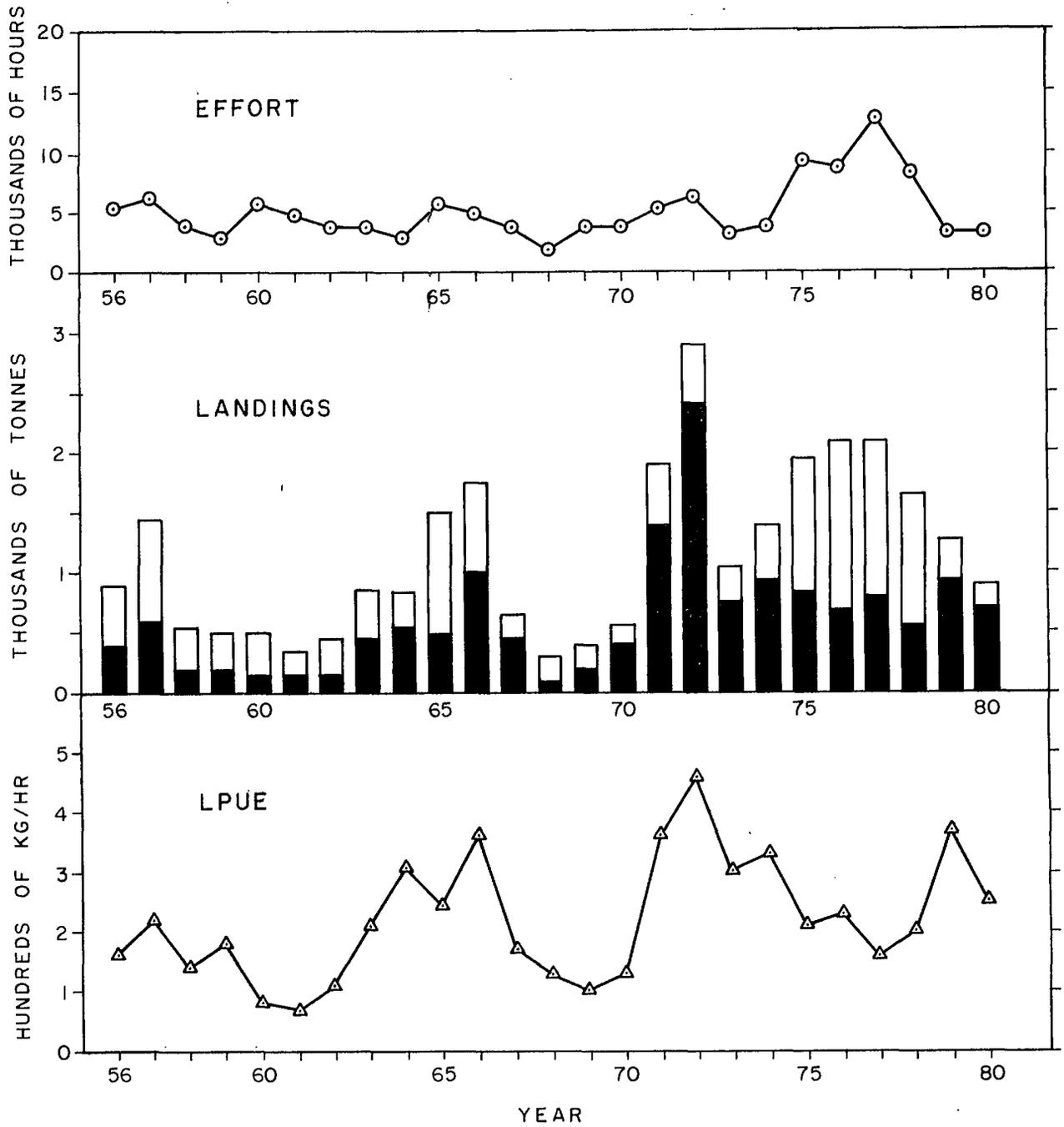


Fig. 4.2.1. Canada-U.S. landing statistics for Pacific cod from Area 3C, April-September, 1956-80. (Shaded area = Canada interviewed landings.)



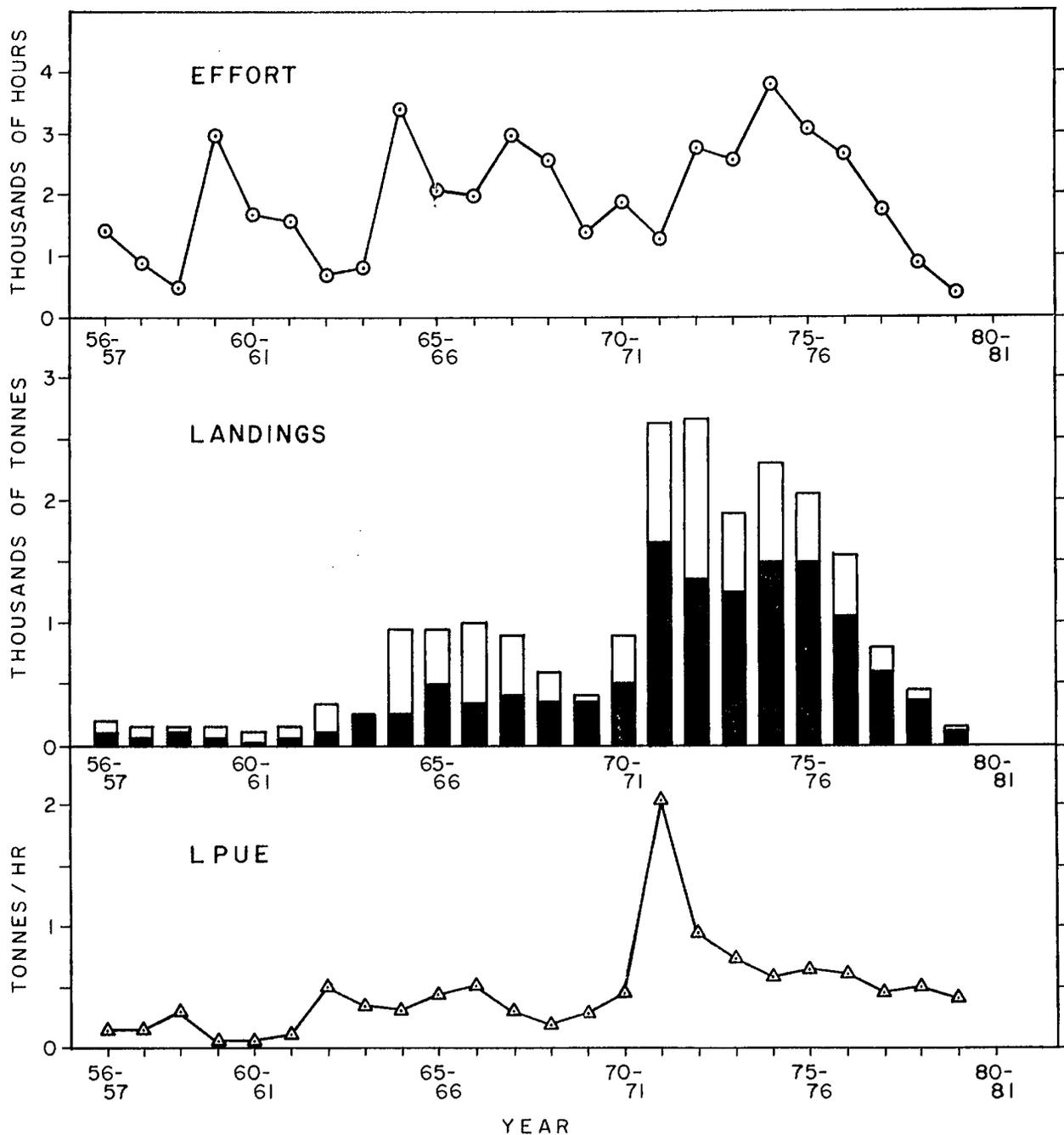
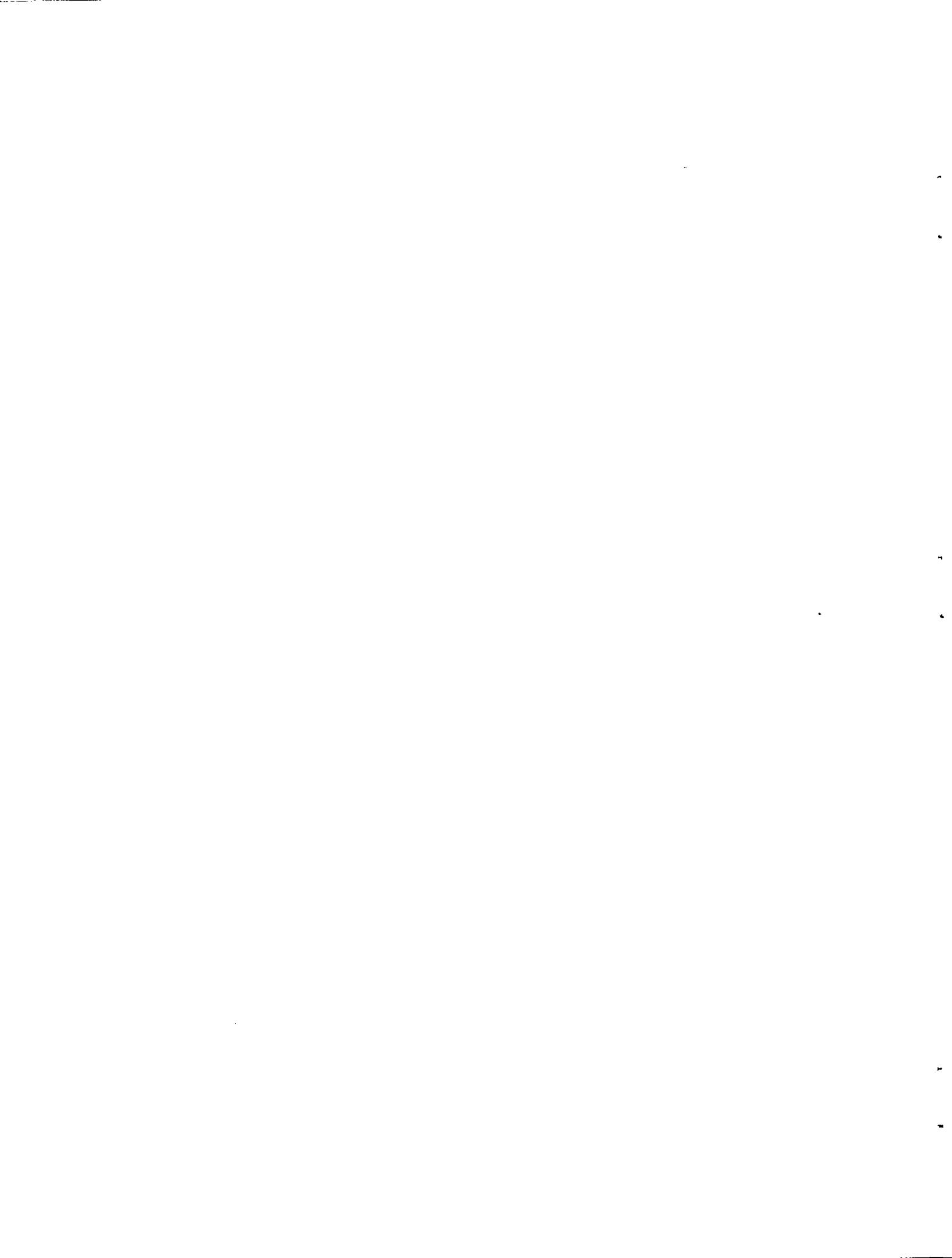


Fig. 4.2.2. Canada-U.S. landing statistics for Pacific cod from Area 3C, October-March, 1956-80. (Shaded areas = Canada interviewed landings).



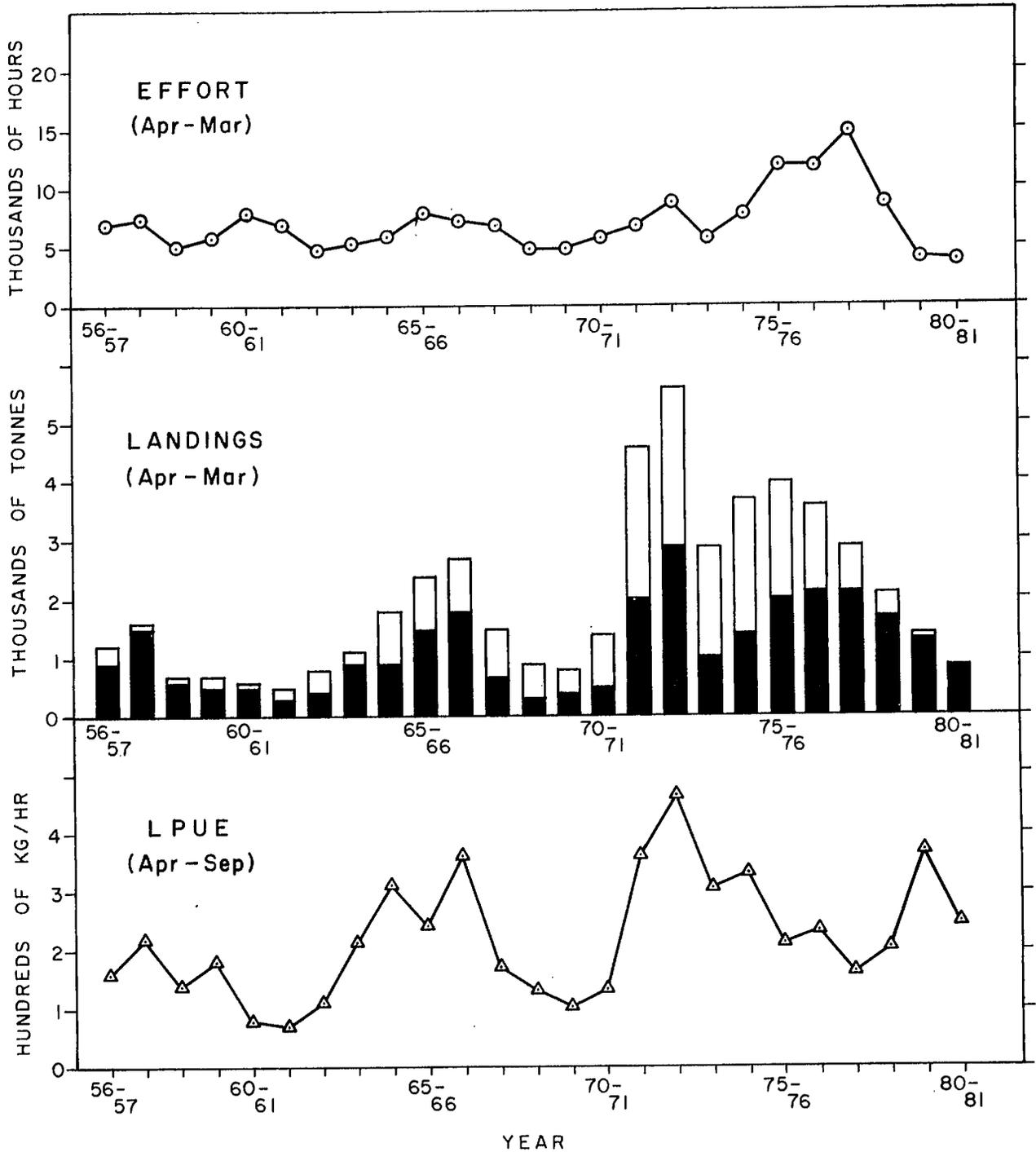
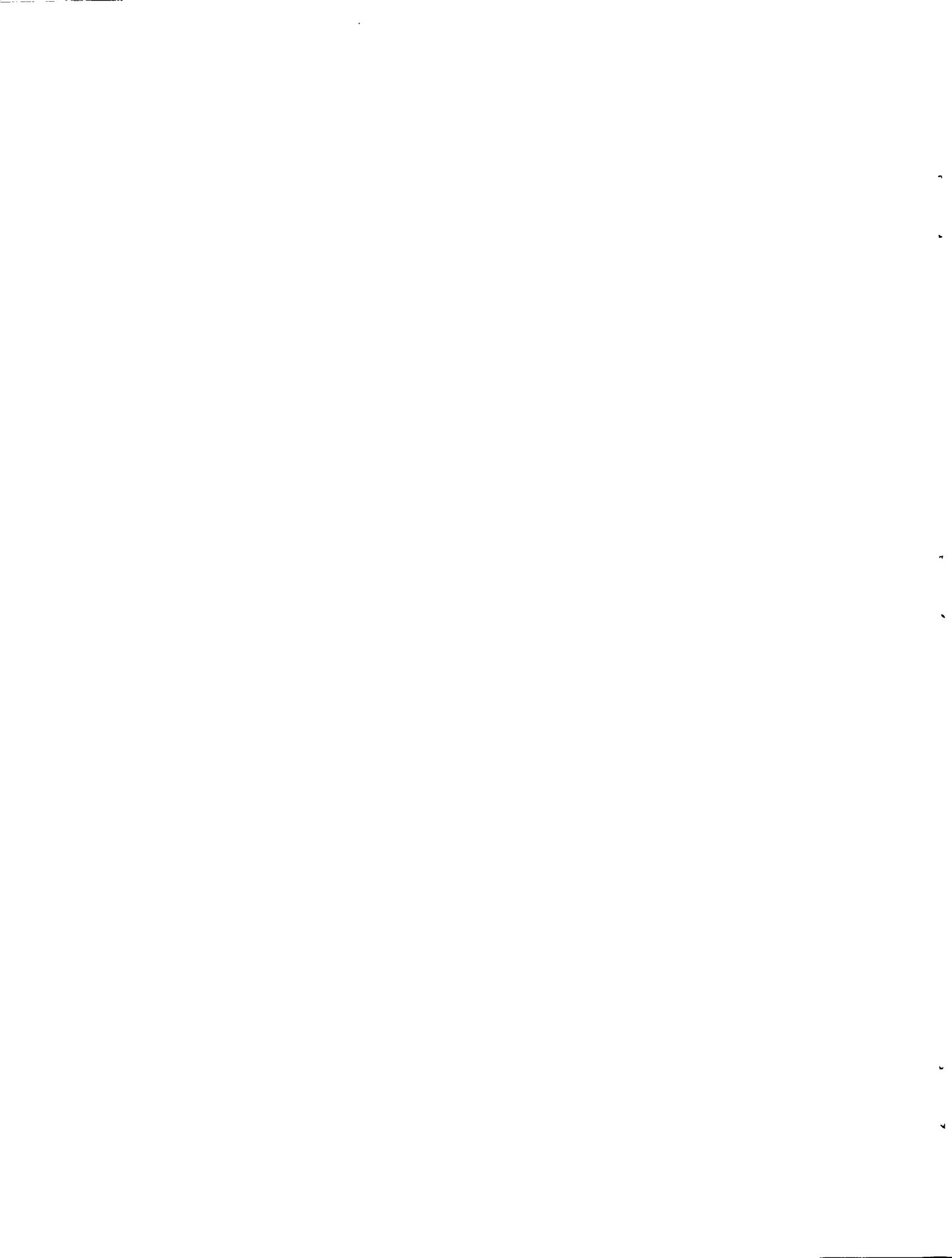


Fig. 4.2.3. Canada-U.S. landing statistics for Pacific cod from Area 3C, April-March, 1956-80. (Shaded areas = April-September landings.)



4.3 Lingcod

4.3.1 Introduction

Commercial trawling grounds off the west coast of Vancouver Island, particularly the southwest coast, are the most important in terms of lingcod production from Canadian waters. Trawl landings of lingcod from the west coast of Vancouver Island comprised an average of 18% of the annual Canadian groundfish trawl production from these waters during 1975-79.

Delineation of lingcod stocks is not clearly understood. The limited results from tagging studies indicate adult lingcod do not migrate extensively. The extent of juvenile movement is poorly understood. For present purposes, the state of the lingcod resource off the west coast of Vancouver Island will be examined by major statistical area on the assumption that negligible mixing occurs among these areas.

4.3.2 Abundance indices

Lingcod off the west coast of Vancouver Island are mainly caught as a component of the multi-species trawl fishery which traditionally, also includes Pacific cod, petrale sole and rock sole. In a multi-species trawl fishery it is difficult, if not impossible, to identify accurately the effective effort directed at a single species. 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. landings of lingcod by the total fishing effort of both countries.⁵ This will be referred to as TOTAL CPUE. This method will tend to overestimate declining abundance since no allowance is made for the possibility that fishermen have re-directed effort to other more remunerative species. However, because lingcod have, historically, commanded the highest price per pound to trawl fishermen there is likely strong incentive to direct effort at lingcod, particularly during periods of high demand and relatively high abundance. It is noteworthy that poor market conditions in 1980 resulted in industry restrictions in the form of trip limits and a substantial decline in price paid per pound.

There are several techniques for eliminating extraneous effort, but for present purposes attention will be confined to interviewed Canadian trawl landings of lingcod which constitute 25% or more of the landings during a particular haul or trip. Dividing this landing by the corresponding fishing effort yields what is defined as 25% qualified CPUE. This method will tend to under-estimate declining abundance 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.

⁵Sources of data: 1954-55, Ketchen (1976); 1956-78, Pacific Marine Fisheries Commission Data Series; 1979-80 provisional.

4.3.3 Southwest Vancouver Island (Area 3C)

4.3.3.1 Landing statistics

Lingcod from the southwest coast of Vancouver Island are landed primarily by the Canada-U.S. trawl fisheries. Minor amounts are also landed by the commercial handline/troll fisheries. Unknown quantities are also landed by recreational and native food fisheries.

Trawling grounds off the southwest coast of Vancouver Island are the most important in terms of lingcod production from waters off Canada. During 1970-80, an average of 937 t or 42% of all Canada-U.S. trawl landings from international statistical areas adjacent to the Canadian coast originated in Area 3C.

Historically, trawl production from this area has fluctuated substantially (447-2,000 t/yr) without trend since at least 1954 (Table 4.3.1, Fig. 4.3.1A). In recent years trawl production has declined from a high of 1,798 t in 1975 to a record low of 447 t in 1978. Production remained at low levels in 1980. Production from the commercial line fisheries has fluctuated without trend since 1954, but the fluctuations have been modest (100-300 t/yr).

Fluctuations in TOTAL CPUE have closely paralleled total trawl landings during most years. Fluctuations in 25% qualified CPUE appear highly irregular but also paralleled fluctuations in landings (Fig. 4.3.2). The fluctuating trend in CPUEs appears reflective 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.

4.3.3.2 Stock Assessment

Lingcod have undergone marked fluctuations in abundance during 1954-80. Preliminary investigation into the cause of these fluctuations indicates there is a significant density-dependent relationship ($p < 0.01$) between indices of parental stock and relative indices of age-3 recruits for the range of stock levels during 1954-79 (Fig. 4.3.3). The relationship, based on a linear solution to the Ricker (1954) equation $R = \alpha Pe^{-\beta P}$, indicates 41% of the variance in recruitment is explained by parental stock size (Fig. 4.3.4). Because there is a high degree of measurement error in the estimates of both stock and recruitment parameters and because of the potential for environmental influence on recruitment the relationship is of little predictive value. However, this relationship does identify a mechanism that may be important to the determination of year-class strength.

During 1977-79 lingcod in commercial trawl landings from waters off the southwest coast of Vancouver Island ranged in ages from 3-17 yr. However, lingcod cease to be of commercial importance after about age 9. In 1977 and 1978 the modal age in samples from the commercial trawl fishery was age 6 and 7, respectively (Fig. 4.3.5). The shift in the modal age in 1979 to age 4-5 indicates the most recent surge in recruitment was the result of one or two strong year-classes from the mid-1970s.

An absence of an adequate time-series of catch at age data precludes an assessment of stocks based on cohort analysis or yield per recruit considerations. In an attempt to assess stock productivity and maximum sustainable yields the relationship between estimates of CPUE and effort were examined using the discrete-time, stochastic version of the Schaefer model (Schnute 1977) and Gulland's (1961) method. There was no conformity of the data to the Gulland method and results of the Schaefer analysis were rejected on the basis of variance considerations. Suffice it to say that there are no outstanding differences in trends between CPUE estimates. Neither the estimate of TOTAL CPUE or 25% qualified CPUE reflects any apparent long-term trend in stock abundance, assuming that a more obvious decline in CPUE is not being concealed by increased fishing efficiency. However, the current low level of abundance warrants some concern, especially if it is related to over-exploitation.

4.3.3.3 Recommendations

A winter lingcod closure for all types of lingcod fishing is recommended for the November 15-April 15 period. This will remove fishing pressure during the period when stocks are highly vulnerable to exploitation and essential to survival during the egg stage (see Section 3.4.5). This will also prevent landings of lingcod at a time when the quality of the flesh is allegedly poor. Landing records for 1978-79 indicate a closure during November 15-April 15 period will not affect the rockfish and Pacific cod trawl fisheries off the west coast of Vancouver Island. In addition, a provisional total allowable catch (TAC) of 600 t of lingcod is recommended for Area 3C during the open season.

4.3.4 Northwest Vancouver Island

4.3.4.1 Landing statistics

Canada-U.S. trawl landings of lingcod from the northwest coast of Vancouver Island averaged 217 t or only 10% of the annual coast-wide trawl production during 1970-80. Trawl production was relatively low during 1954-64, frequently being lower than those of the line fisheries (Table 4.3.1; Fig. 3.3.1B). However, during 1965-70, Canadian effort increased substantially and was primarily directed 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 Canada-U.S. trawl effort. Total trawl production reached a peak in 1968 but fell abruptly between then and 1972. CPUE estimates have paralleled the fluctuations in annual trawl landings during the course of the fishery (Fig. 4.3.6). Canadian trawl effort declined sharply between 1971 and 1972 and suggests that abundance of lingcod fell to a level which could no longer support a target fishery. Although landings have remained at relatively low levels since 1970, CPUE estimates rebounded sharply during 1974-78 to levels comparable to that which prevailed in 1968. The small line fishery has fluctuated without trend during 1954-80. However during periods of low trawl productivity line landings equalled or surpassed those of the trawl fleet.

4.3.4.2 Stock assessment

Lingcod stocks off the northwest coast of Vancouver Island have undergone substantial fluctuations in abundance similar in periodicity to stocks off the southwest coast of Vancouver Island. Production from the Canada-U.S. trawl fisheries appear dependent on natural fluctuations in recruitment.

The population dynamics of lingcod stocks, as indexed by trawl fishery statistics, do not conform to the Gulland (1961) or Schaefer stock production models. Nevertheless, there is no evidence of any long-term trend in stock abundance. Even though stocks are currently at low levels, lingcod do not appear over-exploited.

4.3.4.3 Recommendation

A closure covering the November 15-April 15 period is recommended for all types of lingcod fishing and as indicated for Area 3C (Section 4.3.3.3) should not disrupt the trawl fishery for other species. Although stocks do not appear depleted the close proximity of Area 3D with Area 3C makes it difficult to separate Area 3D from Area 3C with respect to a closure without jeopardizing the effectiveness of the closure in Area 3C. A provisional TAC of 200 t is recommended during the open season subject to review in mid-season or at such time when the assigned quota becomes fully utilized.



Table 4.3.1. Canada-U.S. lingcod production (t) in waters off the west coast of Vancouver Island, 1954-80a.

Year	Area 3C			Area 3D		
	Total trawl ^b landings(t)	Total trawl ^b CPUE(t/hr)	Line fishery ^c landings(t)	Total trawl ^b landings(t)	Total trawl ^b CPUE(t/hr)	Line fishery ^c landings(t)
1954	781.1	-	239.5	59.0	-	105.9
1955	1,246.9	-	167.5	141.1	-	92.5
1956	1,142.1	-	154.5	164.2	-	124.2
1957	1,035.6	-	293.0	129.7	-	134.6
1958	1,018.3	-	154.4	110.2	-	119.5
1959	1,743.2	0.192	179.6	64.0	0.016	93.4
1960	1,866.5	0.158	216.8	87.1	0.023	105.5
1961	1,971.3	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	1,183.0	0.110	100.0	225.9	0.070	84.5
1965	1,889.2	0.120	121.2	505.3	0.117	89.6
1966	2,053.4	0.155	156.9	584.7	0.146	135.1
1967	1,784.0	0.181	244.2	459.5	0.152	165.8
1968	1,693.7	0.201	160.6	868.2	0.226	107.2
1969	1,082.7	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	165.0	84.8	0.033	180.8
1973	879.5	0.093	182.5	172.4	0.062	83.9

(cont'd.)

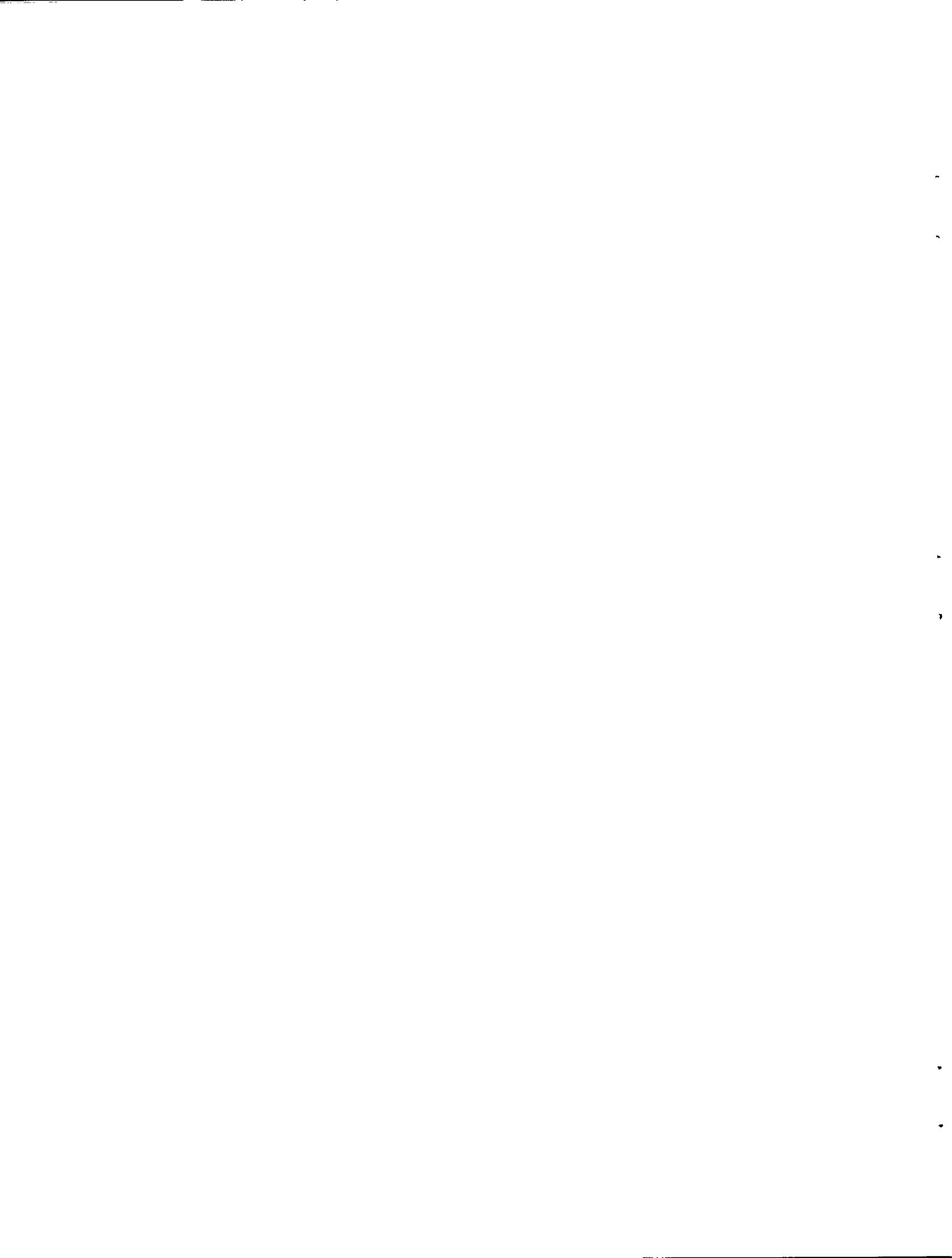
Table 4.3.1. (cont'd)

Year	Area 3C			Area 3D		
	Total trawl ^b landings(t)	Total trawl ^b CPUE(t/hr)	Line fishery ^c landings(t)	Total trawl ^b landings(t)	Total trawl ^b CPUE(t/hr)	Line fishery ^c landings(t)
1974	1,044.2	0.108	224.1	241.8	0.079	112.7
1975	1,798.9	0.134	214.7	347.0	0.092	89.5
1976	1,304.5	0.081	251.0	245.4	0.090	90.1
1977	1,042.6	0.069	264.8	157.9	0.086	107.0
1978	447.2	0.040	198.7	196.7	0.104	93.8
1979	829.0	0.130	171.1	104.5	0.068	75.9
1980	622.4	0.102	205.6	121.5	0.040	70.4

^a Landings do not include production from recreational fisheries, shrimp trawl, trap, gillnet, beach seine or spear-fishing methods.

^b Sources: 1954-55, Ketchen (1976); 1956-78, Pacific Marine Fisheries Commission, Data Series; 1979-80, provisional.

^c Sources: 1954-79 British Columbia Catch Statistics, Department of Fisheries and Environment, Annual Reports; 1980 provisional.



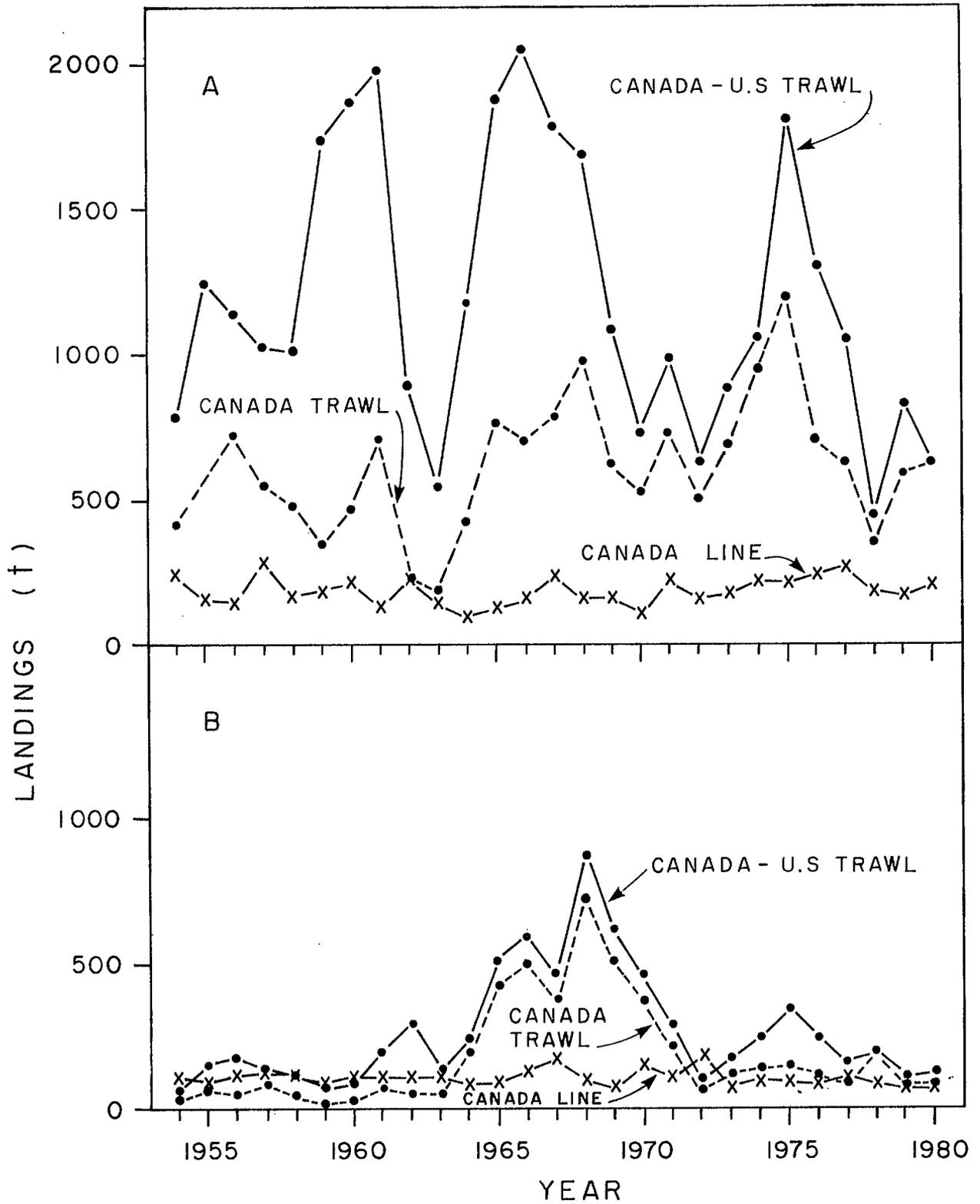
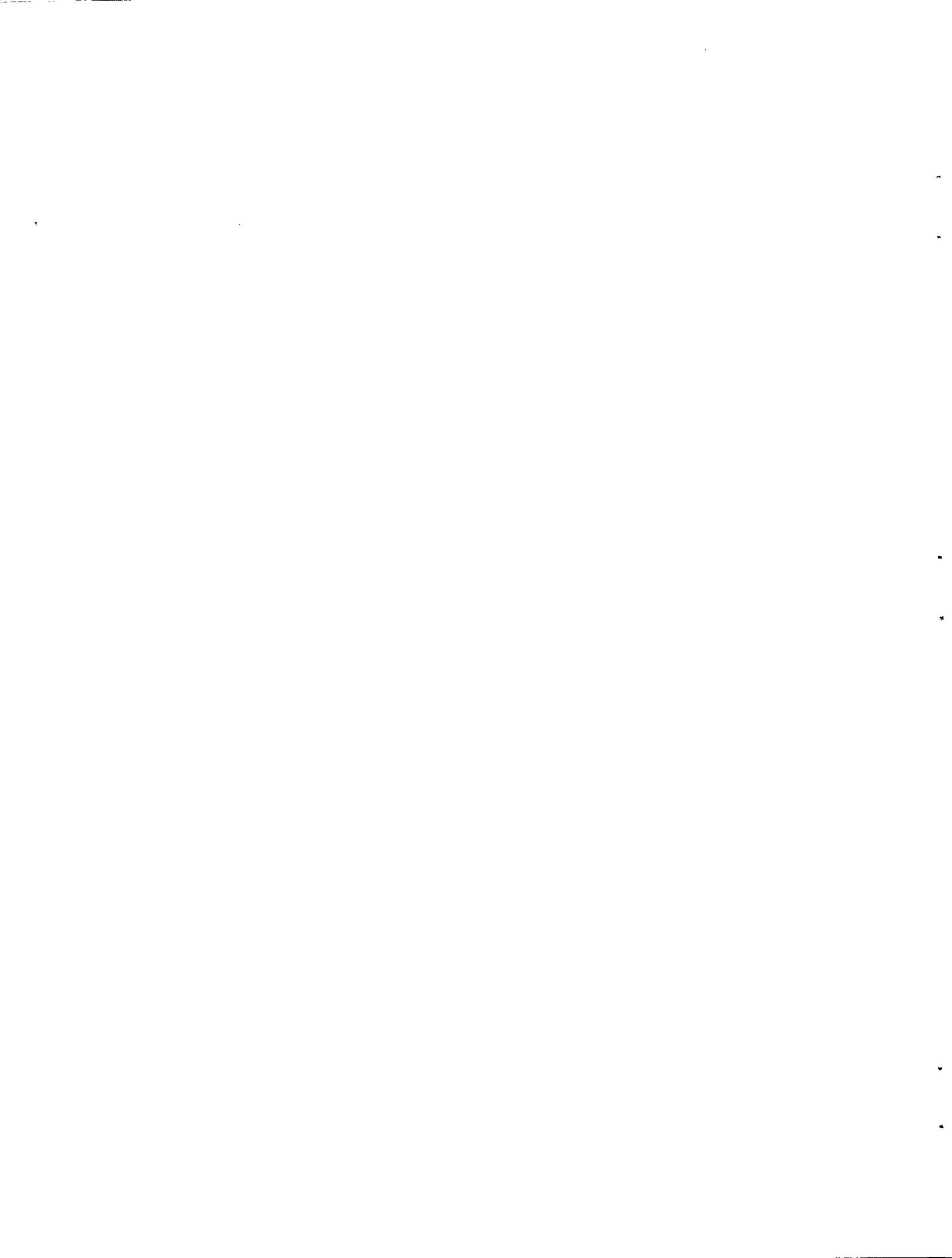


Fig. 4.3.1. Commercial lingcod landings from A. Southwest Vancouver Island (Area 3C) and B. Northwest Vancouver Island (Area 3D), 1954-80.



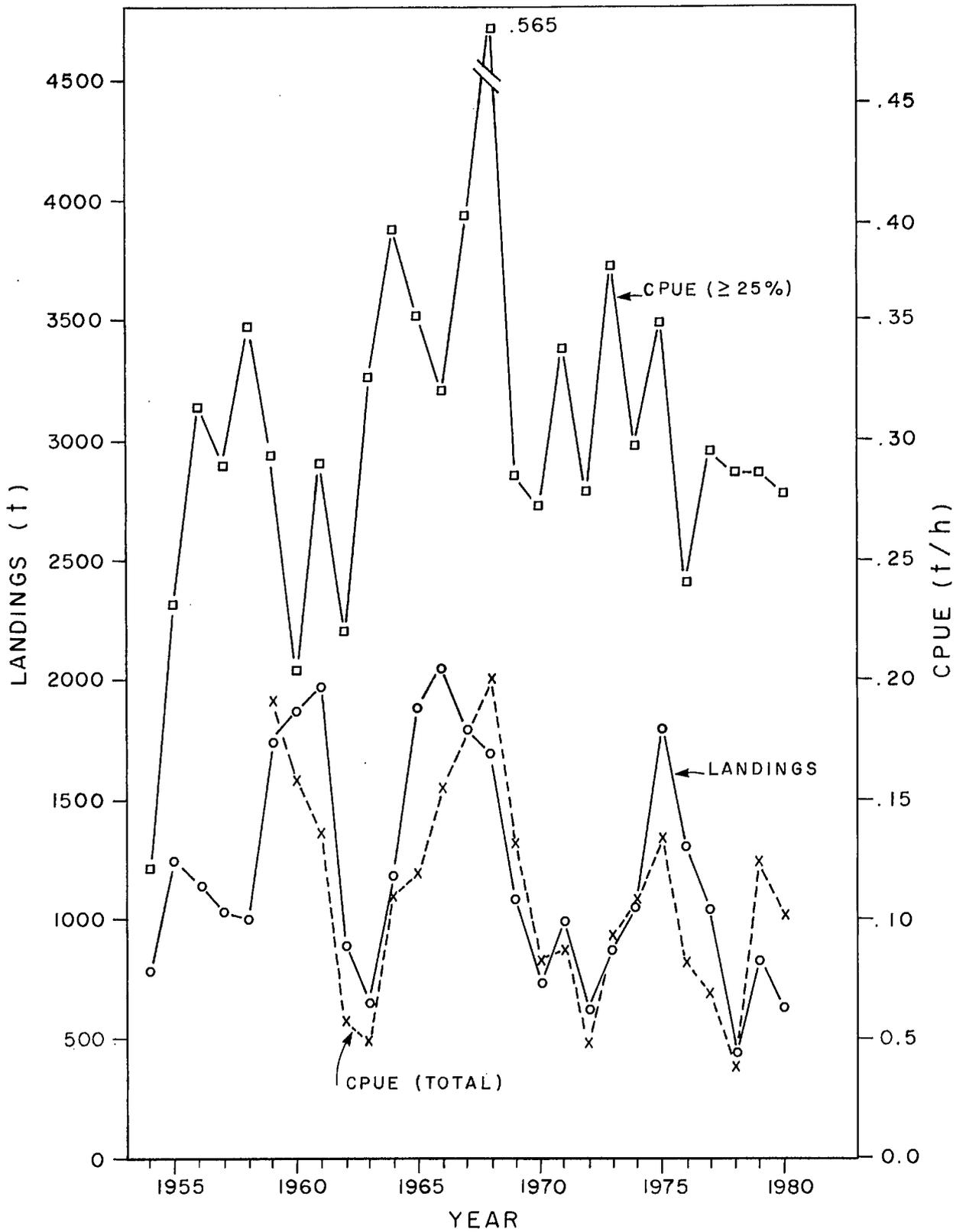


Fig. 4.3.2. Commercial Canada-U.S. lingcod trawl landings and CPUE estimates from southwest Vancouver Island (Area 3C), 1954-80.



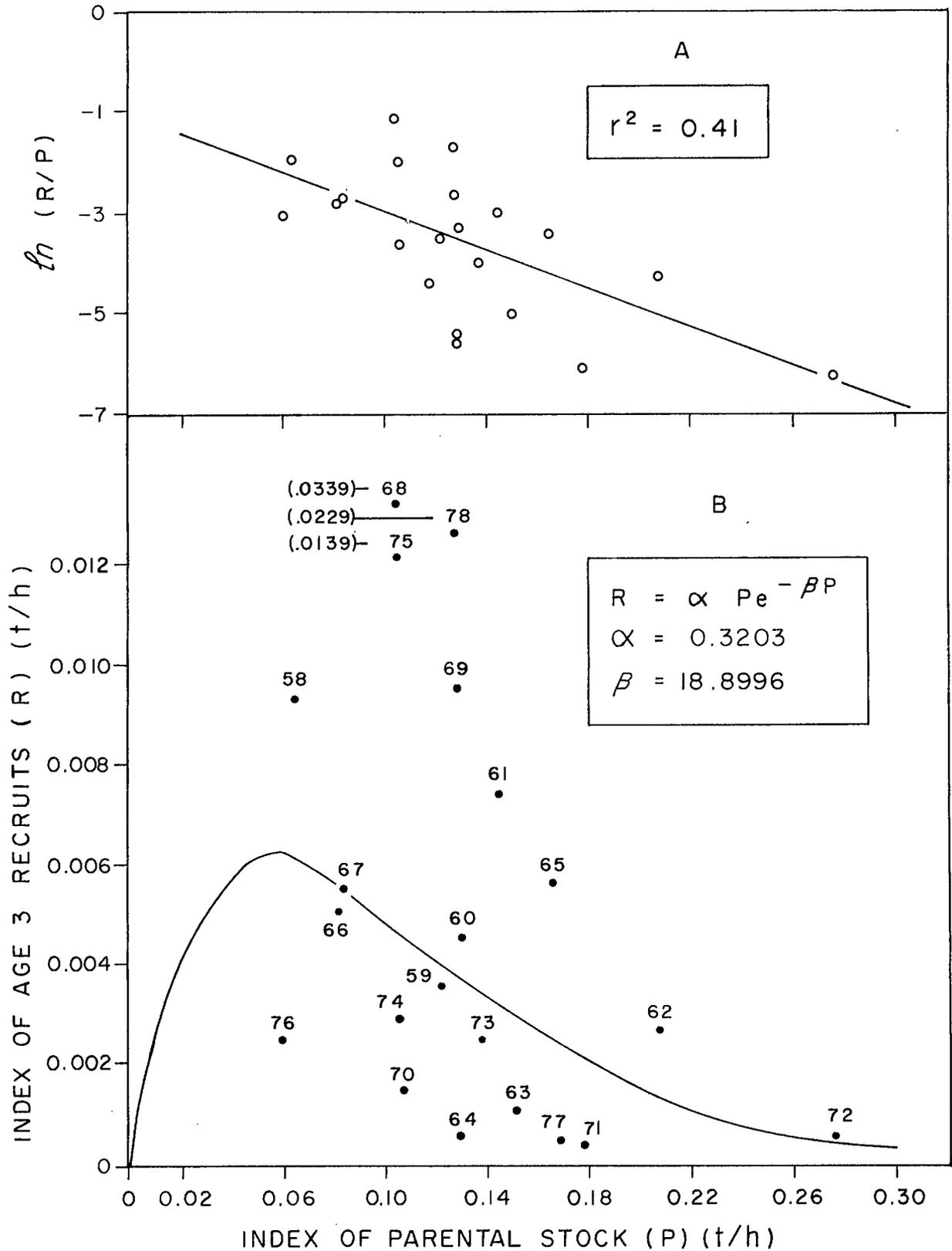


Fig. 4.3.3. Stock-recruitment relationship for lingcod off southwest Vancouver Island, 1954-78: A. Relationship between natural logarithm of indices of relative recruitment (R/P) and parental stock; B. Ricker type stock-recruitment curve.



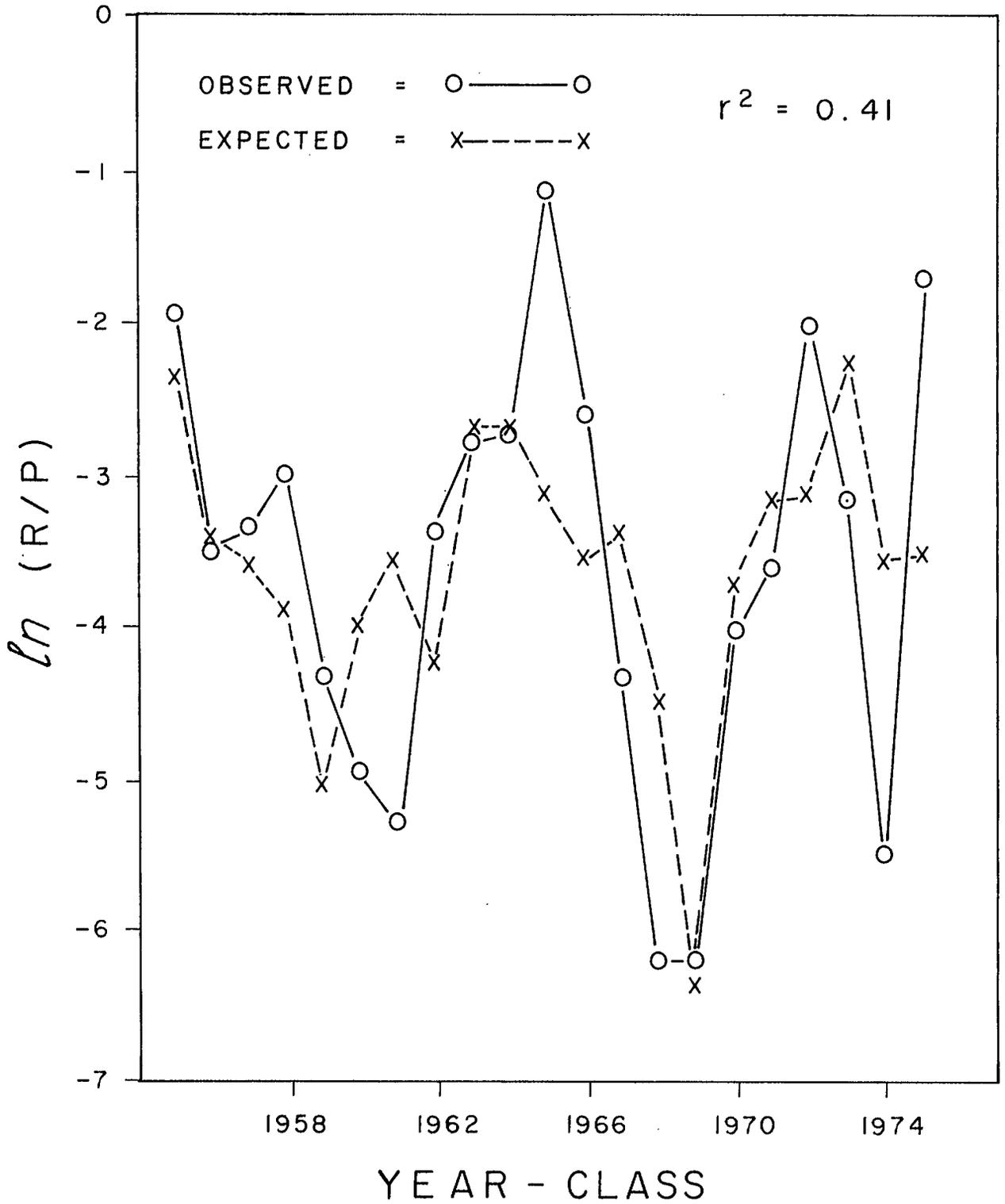


Fig. 4.3.4. Observed vs. expected rate of recruitment 1958-75 for lingcod in Area 3C.

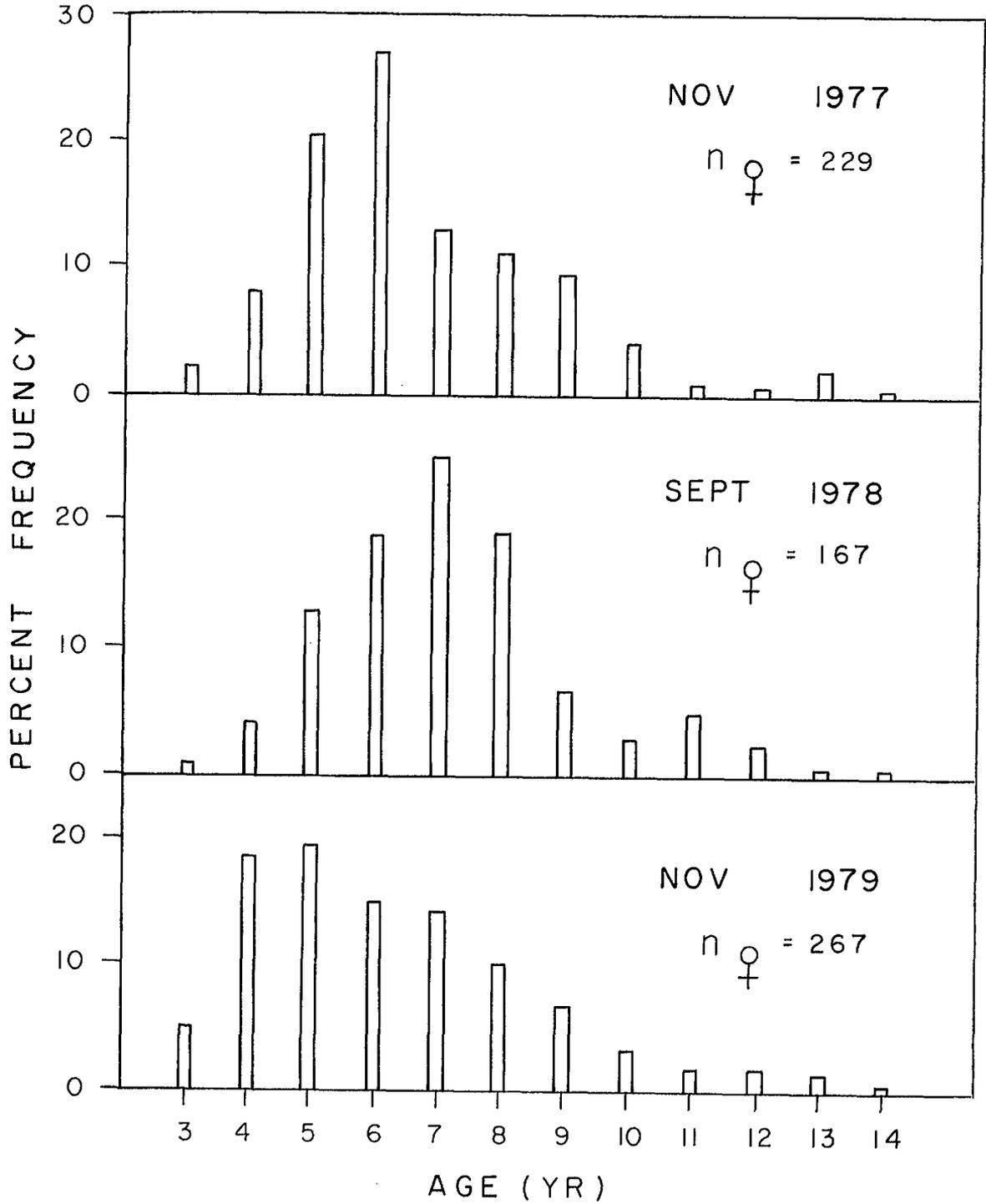


Fig. 4.3.5. Percent age distribution of female lingcod during September-November 1977-79 from southwest Vancouver Island.



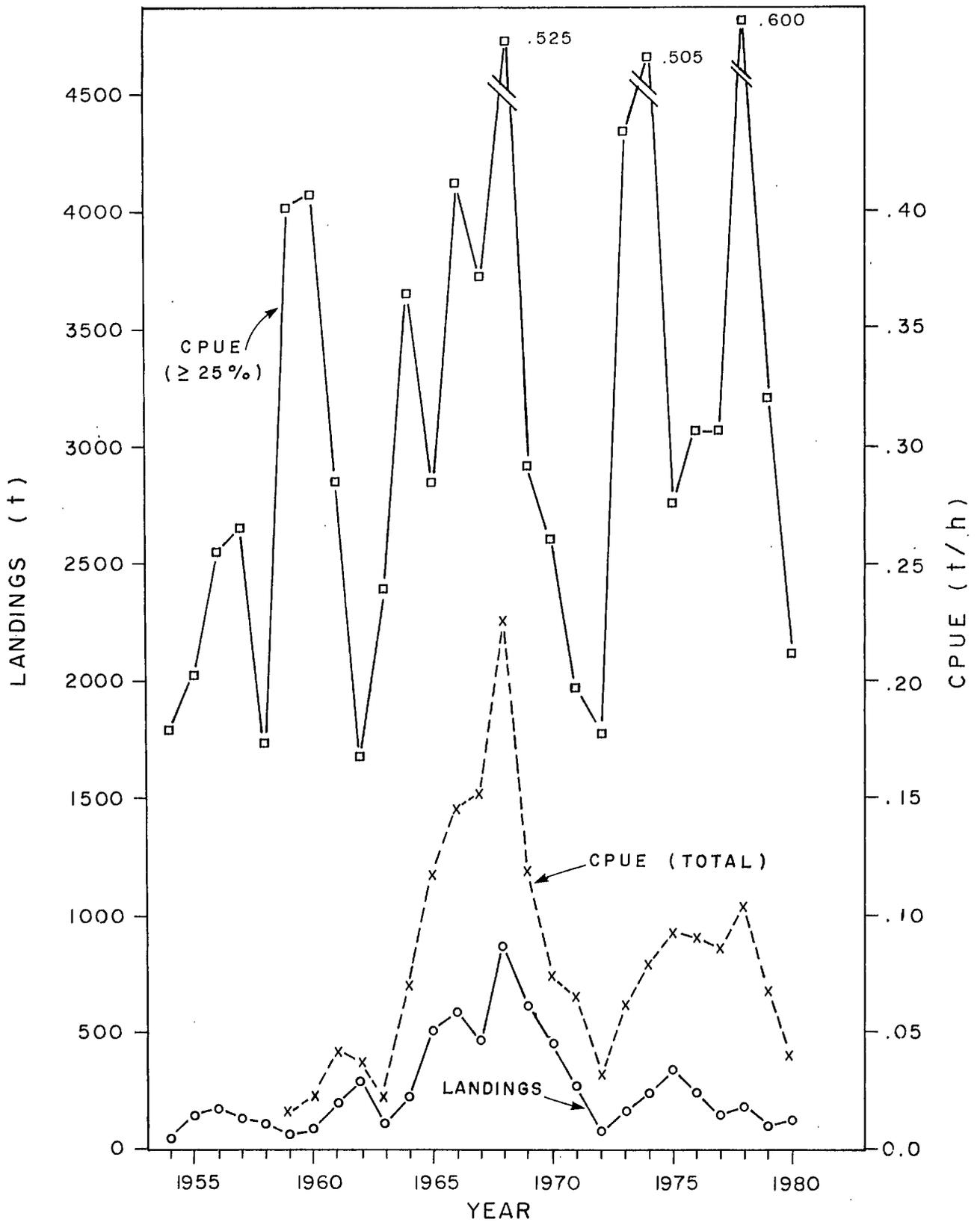


Fig. 4.3.6. Commercial Canada-U.S. lingcod trawl landings and CPUE estimates from northwest Vancouver Island (Area 3D), 1954-80.



4.4 Rockfishes

4.4.1 Pacific ocean perch (Sebastes alutus)

Historical exploitation of S. alutus in this area has been well documented elsewhere (Gunderson 1977, Westrheim 1980) and detailed statistics will not be presented here. The 1979 biomass survey of the west coast of Vancouver Island produced an estimate of approximately 6,200 t for S. alutus. In 1980 the TAC was set at 600 t, a maintenance level if the natural mortality rate was actually 0.10, as believed at the time. In 1981 the TAC was reduced to 500 t in an effort to begin the rebuilding process for this stock. If the population is in fact at ~6,000 t and natural mortality is as low as 0.05, then the amount of rebuilding at an exploitation rate of 0.08 (based on population size and TAC) would be minimal.

4.4.1.1 Recommendation

The 3C-3D area does not have a time series of age or biomass survey data to provide guidance about absolute stock levels. That stock biomass has been substantially reduced from the mid-1960s there is no doubt. The significant contribution of strong cohorts to S. alutus stocks in other areas has been noted and the probability of rebuilding the 3C-3D stock may be highly dependent upon the occurrence of such cohorts. The evidently small size of this stock and the lack of detailed information about recruitment to rockfish populations presents an opportunity for long-term experimental management. The 1981 TAC for this stock was 500 t; if recent estimates of M are correct, this TAC may be ~200 t above 'maintenance' levels. It is recommended that the 500 t TAC be instituted for another two years (i.e. 1982 and 1983) and that the stock be re-surveyed in 1984 to determine stock biomass. In the interim, detailed age composition information will be collected on a regular basis.

This recommendation departs from normal practice but is based on the view that the severely depleted state of this stock may lend some sensitivity to such small absolute (but large relative) changes in TACs. In addition, the penalty for error in such a system would be much lower than in other S. alutus stocks, while the potential benefits to our understanding of stock dynamics may be large.

4.4.2 Canary rockfish (S. pinniger)

4.4.2.1 Southwest Vancouver Island

S. pinniger continues to be a minor species in Area 3C, where total catches have declined to ~30 t/yr in 1979 and 1980 (Table 4.4.1). These catches were well below recommended TACs. Previous assessments have applied the rationale of $EY = M \times \text{Equilibrium biomass}$ with the assumption that the best estimate of M was 0.2. While no independent estimate of M exists, the estimate of Z from 10 samples taken from 1977-79 is 0.04. If the 1977 biomass estimate (U.S.) of 19,940 t were to be treated as a virgin biomass then the yield from such a stock would be less than 400 t. The fishing history of this area indicates this stock is far from a virgin biomass. While catches of 400t/yr were sustained for approximately 12 years, there have been recent symptoms of reduced abundance (lowered LPUE and qualified LPUE) (Fig. 4.4.1). Recent information indicates that the S. pinniger stock in Area 3C has not been able to sustain an annual production of 400 t, and that the stock is at a low level of abundance.

4.4.2.2 Recommendation

It is recommended that the S. pinniger fishery in the Canadian section of Area 3C be a non-directed fishery with a TAC of 100 t.

4.4.2.3 Northwest Vancouver Island (Area 3D)

Canadian landings of S. pinniger from Area 3D did not achieve significant levels until 1976 and have averaged approximately 100 t since. U.S. landings have been variable. Catches declined from 1974 to 1977, then rebounded in 1977 to the highest level on record. Landings in 1979 and 1980 have returned to pre-1978 levels (Table 4.4.1).

Nominal total landings in 1970 and 1980 have been less than 300 t/yr. These landings have been associated with stable qualified and nominal LPUE within the Canadian fishery. U.S. nominal LPUE declined in 1979 from the record 1978 level, but was unchanged in 1980.

Biological data for S. pinniger in this area are available for 1977-1979. Age distributions continued to include a relatively large component of older fish in spite of the substantial U.S. landings during 1978. [N.B. Correction to Westrheim (1980: 21) N₆₇ was reported as 5,200 t; correct estimate is 10,300 t].

4.4.2.4 Recommendation

A TAC of 350 t is again recommended for S. pinniger in the 3D area.

4.4.3 Yellowtail rockfish (S. flavidus)

4.4.3.1 Southwest Vancouver Island (Area 3C)

Previous TAC documents (Ketchen 1980a; Westrheim 1980) have presented detailed treatments of S. flavidus in this area, and they will not be repeated here. This species is of minor importance in this area and rarely constitutes a directed fishery. With the exception of changes in the estimated mortality rate of this species (Appendix Table A1) no new information relevant to management is available. The 1981 TAC was primarily reserved for an incidental catch during the hake fishery in this area.

4.4.3.2 Recommendation

It is recommended that the TAC for S. flavidus in the 3C area remain at 100 t for 1982.

4.4.3.3 Northwest Vancouver Island (Area 3D)

S. flavidus continues to be a minor component of the rockfish fishery in Area 3D. The 1981 landings were less than 50 t by Canadian and U.S. vessels; as such LPUE is not an effective indicator of abundance (Table 4.4.2). Only a single biological sample has been collected from this area and it indicates a total mortality rate, Z, of 0.10.

The rockfish complex in Area 3D has been examined with cluster analysis and analysis of covariance to determine if species groupings exist in catches, that can be used as functional management groups. Results to date do not indicate sufficient persistence of multi-species assemblages to enable joint management.

4.4.3.4 Recommendation

A TAC of 200 t is recommended for the 3D area in 1982. If midwater fishing becomes established, the stock will require more detailed monitoring than in previous years.

4.4.4 Silvergray rockfish (S. brevispinis)

The northwest coast of Vancouver Island (Area 3D) is the only area of significant S. brevispinis landings off Vancouver Island, and this fishery has been prosecuted primarily by U.S. vessels. U.S. landings of S. brevispinis have been erratic and without trend (Table 4.4.3). The 1977-78 landings were less than 20 t/yr, the lowest production in 11 years. Landings then rebounded in 1979 to 232 t and were 421 t during 1980, the highest level since 1967.

Canadian landings have always been minor (usually <10 t/yr) and incidental to other species. In 1979-80, production was less than 21 t/yr and produced little information useful for assessment. This task is further confounded by the lack of species-specific fishing effort for U.S. catches. The variation in species composition of U.S. rockfish catches renders LPUE based on nominal effort a very insensitive indicator of stock changes.

Biological data for Area 3D are limited. Samples from other areas have shown that like other rockfishes S. brevispinis has a very low natural mortality (<0.1). While large harvests may occasionally be removed, they can not be made on a sustained basis.

4.4.4.1 Recommendation

A TAC of 200 t for S. brevispinis for Area 3D is recommended. While it is below historical catches, a cautious approach is warranted by the longevity of S. brevispinis and particularly with regard to the problems in interpreting U.S. data.

Table 4.4.1. Catch (t), effort (h), and CPUE (t/h) of Sebastes pinniger by Canada and United States, 1967-80.

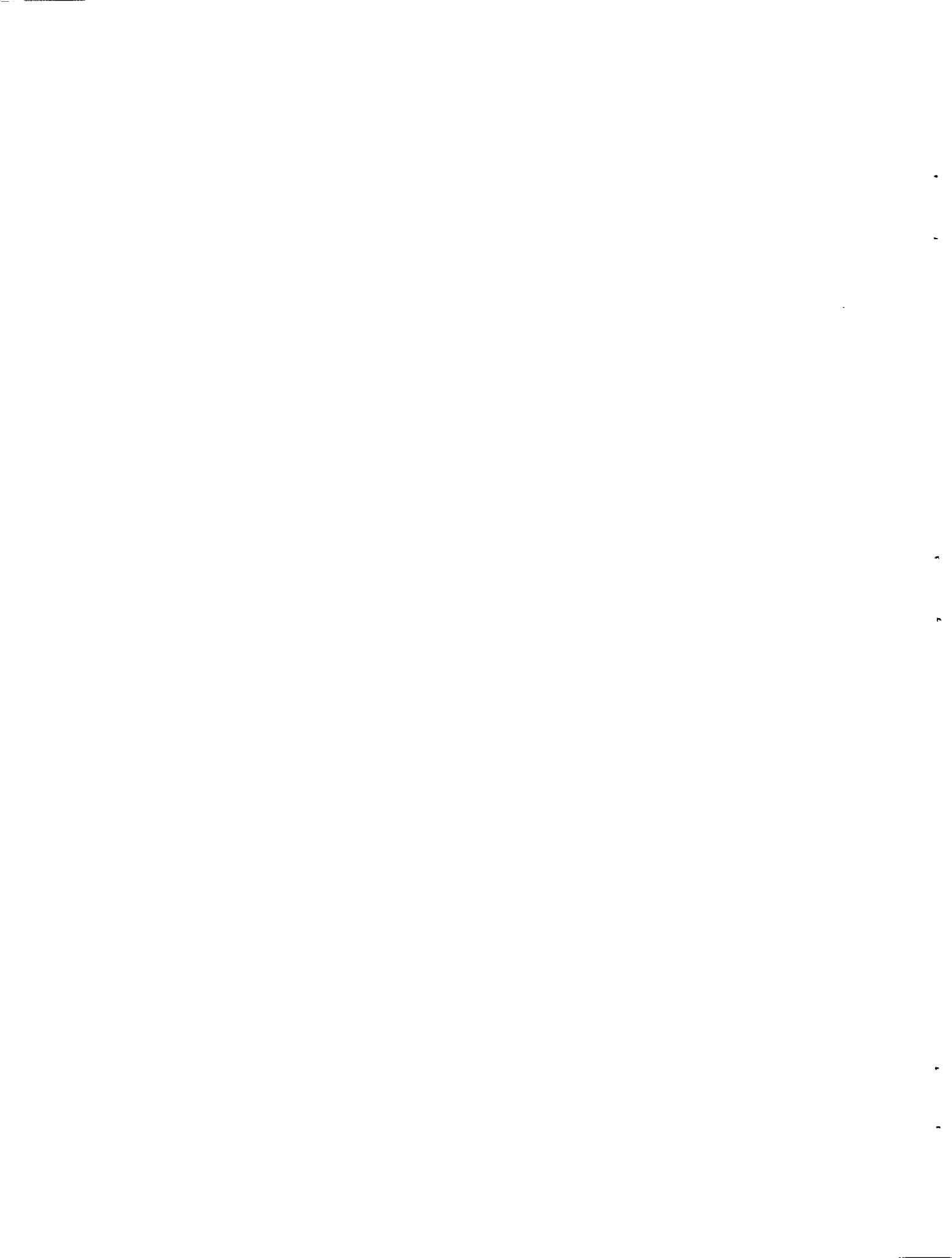
		AREA 3B-C						AREA 3D						
		Interviewed catch (Total in brackets)			Qualified (25%)			Interviewed			Qualified (25%)			
		C	E	CPUE	C	E	CPUE	C	E	CPUE	C	E	CPUE	
1967	CAN	-	-	-	-	-	-	-	-	-	-	-	-	-
	USA	342.1	4,579	.075	-	-	-	352.0	1,344	.262	-	-	-	-
1968	CAN	-	-	-	-	-	-	-	-	-	-	-	-	-
	USA	472.8	7,551	.063	-	-	-	494.9	1,381	.358	-	-	-	-
1969	CAN	-	-	-	-	-	-	-	-	-	-	-	-	-
	USA	495.8	8,619	.058	-	-	-	557.3	2,172	.257	-	-	-	-
1970	CAN	-	-	-	-	-	-	-	-	-	-	-	-	-
	USA	511.8	3,637	.141	-	-	-	727.9	2,978	.244	-	-	-	-
1971	CAN	51.7	355	.146	-	-	-	13.6	48	.283	-	-	-	-
	USA	466.0	4,934	.094	-	-	-	573.3	1,825	.314	-	-	-	-
1972	CAN	0.2	38	.005	-	-	-	-	-	-	-	-	-	-
	USA	168.8	4,823	.035	-	-	-	198.5	1,691	.117	-	-	-	-
1973	CAN	-	-	-	-	-	-	-	-	-	-	-	-	-
	USA	179.0	4,182	.043	-	-	-	473.7	1,613	.294	-	-	-	-
1974	CAN	9.9	333	.030	-	-	-	3.8	59	.064	-	-	-	-
	USA	169.5	5,165	.033	-	-	-	586.0	1,849	.317	-	-	-	-
1975	CAN	6.7	178	.038	-	-	-	7.0	10	.700	-	-	-	-
	USA	549.8	10,101	.054	-	-	-	442.3	2,034	.217	-	-	-	-
1976	CAN	51.8	627	.083	-	-	-	137.6	157	.876	-	-	-	-
	USA	644.2	12,408	.052	-	-	-	170.4	1,550	.110	-	-	-	-
1977	CAN	119.8	1,766	.068	37.88	162.50	.233	97.0	135	.719	89.59	66.75	1.34	
	USA	302.8	12,464	.024	-	-	-	85.4	1,037	.082	-	-	-	
1978	CAN	14.5	254	.057	1.91	9.25	.206	54.1	181	.300	37.77	47.42	.80	
	USA	299.0	5,033	.059	-	-	-	829.1	910	.910	-	-	-	
1979	CAN	22(32.5)	477	.046	4.30	22.00	.195	91.8(100.4)	203	.451	41.28	80.75	.51	
	USA	9.5	13,449	.001	-	-	-	280.3	1,214	.231	-	-	-	
1980	CAN	17.7	740	.024	8.67	72.42	.119	107.5	306	.352	91.12	124.50	.73	
	USA	13.4	-	-	-	-	-	174.5	-	-	-	-	-	

Table 4.4.2. Catch (t), effort (h), and CPUE (t/h) of Sebastes flavidus by Canada and United States, 1967-80.

		AREA 3B-C						AREA 3D					
		Interviewed catch (Total in brackets)			Qualified (25%)			Interviewed			Qualified (25%)		
		C	E	CPUE	C	E	CPUE	C	E	CPUE	C	E	CPUE
1967	CAN	-	-	-	-	-	-	-	-	-	-	-	-
	USA	121.7	4,579	.027	-	-	-	79.6	1,344	.059	-	-	-
1968	CAN	-	-	-	-	-	-	-	-	-	-	-	-
	USA	1,081.7	7,551	.143	-	-	-	16.0	1,381	.012	-	-	-
1969	CAN	-	-	-	-	-	-	-	-	-	-	-	-
	USA	1,575.8	8,619	.183	-	-	-	113.3	2,172	.052	-	-	-
1970	CAN	-	-	-	-	-	-	-	-	-	-	-	-
	USA	379.9	3,637	.104	-	-	-	142.1	2,978	.048	-	-	-
1971	CAN	9.7	100	.097	-	-	-	4.8	38	.126	-	-	-
	USA	398.0	4,934	.081	-	-	-	91.2	1,825	.050	-	-	-
1972	CAN	11.3	437	.026	-	-	-	-	-	-	-	-	-
	USA	416.3	4,823	.086	-	-	-	115.6	1,691	.068	-	-	-
1973	CAN	13.8	247	.056	-	-	-	-	-	-	-	-	-
	USA	227.3	4,182	.054	-	-	-	17.3	1,613	.011	-	-	-
1974	CAN	16.8	631	.027	-	-	-	0.3	11	.027	-	-	-
	USA	123.5	5,165	.024	-	-	-	111.3	1,849	.060	-	-	-
1975	CAN	5.6	217	.026	-	-	-	0.6	14	.043	-	-	-
	USA	124.9	10,101	.012	-	-	-	89.7	2,034	.044	-	-	-
1976	CAN	47.7	931	.051	-	-	-	25.4	141	.180	-	-	-
	USA	1,024.3	12,408	.083	-	-	-	3.0	1,550	.002	-	-	-
1977	CAN	238.6	1,858	.128	188.90	82.5	2.290	8.0	53	.151	6.85	28.5	.240
	USA	542.3	12,464	.044	-	-	-	99.4	1,037	.096	-	-	-
1978	CAN	42.6	741	.058	12.84	29.5	.435	35.7	254	.141	14.64	15.6	.938
	USA	647.8	5,033	.129	-	-	-	-	-	-	-	-	-
1979	CAN	32.8(40.4)	659	.049	1.60	8.0	.200	6.6(8.4)	40	.162	3.00	8.0	.375
	USA	-	-	-	-	-	-	.4	1,214	.0003	-	-	-
1980	CAN	33.8	468	.072	2.10	3.0	.700	17.7	91	.193	15.89	49.9	.318
	USA	.5	-	-	-	-	-	31.9	-	-	-	-	-

Table 4.4.3. Catch (t), effort (h), and CPUE (t/h) of Sebastes brevispinis by Canada and United States, 1967-80.

		AREA 3B-C						AREA 3D					
		Interviewed catch (Total in brackets)			Qualified (25%)			Interviewed			Qualified (25%)		
		C	E	CPUE	C	E	CPUE	C	E	CPUE	C	E	CPUE
1967	CAN	-	-	-	-	-	-	-	-	-	-	-	-
	USA	43.1	4,579	.009	-	-	-	148.5	1,344	.110	-	-	-
1968	CAN	-	-	-	-	-	-	-	-	-	-	-	-
	USA	24.7	7,551	.003	-	-	-	161.4	1,381	.117	-	-	-
1969	CAN	-	-	-	-	-	-	-	-	-	-	-	-
	USA	5.8	8,619	.001	-	-	-	320.6	2,172	.148	-	-	-
1970	CAN	-	-	-	-	-	-	-	-	-	-	-	-
	USA	38.5	3,637	.011	-	-	-	297.9	2,978	.100	-	-	-
1971	CAN	2.0	3	.667	-	-	-	2.6	46	.057	-	-	-
	USA	50.6	4,934	.010	-	-	-	133.9	1,825	.073	-	-	-
1972	CAN	-	-	-	-	-	-	.3	38	.008	-	-	-
	USA	12.8	4,823	.003	-	-	-	371.3	1,691	.220	-	-	-
1973	CAN	.2	38	.005	-	-	-	-	-	-	-	-	-
	USA	-	4,182	-	-	-	-	205.9	1,613	.128	-	-	-
1974	CAN	-	-	-	-	-	-	1.4	12	.117	-	-	-
	USA	-	5,165	-	-	-	-	217.9	1,849	.118	-	-	-
1975	CAN	.5	35	.014	-	-	-	3.2	9	.356	-	-	-
	USA	98.1	10,101	.010	-	-	-	65.9	2,034	.032	-	-	-
1976	CAN	4.6	9	.511	-	-	-	.1	4	.025	-	-	-
	USA	52.5	12,408	.004	-	-	-	254.1	1,550	.164	-	-	-
1977	CAN	18.0	476	.038	7.75	5.00	1.550	10.3	40	.258	9.45	23.25	.406
	USA	626.4	12,464	.050	-	-	-	18.4	1,037	.018	-	-	-
1978	CAN	1.0	48	.021	-	-	-	20.8	236	.008	1.27	7.75	.164
	USA	546.7	5,033	.112	-	-	-	16.9	910	.019	-	-	-
1979	CAN	1.1(1.1)	21	.050	-	-	-	20.9(20.9)	109	.192	12.80	17.70	.723
	USA	1.3	13,449	-	-	-	-	231.6	1,214	.191	-	-	-
1980	CAN	2.9	10	.290	2.45	6.58	.372	20.2	194	.104	7.26	8.50	.854
	USA	-	-	-	-	-	-	44.5	-	-	-	-	-



4.5 Petrale sole

4.5.1 Introduction

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 t in 1948 production by Canadian and U.S. trawlers operating in British Columbia waters followed a long downward trend to less than 500 t in 1970. Since that time landings have averaged about 1,100 t.

4.5.2 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.

4.5.3 Production and abundance trends

4.5.3.1 The southern stock

In their study of the fishery from its inception in the late 1930s to 1962, Ketchen and Forrester (1966) noted that both landings and CPUE reached a peak in the late 1940s 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 (Table 4.5.1). 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 recruit, led to the conclusion that success of the fishery during the 1940s 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 over-shadowed 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, both may have been only partly the result of the exceptionally favourable (warm) years which produced the 1958-62 and 1970 year-classes.

4.5.3.2 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. Landings reached a low point in 1960 (425 t) and subsequently recovered to 993 t in 1966, slightly out of phase with the surge noted in the fishery on the southern stock (Table 4.5.2). The second surge coincided with that in the south, but the 1974 peak amounted to less than 600 t.

4.5.4 Current stock condition

There is no question that the petrale sole stocks are at a relatively low level of abundance, especially in the case of the northern stock, landings from which barely reach 300 t--entirely incidental to other fisheries. The southern stock fares somewhat better (ca. 1,000 t/yr) 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-progeny 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.

4.5.5 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 t is recommended. In regard to the northern stock it is recommended that a TAC of 100 t be applied to the first three months of the calendar year. Thereafter in Area 3D throughout the year free fishing should be permitted.

Table 4.5.1. Canada-U.S. landings (t) of petrale sole from southwest Vancouver Island (Area 3C) -- the area occupied by the "southern stock", 1942-80.

Year	Flattery Spit	Northern section Area 3C	Total Area 3C	Year	Flattery Spit	Northern section Area 3C	Total Area 3C
1942	?	-	1,561	1962	215	636	851
1943	?	-	2,264	1963	90	656	746
1944	?	-	1,489	1964	71	529	600
1945	?	-	718	1965	140	645	785
1946	?	-	906	1966	118	508	626
1947	?	-	627	1967	106	256	362
1948	?	-	1,321	1968	114	232	346
1949	?	-	1,178	1969	255	142	397
1950	?	-	854	1970	80	143	273
1951	?	-	794	1971	74	518	592
1952	?	-	948	1972	22	756	778
1953	?	-	748	1973	211	452	663
1954	?	-	664	1974	230	675	905
1955	?	-	415	1975	474	465	939
1956	40	520	560	1976	304	452	756
1957	9	612	621	1977	157	301	458
1958	19	494	513	1978	287	108	395
1959	33	939	972	1979	256	92	348
1960	233	746	979	1980	a	115	?
1961	375	734	1,109				

^a 1980 U.S. landings not available

Table 4.5.2. Canada-U.S. landings (t) of petrale sole from "northern stock", 1942-80.

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

4.6 Dover sole

4.6.1 Introduction

Industrial Development Program exploratory fishing surveys (Harling et al. 1977, Harling et al. 1978) have located deepwater commercial concentrations of Dover sole off the northwest Queen Charlotte Islands. More recently, attention has been focused on deepwater concentrations of Dover sole off the west coast of Vancouver Island, notably in the area known as Estevan Deep. A research survey was undertaken in February-March 1981 for the purpose of determining the exploitable biomass of Dover sole in this area.

4.6.2 Landing statistics

Landing statistics were compiled for U.S. and Canadian landings in Areas 3C and 3D (Table 4.6.1). Area 3C includes both U.S. and Canadian fishing zones. U.S. fishermen have landed an average of 339 t of Dover sole annually from the west coast of Vancouver Island during the period from 1954-79. The bulk of these landings have been from the U.S. portion of Area 3C. U.S. landings have shown wide annual fluctuations (100-900 t) during this time period. Effort figures associated with these landings are not available and CPUE, commonly used as an abundance indicator, cannot be computed for the U.S. landings with regard to Dover sole.

Until recently, Canadian landings of Dover sole from Areas 3C and 3D have not been significant. However, increased demand for fresh fillets, reduced activity of foreign fleets in Canadian waters, and restrictions in inshore fisheries have made the deepwater fishery in 3C and 3D a more lucrative proposition for Canadian fishermen. In 1980 Canadian landings of Dover sole from the west coast of Vancouver Island reached a peak of 277 t. Indications are that this trend will continue in 1981. Canadian landings for peak years (>100 t) from 1954-80 indicate an active period for the fishery from January to June with highest landings in March and April. Trips in May to the same area (Estevan Deep) are less productive.

4.6.3 Condition of the resource

A research cruise to Areas 3C and 3D (February-March 1981) found commercial quantities of Dover sole in several areas. North of Barkley Canyon Dover sole catch rates ranged from 1.0-2.2 t/h. South of Clayoquot Canyon catch rates ranged from 0.3-1.9 t/h. In Estevan Deep catch rates of 3.4 t/h were achieved. The most productive fishing took place from 385-549 m (200-300 fm). Maturity data collected suggests that the target of this fishery is a spawning population. The distribution and location of this population during the summer months is not known. Without information on age composition it is impossible to determine how many year-classes are supporting the fishery. It is also not possible at this time to ascertain if separate stocks of Dover sole exist off the west coast of Vancouver Island. Unrestricted development of the fishery is undesirable until more is known about the population structure and stock definition. It is suggested that the winter fishery be closely monitored.

4.6.4 Recommendations

The following TACs are recommended: Area 3C (Canadian zone) 150 t; Area 3D 100 t.

Pending analyses of the survey data the above figures may be altered early in 1982.

Table 4.6.1. Canada-U.S. Dover sole landings (t) for west coast of Vancouver Island, 1954-80

Year	Landings (t)		
	Canadian ^a	U.S. ^b	Total
1954	28	141	169
1955	92	461	553
1956	54	611	665
1957	47	274	321
1958	36	304	340
1959	6	372	378
1960	5	569	574
1961	30	559	589
1962	8	901	909
1963	29	412	441
1964	11	274	285
1965	14	269	283
1966	4	157	161
1967	8	108	116
1968	3	150	153
1969	38	246	284
1970	192	424	616
1971	207	206	413
1972	11	151	162
1973	8	116	124
1974	13	170	183
1975	15	176	191
1976	23	588	611
1977	47	299	346
1978	94	296	390
1979	55	578	633
1980	277	c	?

^aTrip logs and sales slips 0% qual. (excluding discards).

^b1954-76 from Ketchen (1976) (including U.S. portion of Area 3C).

1977-79 supplied by Washington State Department of Fisheries.

^cnot available.

4.7 Walleye pollock

Canadian trawlers have not landed significant quantities of pollock from the west coast of Vancouver Island (Table 6.2.1). Estimates of the incidental catch of pollock in the summer midwater trawl fishery for Pacific hake were about 70 t in 1979 and 1,800 t in 1980. The impact of these removals is unknown. Surveys to locate pollock spawning in this region have not been conducted, so it is not known whether the stock is resident. Pollock spawning in the Strait of Georgia could migrate to the west coast after spawning in the Strait, as do some herring and Pacific cod, which might explain similarities in length frequencies between the two areas, but tagging has not been conducted to test this possibility. Hydroacoustic biomass estimates of midwater fish made in September and November 1980 indicate that pollock biomass was greater than 10,000 t, but this is unreliable since the proportion of pollock to other species is based on very few trawl catches.

4.7.1 Recommendation

A TAC cannot be recommended for pollock in Major Areas 3C and 3D at this time. The hake fishery should be monitored to provide accurate estimates of the incidental catch of pollock.

5. QUEEN CHARLOTTE SOUND (5A AND 5B) STOCK ASSESSMENTS

Principal species (based on a 5-yr average) in the Canada-U.S. landings from Queen Charlotte Sound are Other rockfish (3,903 t), Pacific cod (2,105 t), Pacific ocean perch (2,072 t), lingcod (505 t), and rock sole (492 t) (Table 5.1).

In the following sections stock assessments are presented for Other rockfish, Pacific ocean perch, Pacific cod, lingcod, and rock sole.

Table 5.1. Canada-U.S. groundfish landings (t) by main species for Queen Charlotte Sound (Areas 5A and 5B), 1976-80.

Species	Canada-U.S. landings ^a (t)					5-yr average
	1976	1977	1978	1979	1980 ^b	
Other rockfish	2,612.5	4,126.2	7,033.9	3,672.7	2,071.1	3,903.3
Pacific cod	2,271.0	1,269.6	3,717.4	1,880.6	1,387.4	2,105.2
Pacific ocean perch	1,965.3	2,104.1	2,635.2	1,548.9	2,103.8	2,071.5
Lingcod	702.2	427.2	603.4	386.0	408.0	505.4
Rock sole	548.4	272.0	590.4	400.9	647.3	491.8

^a Included are landings by trawl, trap, longline, handline, and troll.

^b 1980 handline and troll landings not available.

5.1 Rockfishes

Four rockfish species (S. alutus, S. flavidus, S. pinniger and S. brevispinis) constitute major landings from the Queen Charlotte Sound area. Of the four species, only S. alutus provides a directed fishery throughout the year. The remaining three species comprise a complex that is variable in its composition over time and space (Figs. 5.1.1, 5.1.2). The composition of this complex has been investigated using cluster analysis and analysis of covariance however the results to date, though incomplete, are not encouraging. While some areas or years appear to present opportunities for joint management and optimization, the lack of persistence of observed groups over more than one year suggests a highly dynamic mixing of species or target activity by the fleet. Subsequent efforts are being directed to resolving these two effects, where possible. Until these analyses are complete, the species will continue to be assessed on an individual basis.

5.1.1 Yellowtail rockfish (Sebastes flavidus)

After a long period of pre-eminent status in the shelf rockfish landings from the 5A-B areas, S. flavidus has undergone a decline in annual production. At least some of this decline is attributable to the declining participation in the fishery by U.S. vessels. Market limits imposed by plants were another causative agent during 1980. Consideration of fisheries statistics however, shows a decline in both qualified and nominal CPUE during 1980 (Table 5.1.1). These declines were attendant to substantial declines in effort (26% and 49% respectively for 1979 and 1980) over the previous two years. Fisheries statistics are somewhat difficult to interpret due to the inverse covariance of CPUE and effort, however the qualified CPUE should not be as sensitive to effort changes. The concomitant declines of both qualified CPUE and qualified effort cause concern, particularly since qualified effort has been declining since 1978 in Area 5A.

5.1.1.1 Condition of the resource

Fisheries statistics comprise the only time-series of data for S. flavidus in Areas 5A-B and they require interpretation because of poor resolution of U.S. effort. While weak markets for rockfish have had a negative influence on landings during 1980, the decreased catch rate for this species presents an unhealthy situation. As with other rockfishes, the natural mortality rate of S. flavidus has been estimated through revised ageing techniques to be much lower than previously believed. The best previous estimate of M for S. flavidus was 0.20, whereas the present estimate for B.C. waters is 0.075.

The 1978 biomass surveys in Queen Charlotte Sound produced a mean biomass estimate of 16,900 t. If such a biomass were to be treated as an equilibrium biomass, then the yield might be approximately 1,300 t. The historical statistics of the fishery in this area suggest that this estimate may be somewhat conservative.

Production analysis of this fishery using the model of Deriso (1980) was attempted although it was not possible to incorporate consideration of the changes in the structure of the population into this type of model. The sustainable annual yield suggested by this model was 2,200 t, although it was achieved at an assumed exploitation rate of 0.3. Obviously, the other known characteristics of this species argue that such an exploitation rate could not be sustained. More realistic treatment of the age structure of this stock is hampered by an absence of reliable, historical ageing data.

5.1.1.2 Recommendation

A TAC of 1,500 t of S. flavidus for Queen Charlotte Sound is recommended for 1982.

5.1.2 Canary rockfish (Sebastes pinniger)

Historical North American landings of S. pinniger in Queen Charlotte Sound reached a maximum of 944 t in 1968 and have never approached that level in recent years, despite levels of effort well in excess of that expended in 1968 (Table 5.1.2). Canadian landings increased to about 300 t in 1978 and have remained at that level.

5.1.2.1 Condition of the resource

While the peak catches of S. pinniger have never been re-attained, fishery statistics remained relatively stable until 1977, when decreases in both Canadian and U.S. CPUE occurred. Since 1977 Canadian nominal CPUE has more than doubled, while qualified CPUE increased in 1978 and has remained stable since. This would suggest that stock biomass is not being severely depleted although increasing knowledge of fishing grounds by Canadian fishermen could conceivably maintain the CPUE artificially. The increase in qualified effort during 1979-80 suggests that fishermen may target more on S. pinniger than in previous years.

Biological data for Queen Charlotte Sound cover the 1977-79 period. There remains a large proportion of older fish in the stock although not to the same extent as in Area 3D. Although only five samples have been collected, there is no evidence of truncation of the age composition.

5.1.2.2 Recommendation

A TAC of 500 t is recommended for S. pinniger in Areas 5A-B in the aggregate. This fishery should be closely monitored for the persistence of catch rates observed in recent years.

5.1.3 Silvergray rockfish (Sebastes brevispinis)

Historical production of S. brevispinis in Queen Charlotte Sound has followed much the same trend as S. pinniger in that production peaked in the late 1960s (1,164 t) and has not approached this level since (Table 5.1.3). Unlike S. pinniger however, the highest catch of S. brevispinis coincided with the highest effort; the lack of species resolution in U.S. effort should again be noted. There is a very strong correlation between catch and effort for the Canadian fleet ($r = 0.969$), although the correlation between catch and CPUE is not as strong ($r = 0.793$). The latter may represent some availability variation for the fish. The success of recent year fishing may be due to the decrease in total effort, through gradual withdrawal of U.S. effort.

5.1.3.1 Condition of the resource

The statistics of the nominal and qualified fisheries for S. brevispinis in Queen Charlotte Sound portray somewhat different situations. The high correlation between landings and effort suggests that the stock may have suffered no ill effects from the historical fishery. On the other hand, the lower correlation between effort and CPUE, the declining qualified CPUE in 1980, plus the general decline in effort for the nominal fishery indicates a fishery much closer to full exploitation.

Biological data from the fishery are limited but recent material indicates a very low rate of instantaneous natural mortality, possibly less than 0.05. If we assume the previous rationale regarding equilibrium biomass, and if $M = 0.05$, then the average yield for 1967-80 of 580 t/yr implies a virgin (N_{67}) biomass of approximately 23,000 t. The validity of this figure is dependent upon the degree to which the stock satisfies the assumption of parabolic surplus production with regard to biomass level.

5.1.3.2 Recommendation

A TAC of 600 t for S. brevispinis from Queen Charlotte Sound is recommended for 1982.

5.1.4 Other rockfishes

The incidental nature of the fisheries for other Sebastes spp. in Queen Charlotte Sound precludes detailed conclusions about their stock conditions, since statistics for such fisheries are extremely insensitive to biomass changes. Recent information from ageing studies shows these species to have mortality rates as low as those species previously discussed.

5.1.4.1 Recommendations

No changes are recommended for the other Sebastes spp. TACs, for 1982. The TACs recommended are guideline figures only. 1982 TACs for these species in Queen Charlotte Sound are thus:

<u>S. babcocki</u>	200 t
<u>S. entomelas</u>	250 t
<u>S. paucispinis</u>	300 t
<u>S. proriger</u>	250 t
<u>S. reedi</u>	250 t

Table 5.1.1. Catch (t), effort (h), and CPUE (t/h) of Sebastes flavidus by Canada and United States, 1967-1980.

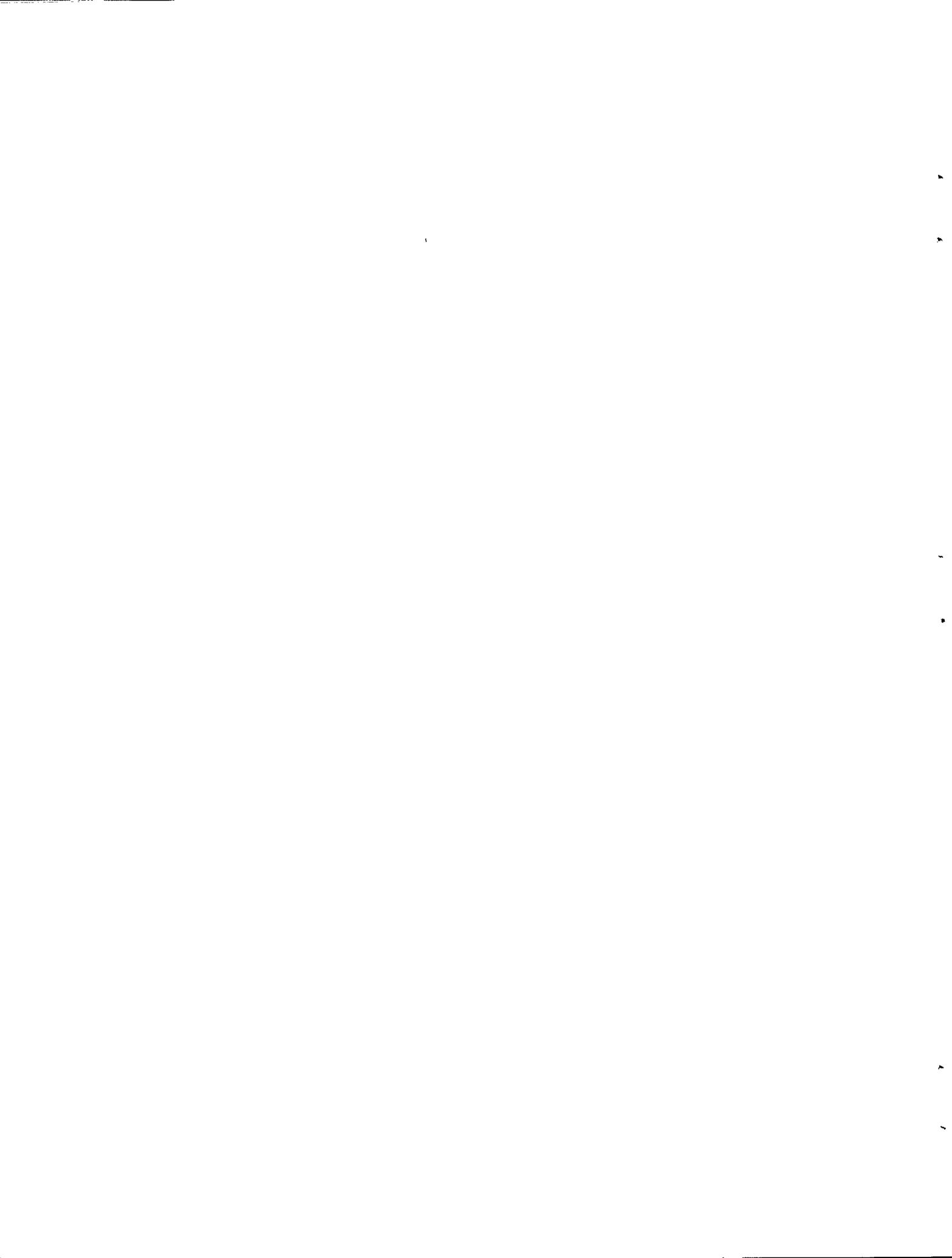
Year		Area 5A-B			Qualified (25%)		
		C	E	CPUE	C	E	CPUE
1967	CAN	-	-	-	-	-	-
	USA	872.5	9,313	.094	-	-	-
1968	CAN	-	-	-	-	-	-
	USA	281.4	8,488	-	-	-	-
1969	CAN	-	-	-	-	-	-
	USA	2,129.8	13,557	.157	-	-	-
1970	CAN	-	-	-	-	-	-
	USA	2,568.0	9,264	.277	-	-	-
1971	CAN	209.8	966	.217	-	-	-
	USA	1,805.0	7,137	.253	-	-	-
1972	CAN	678.2	2,414	.281	-	-	-
	USA	2,349.4	9,224	.254	-	-	-
1973	CAN	519.2	1,387	.374	-	-	-
	USA	2,837.7	9,625	.295	-	-	-
1974	CAN	153.4	1,188	.129	-	-	-
	USA	924.1	8,797	.105	-	-	-
1975	CAN	383.4	1,760	.218	-	-	-
	USA	379.3	5,179	.073	-	-	-
1976	CAN	627.6	4,360	.144	-	-	-
	USA	341.5	4,620	.074	-	-	-
1977	CAN	1,012.1	4,744	.213	871.06	2,672	.326
	USA	507.1	5,165	.098	-	-	-
1978	CAN	1,644.3	5,045	.326	1,428.60	2,543	.562
	USA	484.1	927	.522	-	-	-
1979	CAN	1,318.9(1,334)	3,732	.353	1,197.90	1,727	.694
	USA	191.4	1,687	.113	-	-	-
1980	CAN	461.0	2,507	.184	367.67	997	.369
	USA	48.1	-	-	-	-	-

Table 5.1.2. Catch (t), effort (h), and CPUE (t/h) of Sebastes pinniger by Canada and United States, 1967-1980.

Year		Area 5A-B			Area 5A-B		
		Interviewed Catch (Total in brackets)		CPUE	Qualified (25%)		CPUE
		C	E		C	E	
1967	CAN	-	-	-	-	-	-
	USA	226.4	9,313	.024	-	-	-
1968	CAN	-	-	-	-	-	-
	USA	943.5	8,488	.111	-	-	-
1969	CAN	-	-	-	-	-	-
	USA	455.6	13,557	.034	-	-	-
1970	CAN	-	-	-	-	-	-
	USA	171.8	9,264	.019	-	-	-
1971	CAN	18.0	365	.049	-	-	-
	USA	167.0	7,137	.023	-	-	-
1972	CAN	0.4	48	.008	-	-	-
	USA	45.9	9,224	.005	-	-	-
1973	CAN	29.1	116	.251	-	-	-
	USA	267.8	9,625	.028	-	-	-
1974	CAN	2.5	78	.032	-	-	-
	USA	466.2	8,797	.053	-	-	-
1975	CAN	21.9	390	.056	-	-	-
	USA	279.9	5,179	.054	-	-	-
1976	CAN	102.6	1,538	.067	-	-	-
	USA	459.4	4,620	.099	-	-	-
1977	CAN	123.4	2,358	.052	54.85	193.5	.283
	USA	84.1	5,165	.016	-	-	-
1978	CAN	262.6	2,692	.098	100.70	241.9	.416
	USA	-	-	-	-	-	-
1979	CAN	278.5(307.8)	2,981	.093	139.60	356.1	.392
	USA	56.1	1,687	.033	-	-	-
1980	CAN	277.4	2,189	.127	188.69	431.6	.437
	USA	87.9	-	-	-	-	-

Table 5.1.3. Catch (t), effort (h), and CPUE (t/h) of Sebastes brevispinis by Canada and United States, 1967-1980.

Year		Area 5A-B			Qualified (25%)		
		Interviewed Catch (Total in brackets)		CPUE	C	E	CPUE
		C	E				
1967	CAN	-	-	-	-	-	-
	USA	348.5	9,313	.037	-	-	-
1968	CAN	-	-	-	-	-	-
	USA	799.9	8,488	.094	-	-	-
1969	CAN	-	-	-	-	-	-
	USA	1,161.1	13,557	.086	-	-	-
1970	CAN	-	-	-	-	-	-
	USA	269.4	9,264	.029	-	-	-
1971	CAN	17.9	322	.056	-	-	-
	USA	689.0	7,137	.097	-	-	-
1972	CAN	53.0	629	.084	-	-	-
	USA	350.7	9,224	.038	-	-	-
1973	CAN	37.5	293	.128	-	-	-
	USA	198.4	9,625	.021	-	-	-
1974	CAN	45.0	414	.109	-	-	-
	USA	336.2	8,797	.038	-	-	-
1975	CAN	30.7	480	.064	-	-	-
	USA	286.2	5,179	.055	-	-	-
1976	CAN	164.4	1,606	.102	-	-	-
	USA	496.6	4,620	.107	-	-	-
1977	CAN	197.7	2,463	.080	119.06	292.5	.407
	USA	209.7	5,165	.041	-	-	-
1978	CAN	723.6	4,072	.178	429.80	932.8	.461
	USA	-	-	-	-	-	-
1979	CAN	675(677.5)	3,834	.176	448.90	1,146.0	.392
	USA	310.1	1,687	.184	-	-	-
1980	CAN	596.2	3,580	.166	439.90	1,317.0	.334
	USA	137.3	-	-	-	-	-



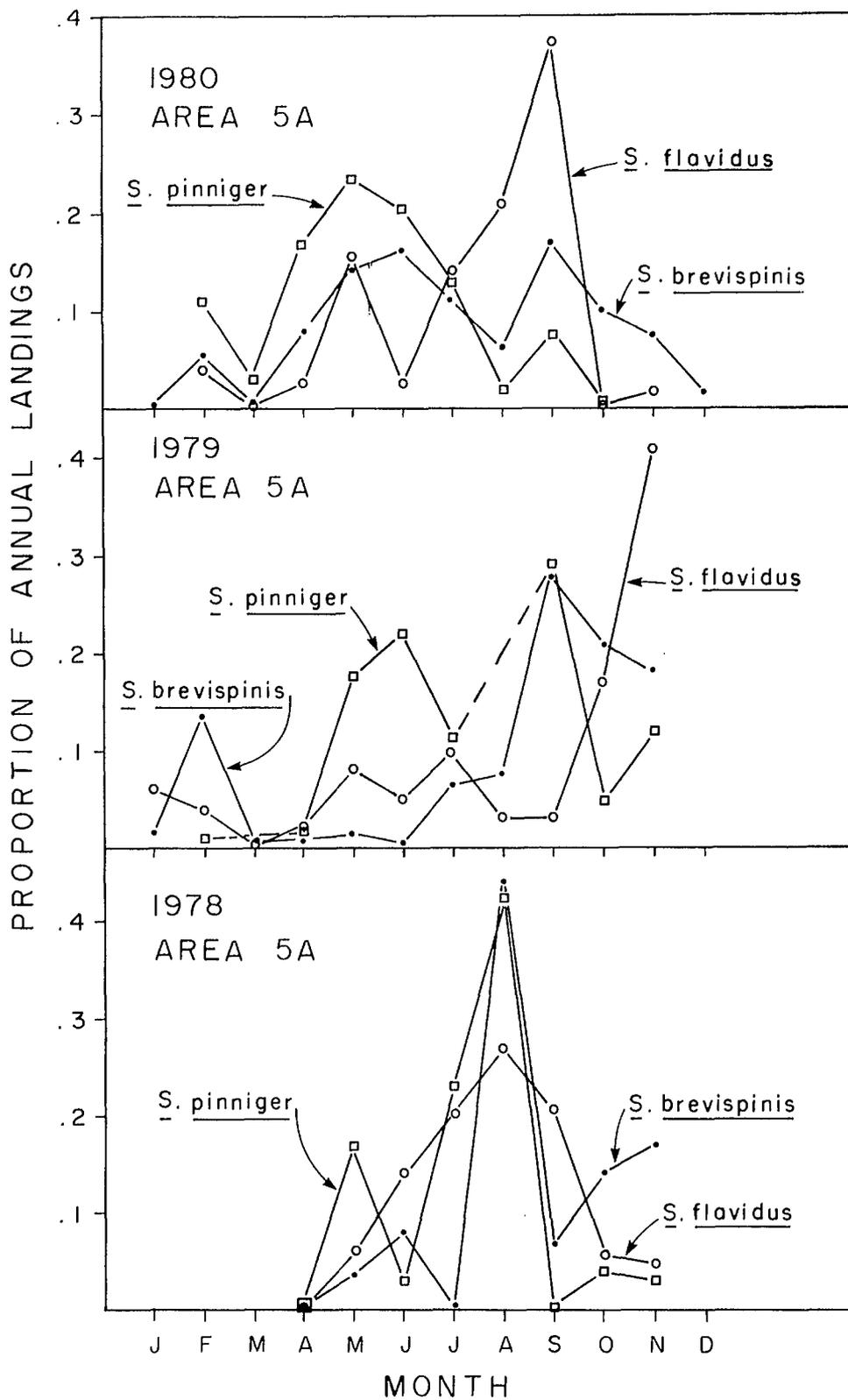
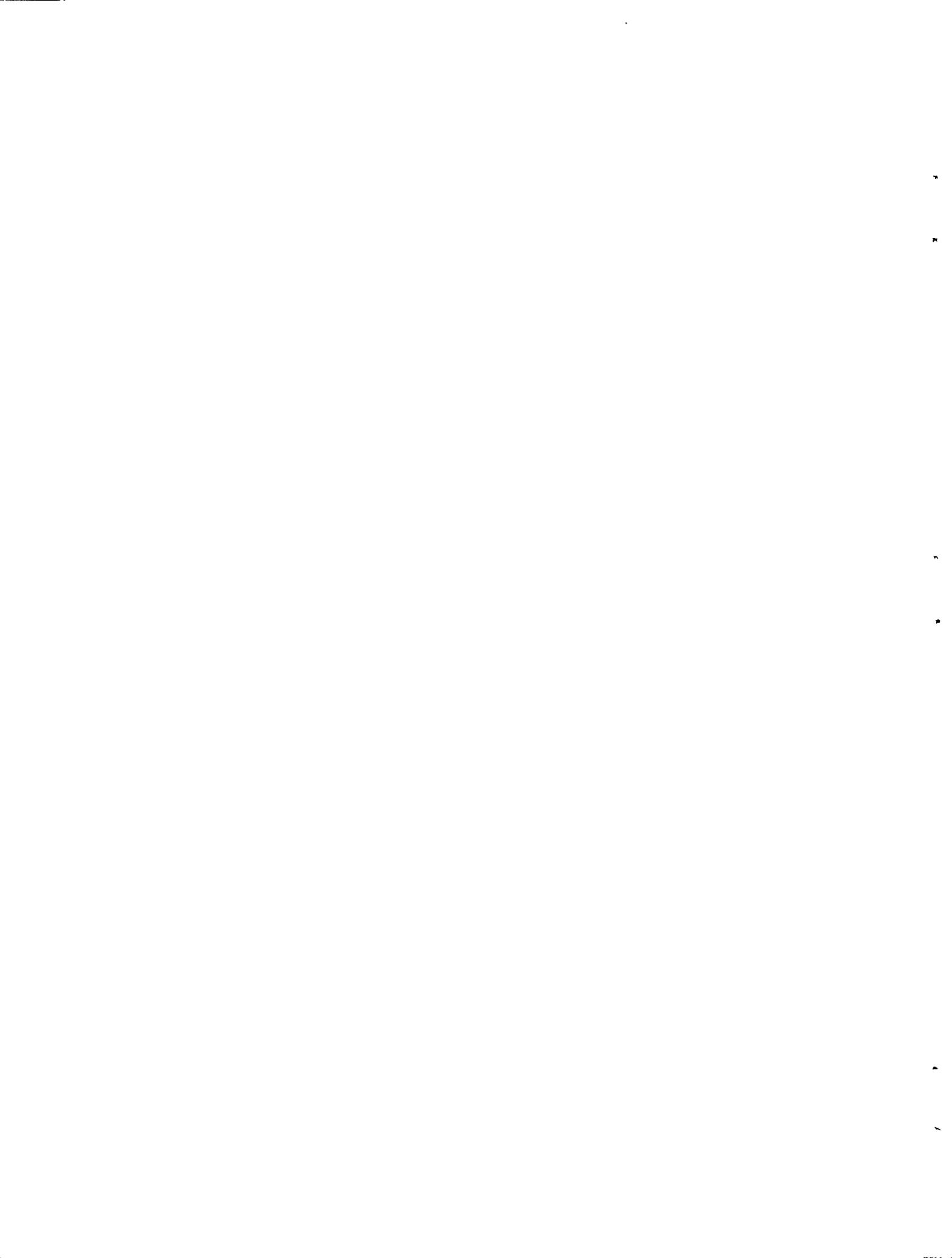


Fig. 5.1.1. Monthly proportions of annual landings for *S. flavidus*, *S. brevispinis*, *S. pinniger* and *S. entomelas* in Area 5A, 1978-80.



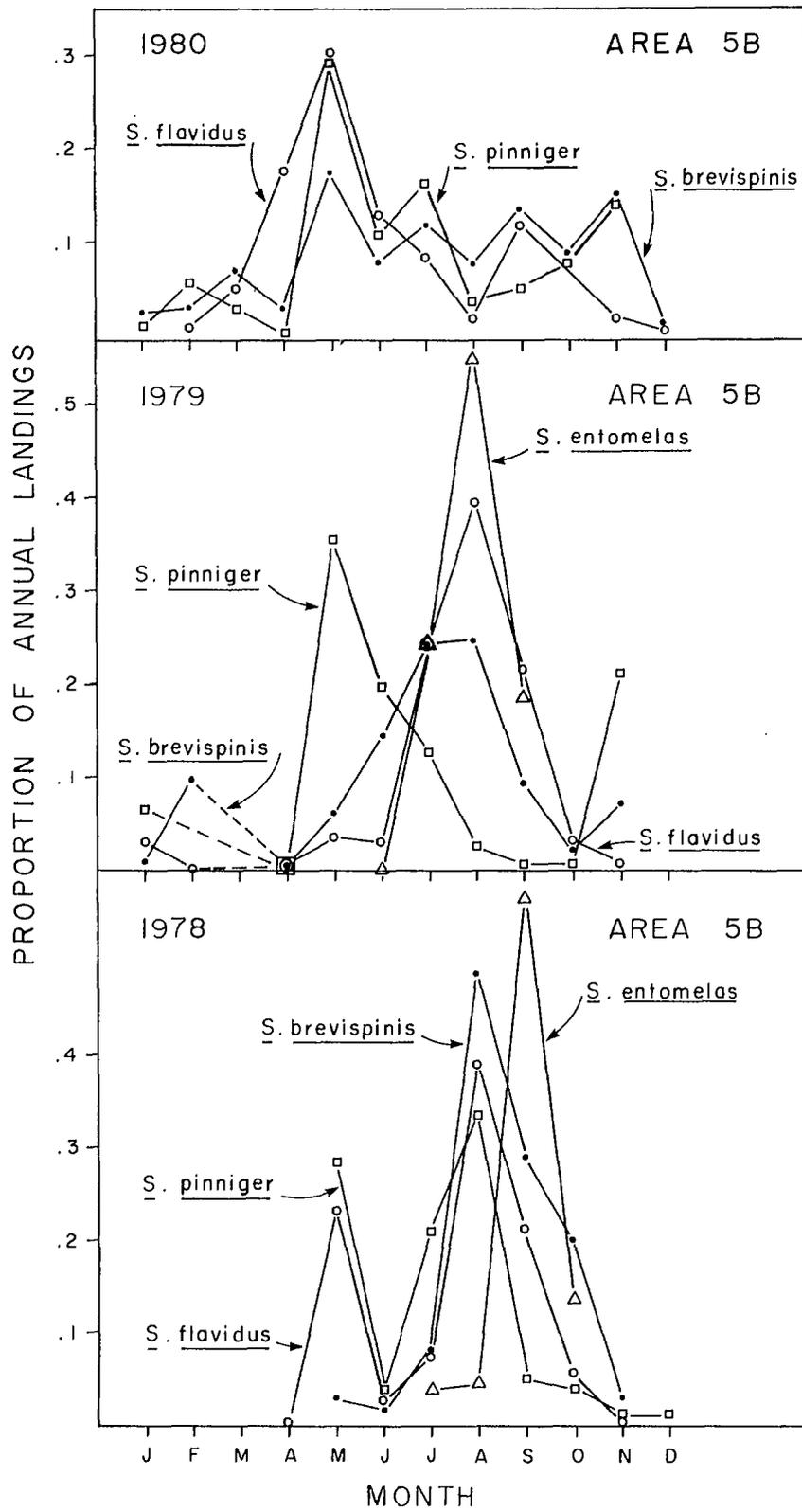
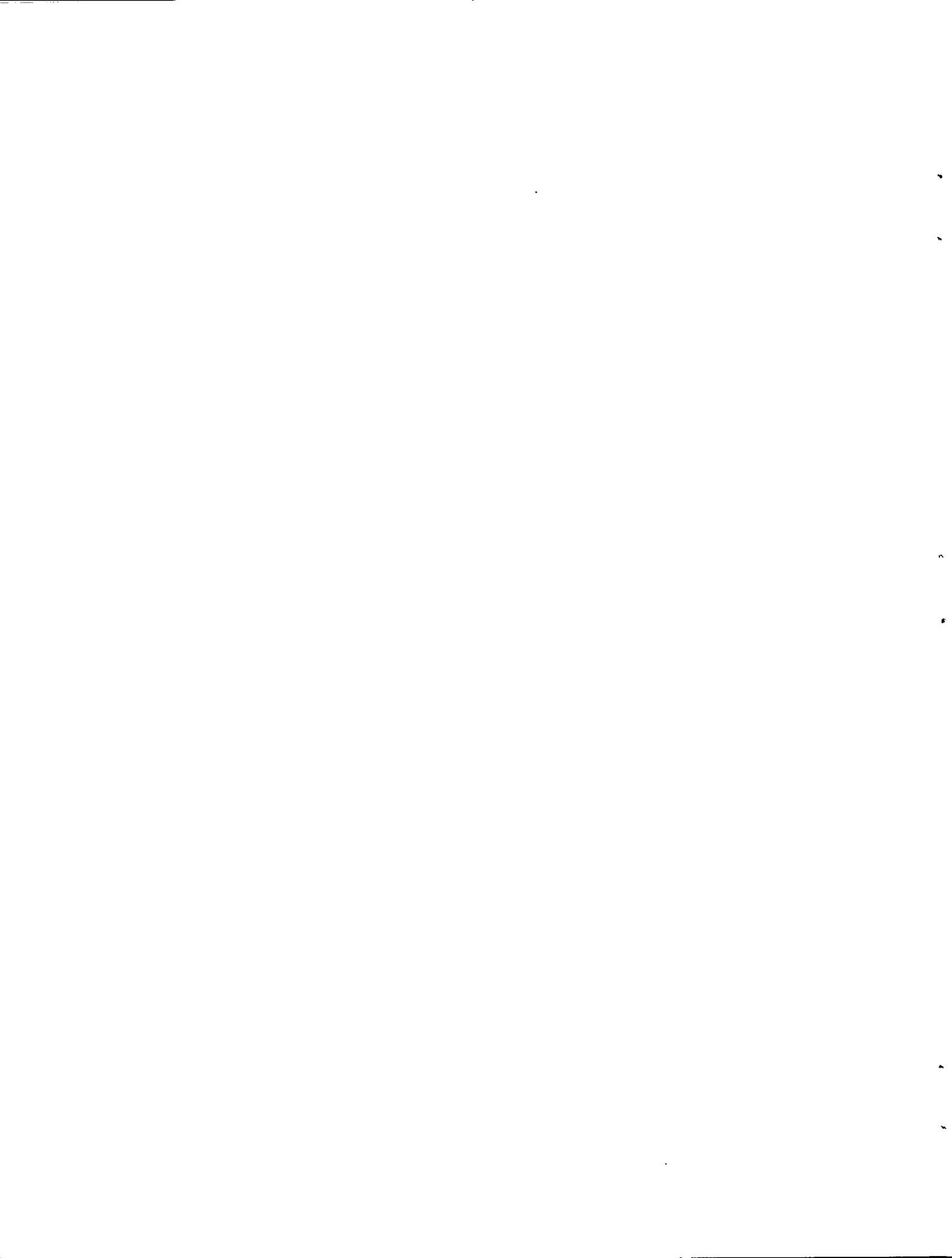


Fig. 5.1.2. Monthly proportion of annual landings of *S. flavidus*, *S. brevispinis*, *S. pinniger* and *S. entomelas* from Area 5B, 1978-80.



5.2 Pacific ocean perch (*Sebastes alutus*)

5.2.1 Data base

The data base for Pacific ocean perch relative to that for other rockfishes is extensive, consisting of more than 20 years of catch statistics, 15 years of age composition data, and results of nine biomass surveys spanning more than a decade. Yet even this accumulation of information, though sufficient to permit general assessment of stock conditions, falls short of the requirements for development of sound management strategies.

In the first place there are uncertainties about the distinctness of stocks supporting the Queen Charlotte Sound trawl fishery. Circumstantial evidence suggests that there are two main stocks, one associated with Goose Island Gully and the other with Mitchell's Gully. A third component is believed to be associated with Moresby Gully in the northern part of the Sound, but, because of its closer connection with Hecate Strait, it is discussed elsewhere (Section 6.8, below).

Second, although there has been a reasonably complete record kept of the domestic (Canada-U.S.A.) catch since the inception of the fishery, the quality of data pertaining to foreign fleets which arrived in 1965 and departed in 1976 leaves considerable uncertainty as to the accuracy of information on total removals from Queen Charlotte Sound stocks. It is believed that both Soviet and Japanese reported catches of ocean perch (*Sebastes alutus*) contained substantial quantities of other rockfishes, even to the exclusion of ocean perch. Furthermore Soviet statistics were not sufficiently precise to distinguish catches in Queen Charlotte Sound (to say nothing of catches in the two main gullies) from those caught elsewhere along the British Columbia coast. In the face of these uncertainties as to species and quantities, reconstruction of catch history has been difficult (Ketchen 1980b). Minimum, maximum and intermediate estimates of annual removals by the U.S.S.R. and Japan were derived for both the Goose Island Gully and Mitchell's Gully "stocks". The intermediate estimates are provided in Tables 5.2.1 and 5.2.2. As yet it is uncertain which of the three series of data, if any, best reflects events as they actually transpired.

A third problem has involved development of an indicator (based on Canadian data) of year-to-year changes in relative abundance of the two main stocks. Such is needed not only for monitoring purposes but also to estimate the total fishing effort to which the stocks have been exposed. This reconstruction exercise using CPUE as the indicator of abundance, with all its limitations and attendant assumptions has recently been completed (Ketchen 1981). Data on CPUE and estimated total fishing effort appear in Tables 5.2.1 and 5.2.2. For purposes of the analysis to be described in the following section, the latter figures were used only to establish the probable magnitude of changes in fishing effort. Likewise statistics of CPUE play no part in the current analysis, but will be used in due course, pending further consideration of possible sources of bias.

The implications of ageing errors are discussed in Appendix 1.

5.2.2 Reconstruction of stock dynamics and estimation of yield

The stock reconstruction model of Fournier and Archibald (in press) has been used to analyze the data described in the previous

section. This model utilizes the underlying regularities in the mortality process being studied and allows incorporation of additional information and assumptions to arrive at biologically realistic solutions. The instantaneous rates of fishing (F) and natural (M) mortalities, as well as the numbers in each age-group for each year of the data series (N_{ij}) are estimated.

Salient aspects of the reconstructions are presented here; a more complete description of the basic model and assumptions employed is presented in Appendix 2. Important features of this application were: the estimation of fishing effort; the incorporation of estimates of ageing errors; the estimation of parameters of the stock-recruit relationship; the time-dependent changes in catchability; and the incorporation of variance in process description as well as in measurements.

Two sample reconstructions are presented; the first with catchability held constant and the second with time-dependent catchability. In both runs M was fixed at 0.05, the best available estimate of M for B.C. waters.

Constant Catchability - Reconstructed stock biomass, historical yields and average annual fishing mortality over the period 1963-1977 are shown in the upper panels of Fig. 5.2.1. Average fishing mortality was highest during 1966-68, when Soviet vessels prosecuted an intense fishery, and reached a second peak during 1974, when Japanese vessels applied the majority of fishing effort. Stock biomass was estimated to be approximately 82,000 t in 1963, prior to the initiation of the major S. alutus fishery. By 1977 the intense foreign and domestic fisheries were estimated to have reduced the stock biomass to approximately 44,000 t, one-half the 1963 level. Table 5.2.3 presents F and abundance by age-group, as estimated by the model for 1963 and 1967; the shift in the age-composition to younger fish in 1977 is noteworthy.

Time-Dependent Catchability - The estimated 1977 stock biomass of 44,000 t from the previous analysis was inconsistent with the declining yield from the stock. If this estimated biomass was correct then yields in excess of those recorded should have been sustainable. This inconsistency prompted additional analysis with variable parameters of exploitation. In particular the evident decrease in biomass was suspected to have had a substantial effect on q, the catchability, particularly for a highly aggregated species such as S. alutus. Results of this re-analysis, which allowed q to vary in order to minimize the objective function, are presented in the lower panels of Fig. 5.2.1 and Table 5.2.3. A time-dependent, linear change in q resulted in a substantially better fit to the data; q increased almost six-fold over this time. 1977 stock size is now estimated to have been approximately 10,000 t. The shift in age composition to younger fish is even more dramatic than for fixed q. Also of note is the maintenance of high average F values since 1966.

The increased catchability implied by the model is difficult to validate. To some extent, boat and net changes were accounted for in the initial calculations of effort (Ketchen 1981). A more probable cause would be the decreased abundance of the stock coupled to relatively similar rockfish school sizes over the years. If fishing success on schools was relatively consistent then q would increase automatically with decreased abundance.

Although recent effort measurements may underestimate fishing mortality, a six-fold increase in q is relatively major and some corroboration of the results of this analysis is required. We might view the two cases presented as extremes, with time dependent changes in q being more conservative from a management viewpoint. Biomass surveys in Goose Island Gully have estimated the stock biomass (>31 cm) to be 64,000 t in 1965 and 23,000 t in 1977; however recent review of these results (Westrheim 1980) suggests these figures may be as low as 22,000 t and 8,200 t for 1965 and 1977, respectively. The reconstruction employing variable q may thus not be too extreme.

5.2.3 Forward simulations of *S. alutus* in Goose Island Gully

To develop management options for the rehabilitation of overexploited *S. alutus* stocks a simple simulation model was constructed to predict stock behaviour under a variety of harvesting strategies. The simulations began in 1977 with stock size and age composition resulting from the two reconstructions previously described. Important components of the simulations are the assignment of mortalities, calculation of numbers in the stock and the catch, conversion of numbers to weight, and the estimation of recruitment. Details of these components are included in Appendix 2.

In the previous reconstructions the variance about the stock-recruit curve was 0.25 and this value has been used for the variance about that relation in the simulations. For presentation purposes the average of 40 simulation runs, each done for 30 years, will be presented. This is not a true presentation of the stochastic nature of the simulations and individual runs must be examined to determine, say, the interval between strong recruitments, or the probability of several strong cohorts in succession.

Fig. 5.2.2 presents the results of trial simulations. In each case the runs were made at a number of harvesting levels (F levels), each as a scaled version of the 1977 F values. The constant catchability simulations indicate that fishing mortality 2.0 times 1977 would maintain the stock at 1977 biomass and deliver a yield of just over 3,000 t in the first years past 1977. On the other hand, time-dependent catchability simulations indicate that the *S. alutus* stock in Goose Island Gully can only withstand low levels of fishing; an F level of only 0.4 times F_{77} keeps the stock constant and permits a yield of only about 700 t.

5.2.4 Conclusions and recommendations

A casual appraisal of the age structure of rockfish stocks illustrates the substantial variation in cohort strength regularly encountered. As noted, the simulations presented here are not intended to be predictions in the strict management sense because analysis is continuing and because the simulation results are presented as average effects. The major emphasis to be placed on these reconstructions and simulations is that they represent the probable extremes of future events, as they can be interpreted from historical data. The most active areas of future research are further examinations of relative sensitivities of errors in measurement and process description, and more realistic forward simulations. Future recommendations of yield will be somewhat dynamic as these activities progress and management will require a more adaptive character.

The improved fit of the model associated with time-dependent catchability argues that such considerations in the reconstructions are genuine and that stock biomass is low. As noted, the corrected biomass estimate of 1977 in Goose Island Gully could be as low as 8,200 t, which also lends credence to the time-dependent catchability approach. Inclusion of 1979-80 data is imminent and should provide additional guidance as to direction of stock trends.

The coupling of stock estimates from reconstructions and biomass surveys in Goose Island Gully leads to the conclusion that stock biomass is in the 8-10,000 t range and it is desirable to reduce fishing mortality below the 1977 level. As an approximation of a 0.4 times F77 and including the contribution of the Mitchell's Gully 'stock'⁶, it is recommended that a TAC of 1,000 t be set for S. alutus in the 5A-B area in 1982.

⁶review of catch statistics in Ketchen (1981) indicates that the Mitchell's Gully stock contributed an average of 27% ± 8% of the Goose Island Gully contribution to the annual catch of S. alutus from Areas 5A-B, 1965-79.

Table 5.2.1. Total catch of Pacific ocean perch, standardized CPUE and calculated total fishing effort in Goose Island Gully, Queen Charlotte Sound.

Year	Catch (t)					Standardized CPUE (t/h) ^c	Calculated all-nation total effort (h) ^c
	Canada ^a	USA ^a	USSR ^b	Japan ^b	Total		
1959	232	1,658	-	-	1,890	0.836	2,261
1960	356	1,323	-	-	1,679	0.698	2,405
1961	118	1,081	-	-	1,199	0.797	1,504
1962	531	1,307	-	-	1,838	1.161	1,583
1963	451	3,261	-	-	3,712	1.457	2,545
1964	362	3,088	-	-	3,450	1.134	3,042
1965	1,387	3,463	2,628	-	7,478	1.491	5,015
1966	2,361	5,869	11,728	794	20,752	1.441	14,401
1967	313	3,493	6,482	1,831	12,119	1.068	11,347
1968	770	3,947	3,356	2,140	10,213	1.045	9,773
1969	1,416	3,367	40	2,049	6,872	0.763	9,007
1970	1,743	3,453	-	1,293	6,489	0.672	9,657
1971	1,093	2,197	80	165	3,455	0.526	6,568
1972	1,951	2,698	-	996	5,645	0.829	6,809
1973	487	1,117	-	2,151	3,755	0.773	4,888
1974	461	1,362	-	5,446	7,269	0.773	9,404
1975	1,032	653	-	2,524	4,209	0.507	8,302
1976	1,015	266	-	1,161	2,442	0.733	3,332
1977	884	809	-	-	1,693	0.660	2,565
1978	831	3 ^d	-	-	865	0.821	1,054
1979	801	150	-	-	951	0.799	1,190

^a Data from Ketchen (1981), Table 3

^b Data from Ketchen (1980^b), Table 17

^c Data from Ketchen (1981), Table 12

^d Estimated from 1977 ratio in this table

Table 5.2.2. Total catch of Pacific ocean perch, standardized CPUE and calculated total fishing effort in Mitchell's Gully, Queen Charlotte Sound.

Year	Catch (t)					Standardized CPUE (t/h) ^c	Calculated all-nation total effort (h) ^c
	Canada ^a	USA ^a	USSR ^b	Japan ^b	Total		
1959	-	-	-	-	-	-	-
1960	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-
1963	-	-	-	-	-	-	-
1964	57	-	-	-	57	-	-
1965	-	20	468	-	488	0.780	626
1966	-	11	1,264	94	1,369	0.815	1,650
1967	71	1,708	3,206	334	5,319	1.157	4,597
1968	106	1,143	575	732	2,556	1.137	2,248
1969	85	1,731	16	1,113	2,945	0.995	2,960
1970	19	707	-	570	1,296	1.010	1,288
1971	6	804	-	3	813	0.954	852
1972	245	580	-	130	955	0.854	1,165
1973	873	1,120	-	271	2,264	1.351	1,676
1974	1,035	684	-	186	1,917	0.974	1,968
1975	799	154	-	198	1,151	0.989	1,164
1976	503	14	-	59	576	0.673	856
1977	190	66	-	-	256	0.551	465
1978	372	3 ^d	-	-	375	0.817	459
1979	467	13	-	-	480	0.670	716

^a Data from Ketchen (1981), Table 3

^b Data from Ketchen (1980^b), Table 17

^c Data from Ketchen (1981), Table 12

^d Estimated from 1977 ratio in this table

Table 5.2.3. Estimated numbers ($N \times 10^4$ fish) and fishing mortality (F) at age for the reconstructed Pacific ocean perch stock in Goose Island Gully, for the years 1963 and 1977. Results are presented from two reconstructions.

Constant catchability reconstruction											
Age (reading across starting at upper left which is 6-yr old fish)											
1963	N	481	755	1,071	1,155	1,509	2,306	1,409	969	494	285
		432	1,095 ^a								
	F	.002	.005	.011	.019	.031	.045	.059	.070	.080	.089
1977	N	1,184	1,453	840	419	238	445	447	467	402	741
		217	70	27	14	17	22	27	26	32	49
		32	25	15	11	19	51 ^b				
	F	.002	.005	.011	.019	.031	.045	.059	.070	.080	.089
		.094	.091	.081	.065	.047	.047	.047	.047	.047	.047
		.047	.047	.047	.047	.047	.047 ^b				

^a represents ages ≥ 17 yr

^b represents ages ≥ 31 yr

Table 5.2.3. (cont'd.)

Time dependent catchability reconstruction

		Age (reading across starting at upper left which is 6-yr old fish).									
1963	N	436	685	989	1,099	1,464	2,234	1,356	932	488	301
		465	1,271 ^a								
1963	F	.003	.006	.011	.019	.029	.042	.057	.072	.083	.087
		.085	.077 ^a								
1977	N	176	253	172	98	61	119	117	115	87	62
		33	9	3	2	3	4	7	8	11	19
1977	F	.017	.032	.056	.093	.145	.210	.284	.360	.416	.438
		.426	.386	.325	.256	.188	.188	.188	.188	.188	.188
		.188	.188	.188	.188	.188	.188 ^b				

^a represents ages \geq 17 yr

^b represents ages \geq 31 yr

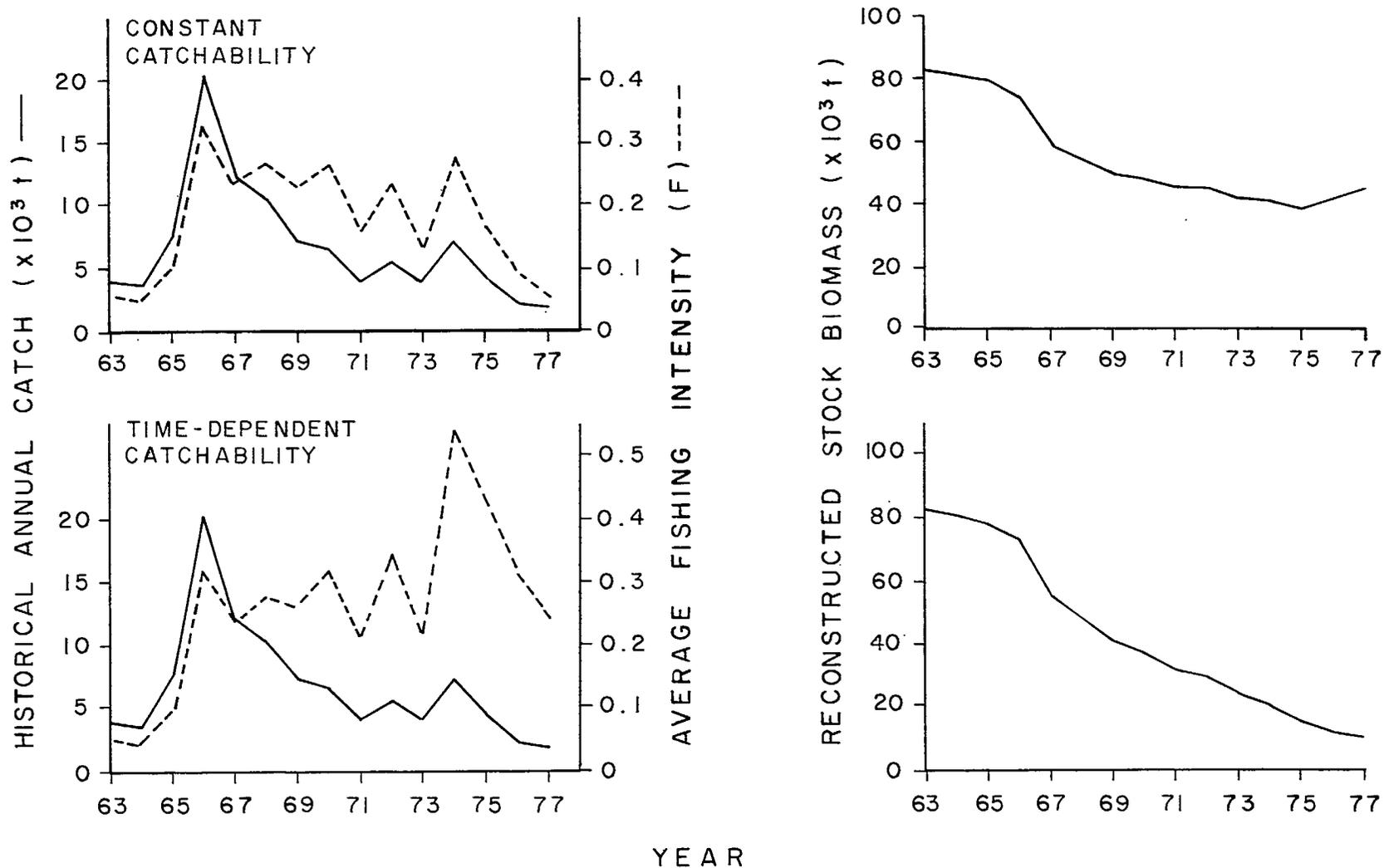
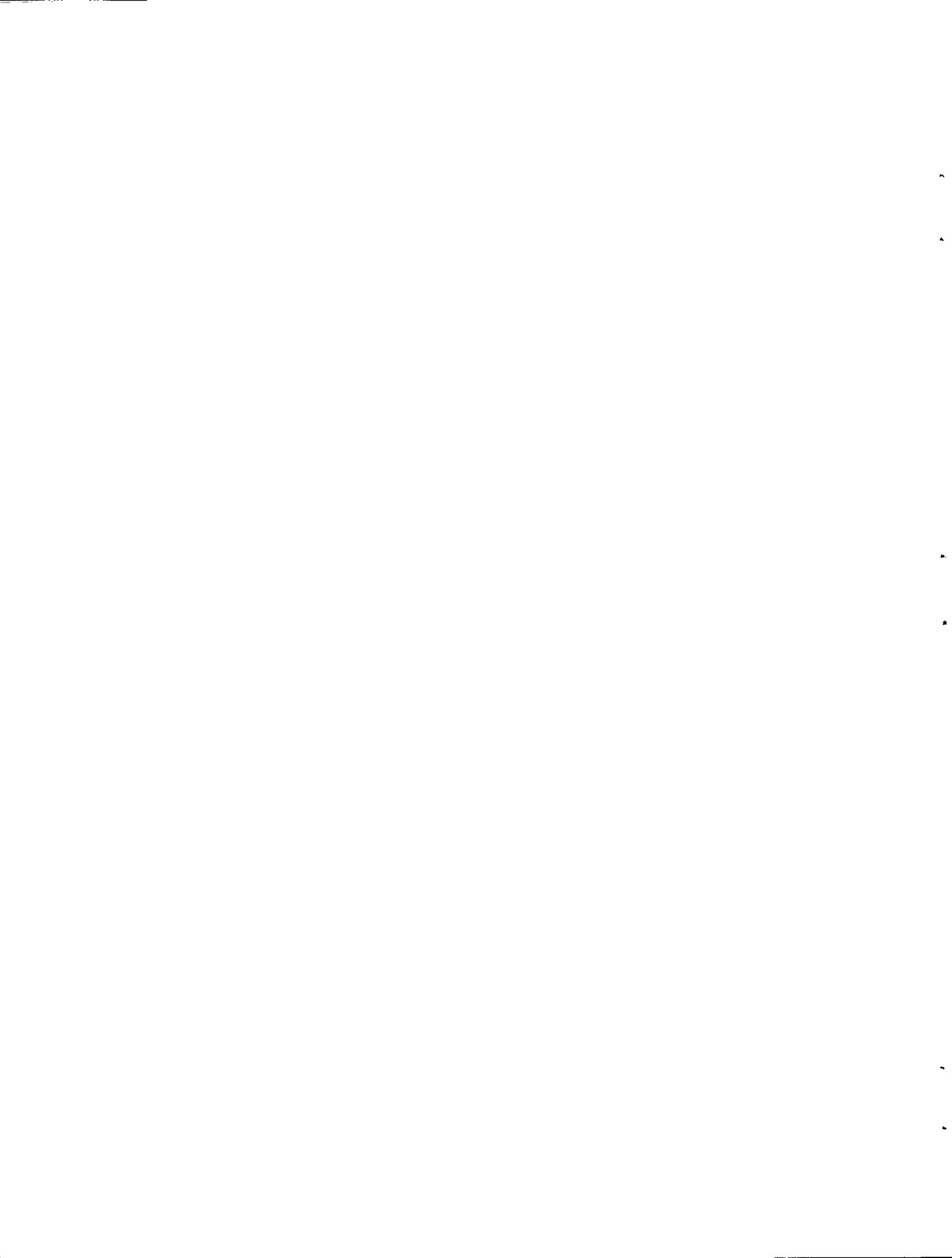
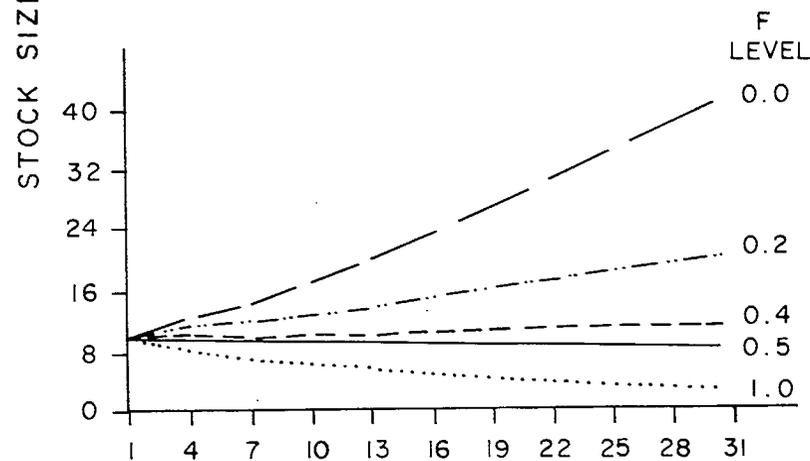
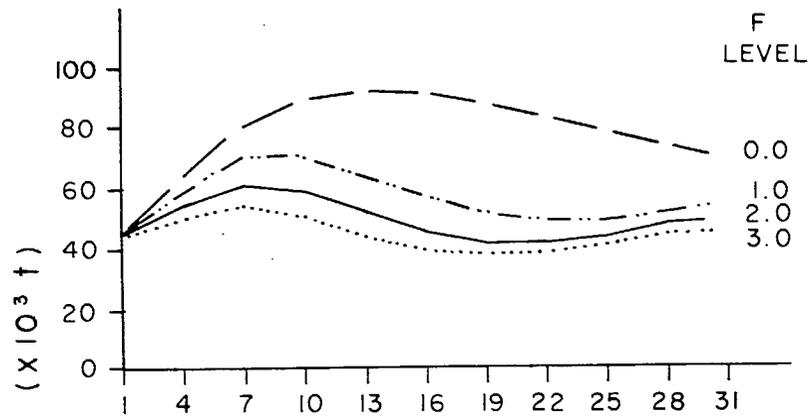
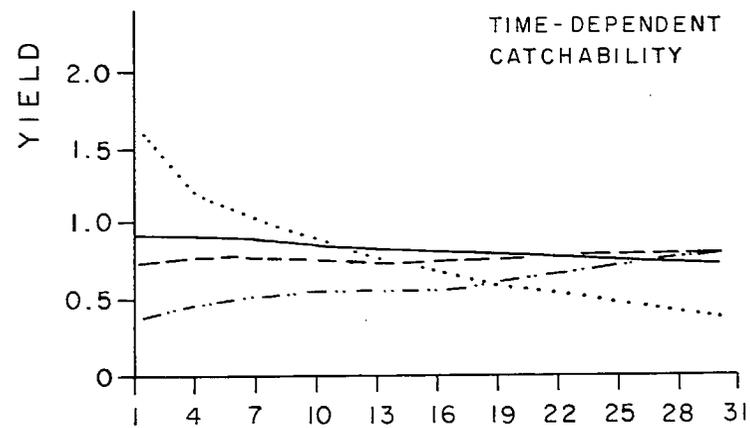
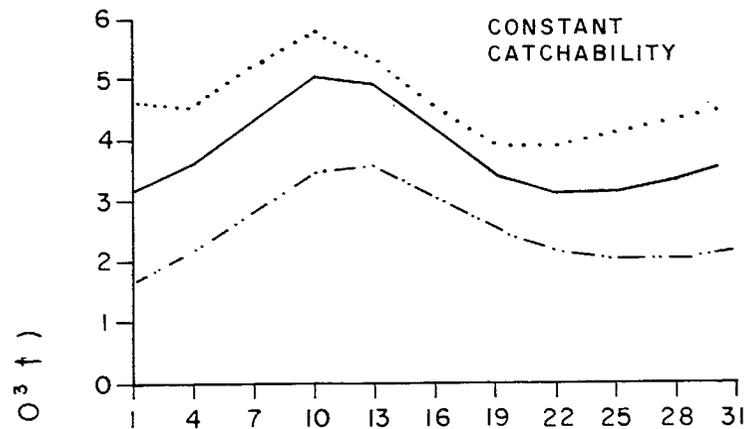


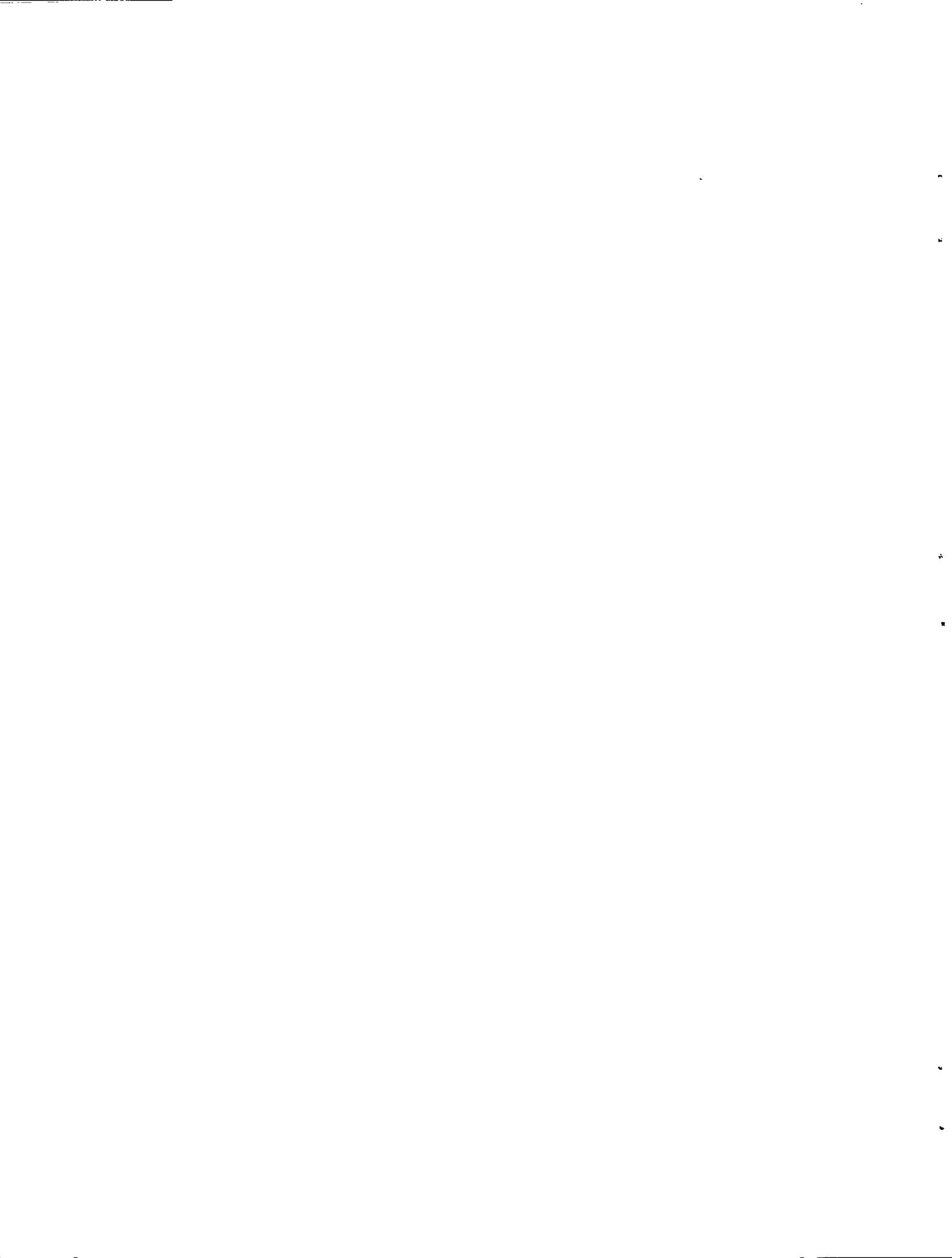
Fig. 5.2.1. Results of two reconstructions of the Pacific ocean perch stock in Goose Island Gully; upper panels with constant catchability, lower with time-dependent catchability. The reconstructed stock biomass is for fish ≥ 6 yr-old and the annual instantaneous fishing mortality (F) is averaged over fish ≥ 11 yr-old in each year.





YEARS INTO THE FUTURE (YEAR 1 = 1977)

Fig. 5.2.2. Forward simulations at different fishing intensities (F levels) for each of the two reconstructions presented for the Pacific ocean perch stock in Goose Island Gully. Results are averaged over 40 stochastic runs with a variance of 0.25 about ϵ_i (see text). (F level is a proportion of the 1977 F level.)



5.3 Pacific cod

5.3.1 Introduction

During 1976-80, Pacific cod comprised approximately 20% of the Canada-U.S. groundfish landings from Queen Charlotte Sound, and ranked second (together with Pacific ocean perch) to rockfishes (Table 5.1). Two relatively large grounds produce virtually all the Pacific cod landed from Queen Charlotte Sound. One is Cape Scott Bank in Area 5A, and the other is Goose Island Bank in Area 5B. These two banks are separated from each other by Goose Island Gully which is 274 m (150 fm) deep at the western end, and 183 m (100 fm) deep at the eastern end. Principal depth range of capture for cod by Canadian vessels during 1956-80 was 55-126 m (30-69 fm) during April-September, and 91-163 m (50-89 fm) during October-March. Currently, we have assumed that Pacific cod on the two banks represent independent stocks. No stock delineation studies have ever been undertaken in Queen Charlotte Sound.

The Pacific cod fishery is highly seasonal in Areas 5A and 5B, primarily due to inclement weather during fall and winter. Westheim (1980) reported that April-September accounted for 78% of the annual landings from Area 5A during 1956-78, and 90% for Area 5B. Canadian participation was relatively minor until 1976 (Fig. 6.1.2).

5.3.2 Statistics and mortality rates

Canadian landing statistics are the only data available, at this time, in sufficient detail for analysis. Analysis of landing statistics using the Option-2 method (see Section 4.2.2 for description) was restricted to Canadian landings, from 5A and 5B during April-September, because of the seasonal nature of the fishery. Results were extrapolated to include U.S. landings. Table 5.3.1 and Figs. 5.3.1, 5.3.2 and 5.3.3 summarize the results.

For Area 5A (during April-September 1956-80), Canada-U.S. trawling effort fluctuated between 1,491 h (1975) and 5,762 h (1963) without appreciable trend (Table 5.3.1 and Fig. 5.3.1). Landings have fluctuated from 74 t (1961) to 1,620 t (1957), also without visible trend. LPUE has fluctuated from 38 kg/h (1962) to 551 kg/h (1957). Two levels of "abundance" are evident--1956-71 and 1972-80. During 1956-71, LPUE values ranged from 38 kg/h to 242 kg/h (except for 1957, 551 kg/h), while during 1972-80 the range was 200-416 kg/h (Table 5.3.1; Fig. 5.3.1).

For Area 5B (during April-September, 1956-80), trawling effort fluctuated between 1,361 h and 11,329 h. Relatively high values during 1970-74 are suspect at this time because Canadian landings comprised a relatively small proportion of the Canada-U.S. landings. Exclusive of 1970-74, a slight increasing trend in effort is evident. Canada-U.S. landings fluctuated between 101 t (1970) and 1,530 t (1975), also with a slight upward trend. LPUEs fluctuated between 9 kg/h (1970) and 409 kg/h (1965), without evident trend (Fig. 5.3.2).

For Queen Charlotte Sound as a whole, effort exhibited little trend (Fig. 5.3.3). Landings fluctuated without trend, but have been relatively high since 1972. LPUE has generally fluctuated with landings.

No age composition data are available yet for Pacific cod landings from Queen Charlotte Sound.

Stock assessment is difficult and hazardous with the limited data available. Canada-U.S. landings from both Areas 5A and 5B continue to fluctuate, as elsewhere in B.C. waters, without evident trend. Coincidentally, LPUEs continue to fluctuate more or less synchronously with landings. None of these phenomena suggest overfishing. Presumably the Pacific cod stocks in Queen Charlotte Sound are in satisfactory condition.

5.3.3 Recommendations

No TAC, or other restraint, is recommended for Pacific cod in Queen Charlotte Sound. A mid-season review is recommended to ensure that any new developments in the fishery can be evaluated.

Table 5.3.1. Canada U.S. landing statistics (Option-2 method) for Pacific cod from Areas 5A and 5B, April-September, 1956-80.

Year	Effort (h)		Landings (t)				LPUE (kg/h)	
	5A	5B	5A		5B		5A	5B
			Can-US	Can Int	Can-US	Can Int		
1956	5,487	3,694	696	178	444	90	127	120
1957	2,941	1,361	1,620	681	294	163	551	216
1958	29,081 ^a	2,177	515	92	446	318	18 ^a	205
1959	2,352	1,954	504	306	331	292	214	169
1960	2,918	2,714	198	113	336	248	68	124
1961	1,644	2,133	74	55	127	98	45	60
1962	3,256	2,327	125	59	232	178	38	100
1963	5,762	4,912	250	33	380	116	43	77
1964	2,265	2,449	358	250	670	204	158	274
1965	2,000	2,737	484	208	1,119	377	242	409
1966	3,328	4,507	740	368	691	194	222	153
1967	2,362	5,894	482	210	730	84	204	124
1968	4,099	4,013	538	305	304	76	131	76
1969	4,491	4,208	276	152	267	75	61	63
1970	3,072	11,329	134	66	101	5	44	9
1971	4,069	8,200	393	147	443	57	97	54
1972	1,906	7,742	653	309	1,462	336	343	189
1973	1,998	6,695	487	213	1,245	203	244	186
1974	2,448	6,016	757	322	1,360	284	309	226
1975	1,491	5,531	620	384	1,530	737	416	277
1976	3,754	3,638	1,036	738	903	703	276	248
1977	3,328	3,416	667	471	487	375	200	143
1978	2,735	3,019	883	711	883	855	323	292
1979	2,022	3,357	808	773	871	756	400	259
1980	1,867	2,720	502	481	605	612	269	222

^a Anomalous value

Source: 1956-78 Canada-U.S. landings from PMFC Groundfish Data Series

1979 U.S. landings from unpublished data

1979-80 Canada landings from Smith (1979-1980)

Canada interviewed landings and effort from PBS computer tape



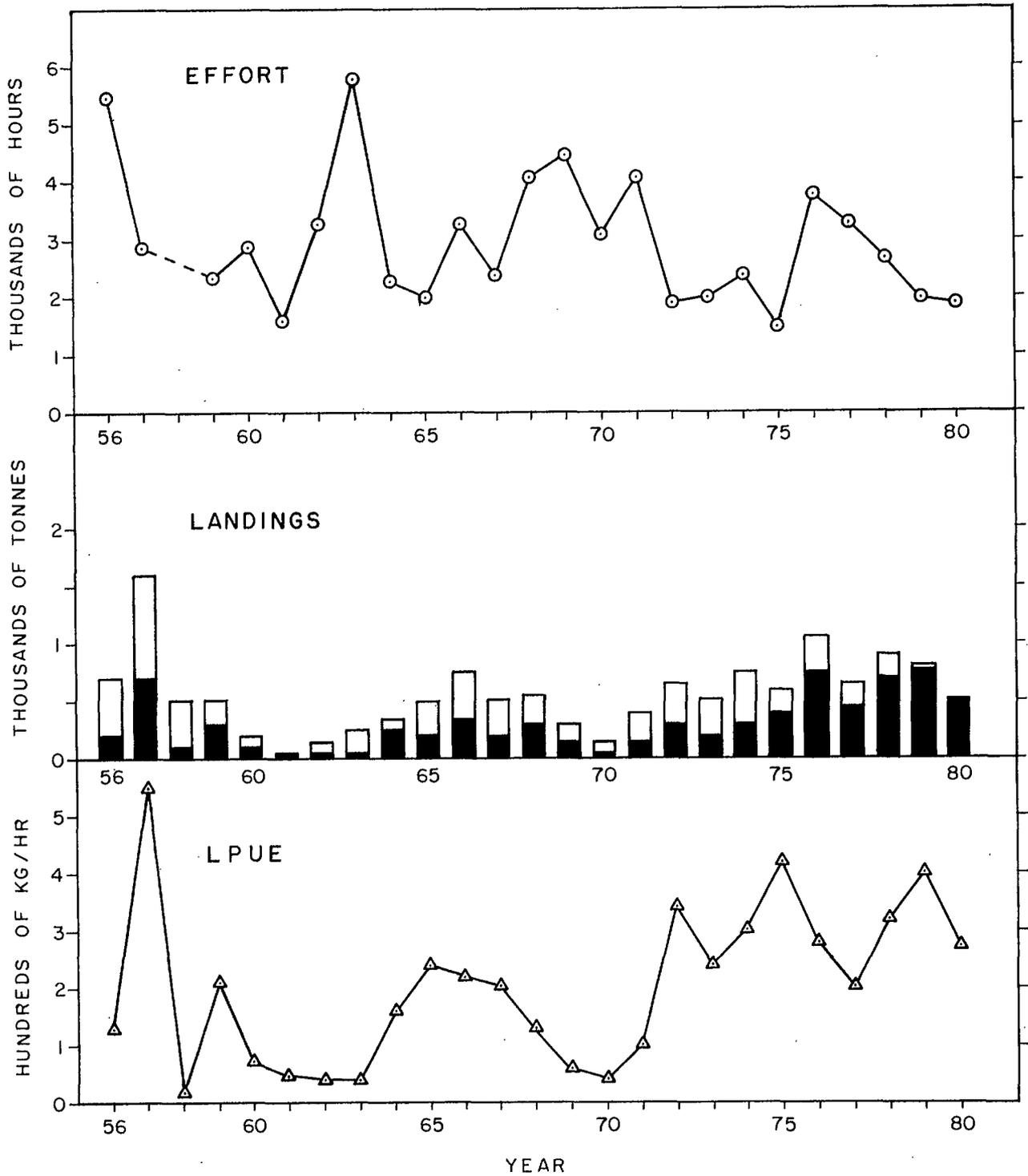
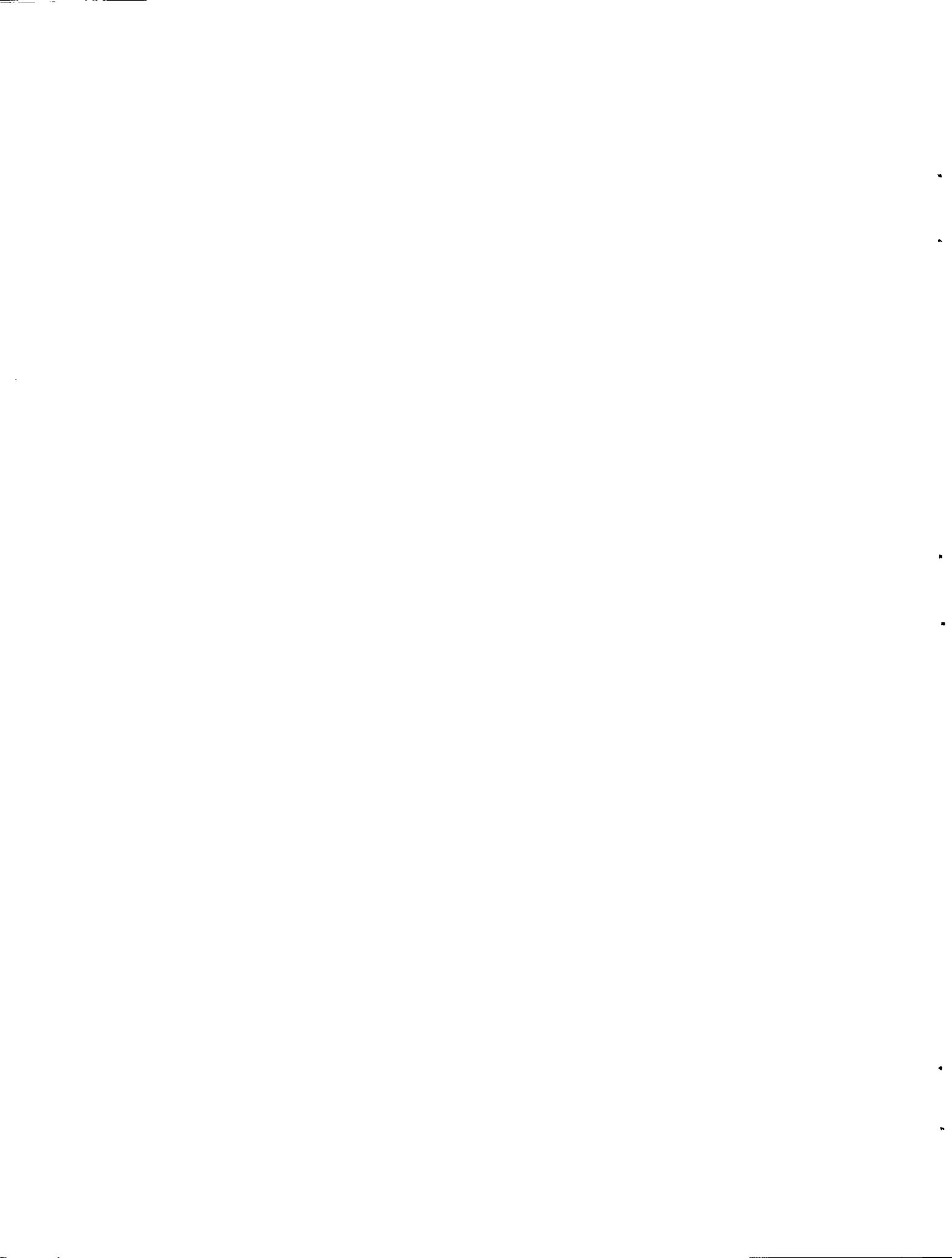


Fig. 5.3.1. Canada-U.S. landing statistics for Pacific cod from Area 5A, April-September, 1956-80. (Shaded areas = Canada interviewed landings.)



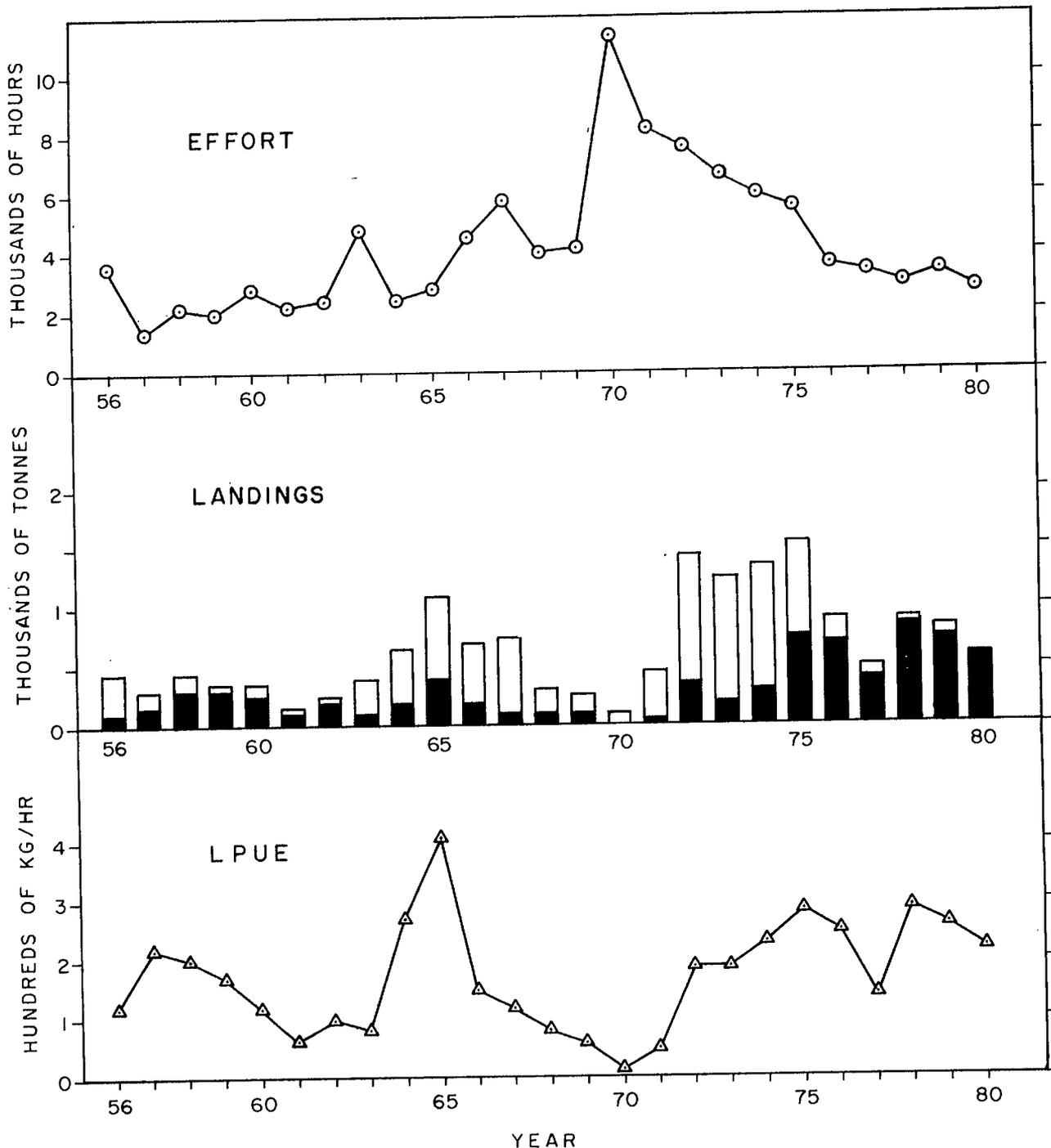
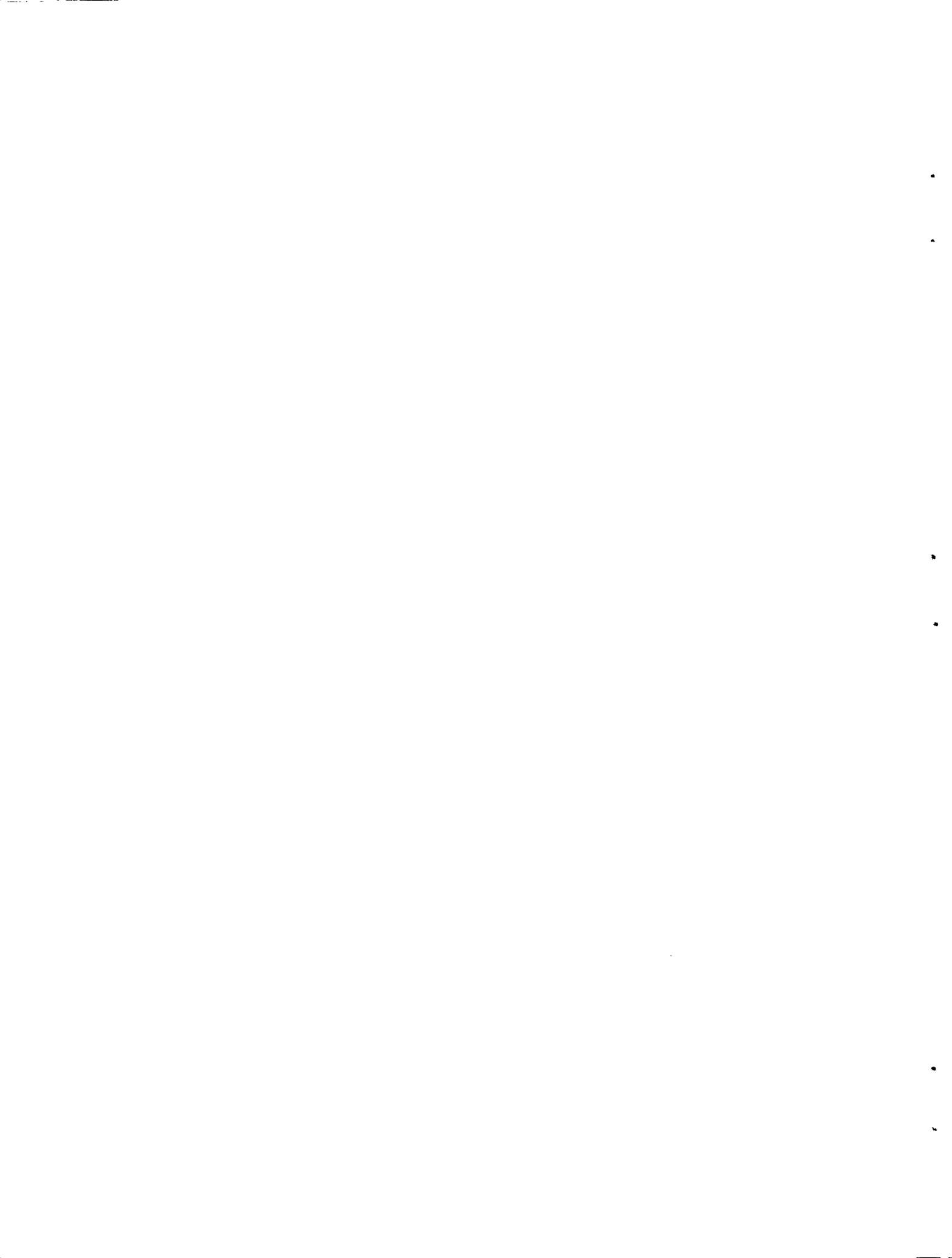


Fig. 5.3.2. Canada-U.S. landing statistics for Pacific cod from Area 5B, April-September, 1956-80. (Shaded areas = Canada interviewed landings.)



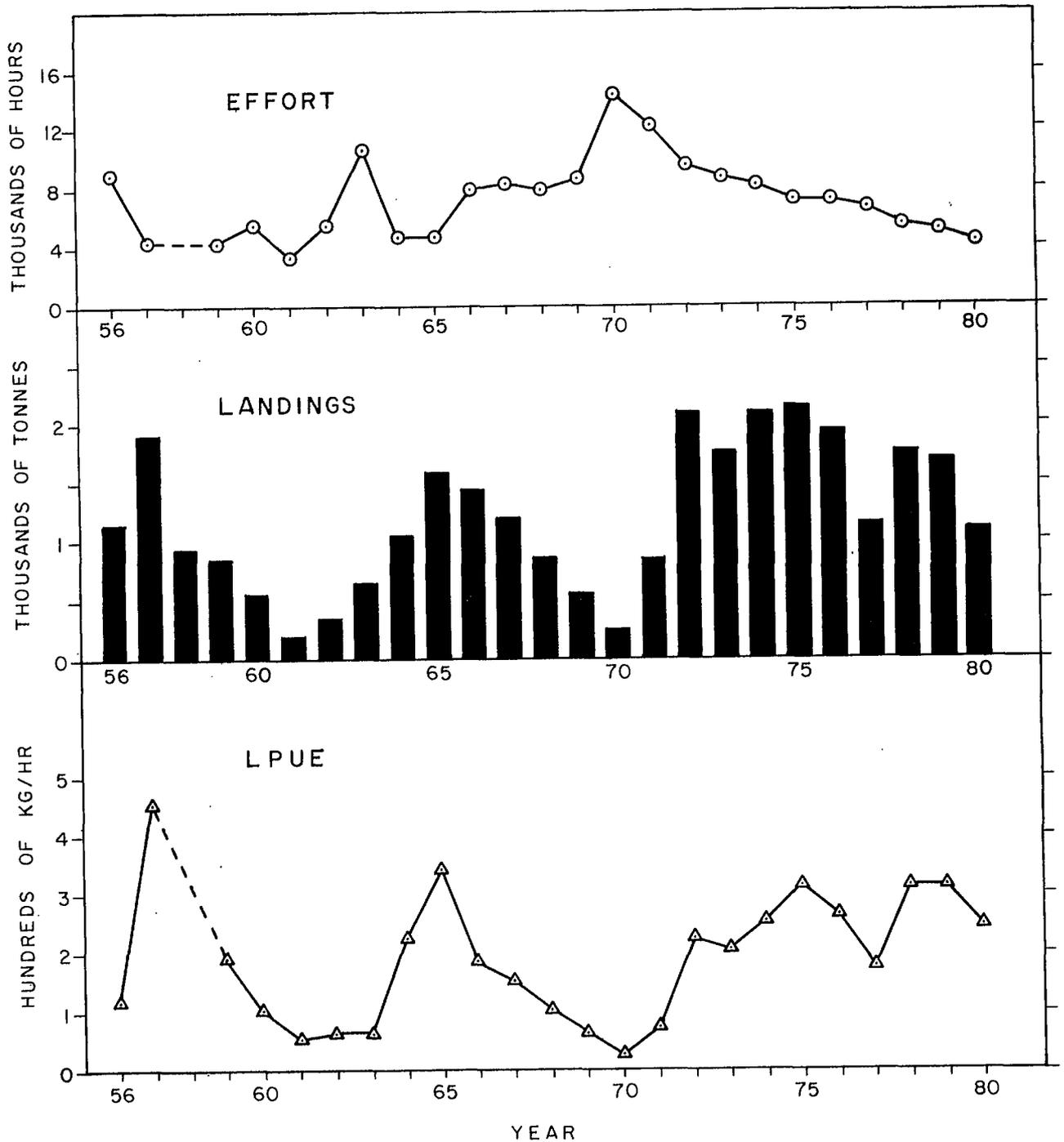
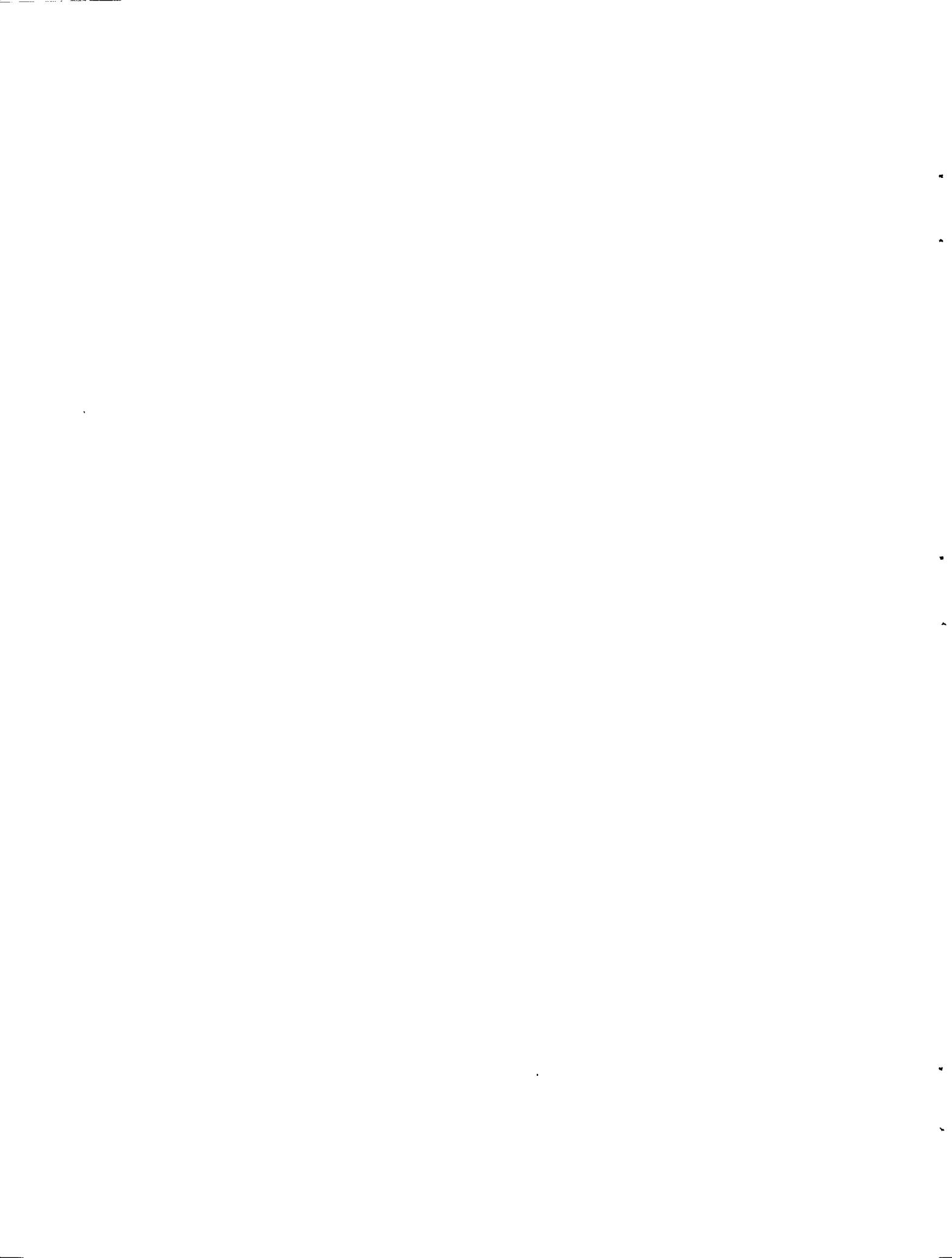


Fig. 5.3.3. Canada-U.S. landing statistics for Pacific cod from Queen Charlotte Sound (Areas 5A + 5B), April-September, 1956-80.



5.4 Lingcod

5.4.1 Introduction

Lingcod have constituted a small percentage of groundfish production from Queen Charlotte Sound during most years since 1954. Lingcod trawl production by the Canadian fleet has amounted to less than 10% of the total Canadian trawl production since 1965.

The movements of stocks in Queen Charlotte Sound are poorly understood. For present purposes lingcod will be considered as a single stock.

5.4.2 Abundance indices

Estimates of TOTAL CPUE and 25% qualified CPUE from the trawl fishery (see Section 4.3.2) were used to examine the state of stocks.

5.4.3 Landing statistics

Trawl production of lingcod from Queen Charlotte Sound constituted an average of 26% of the total Canada-U.S. annual lingcod production from waters off Canada's west coast during 1970-80.

Canada-U.S. trawl production followed an irregular upward trend from 216 t to 897 t during 1954-65 (Table 5.4.1; Fig. 5.4.1). Landings increased substantially after this period and reached a peak in 1968 of 2,269 t. Total Canada-U.S. trawl effort increased during a similar period and reached a peak in 1969. After 1968 trawl production, followed by effort in 1969, declined steadily. Production is currently at low levels.

During 1959-68 CPUE estimates fluctuated at relatively high levels. Periods of high recruitment, reflected by high estimates of both TOTAL and >25% qualified CPUE, occurred in 1961-62 and in 1968. Both estimates of CPUE have declined at an irregular but similar rate since 1968 (Fig. 5.4.2). Line production has been negligible throughout 1954-80.

5.4.4 Stock assessment

The Gulland (1961) and Schnute (1977) stock production models were of no value in estimating productivity of lingcod stocks in Queen Charlotte Sound. Abundance indices indicate that prior to 1969 stocks fluctuated at high levels exhibiting strong fluctuations in recruitment. However, there has been an irregular downward trend in CPUE since 1968 that appears no less evident in 25% qualified CPUE than in TOTAL CPUE estimates.

5.4.5 Recommendations

The long-term decline in CPUE since 1968 warrants concern for lingcod stocks in Queen Charlotte Sound. However, lingcod trawl production by the Canadian fleet averaged only 5% of the total Canadian groundfish production from Queen Charlotte Sound during 1975-80. Except for a brief period of high lingcod production in 1966-68 when lingcod averaged approximately 20% of the total Canadian production of groundfish, lingcod have amounted to less than 10% of total production in all years since 1965. Although lingcod stocks show symptoms of over-exploitation, as a species it has apparently never been relatively abundant in Queen Charlotte Sound during most years since 1965. Stock rebuilding strategies such as time-area closures

or trip limit restrictions may only serve to disrupt the other more lucrative trawl fisheries. The decline in market conditions observed in 1980 may help to reduce the impact of the trawl fishery on lingcod.

A provisional TAC of 400 t is recommended to permit landings at present levels. This will be reviewed if the quota is reached in 1982.

Table 5.4.1. Canada-U.S. lingcod production (t) from Queen Charlotte Sound (Areas 5A + 5B) 1954-80^a.

Year	Total trawl ^b landings(t)	Total trawl ^b CPUE(t/h)	Line fishery ^c landings(t)
1954	216.3	-	9.9
1955	534.8	-	18.4
1956	596.9	-	35.1
1957	580.2	-	11.8
1958	572.4	-	1.8
1959	620.9	0.070	3.8
1960	657.7	0.067	22.6
1961	710.8	0.090	48.5
1962	938.1	0.090	68.5
1963	642.3	0.052	76.1
1964	687.2	0.056	32.9
1965	897.2	0.072	23.6
1966	1,533.1	0.087	58.8
1967	1,660.1	0.090	39.8
1968	2,269.3	0.113	97.3
1969	1,133.5	0.043	56.5
1970	979.7	0.053	81.9
1971	644.1	0.039	58.0
1972	640.0	0.036	108.7
1973	581.5	0.037	66.3
1974	870.9	0.057	83.2
1975	533.0	0.035	74.5
1976	602.8	0.043	91.4
1977	377.9	0.027	77.6
1978	289.0	0.029	28.9
1979	342.6	0.027	32.0
1980	407.4	0.046	34.5

^a Landings do not include production from recreational fisheries, shrimp trawl, trap, gillnet, beach seine or spear-fishing methods.

^b Sources: 1954-55, Ketchen (1976); 1956-78, Pacific Marine Fisheries Commission, Data Series; 1979-80, provisional.

^c Sources: 1954-79, British Columbia Catch Statistics, Department of Fisheries and Environment, Annual Reports; 1980, provisional



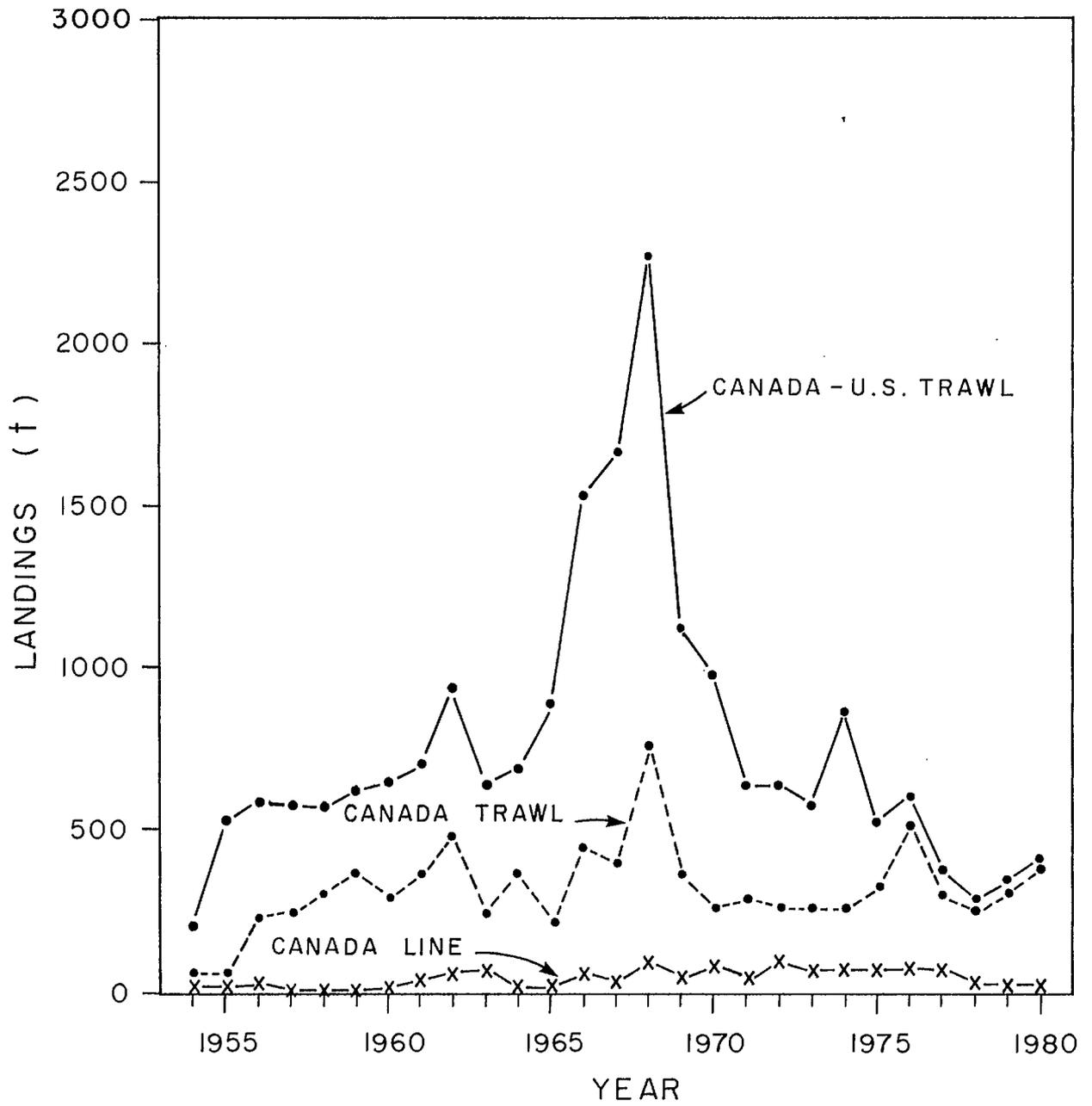


Fig. 5.4.1. Commercial lingcod landings from Queen Charlotte Sound (Areas 5A & 5B), 1954-80.



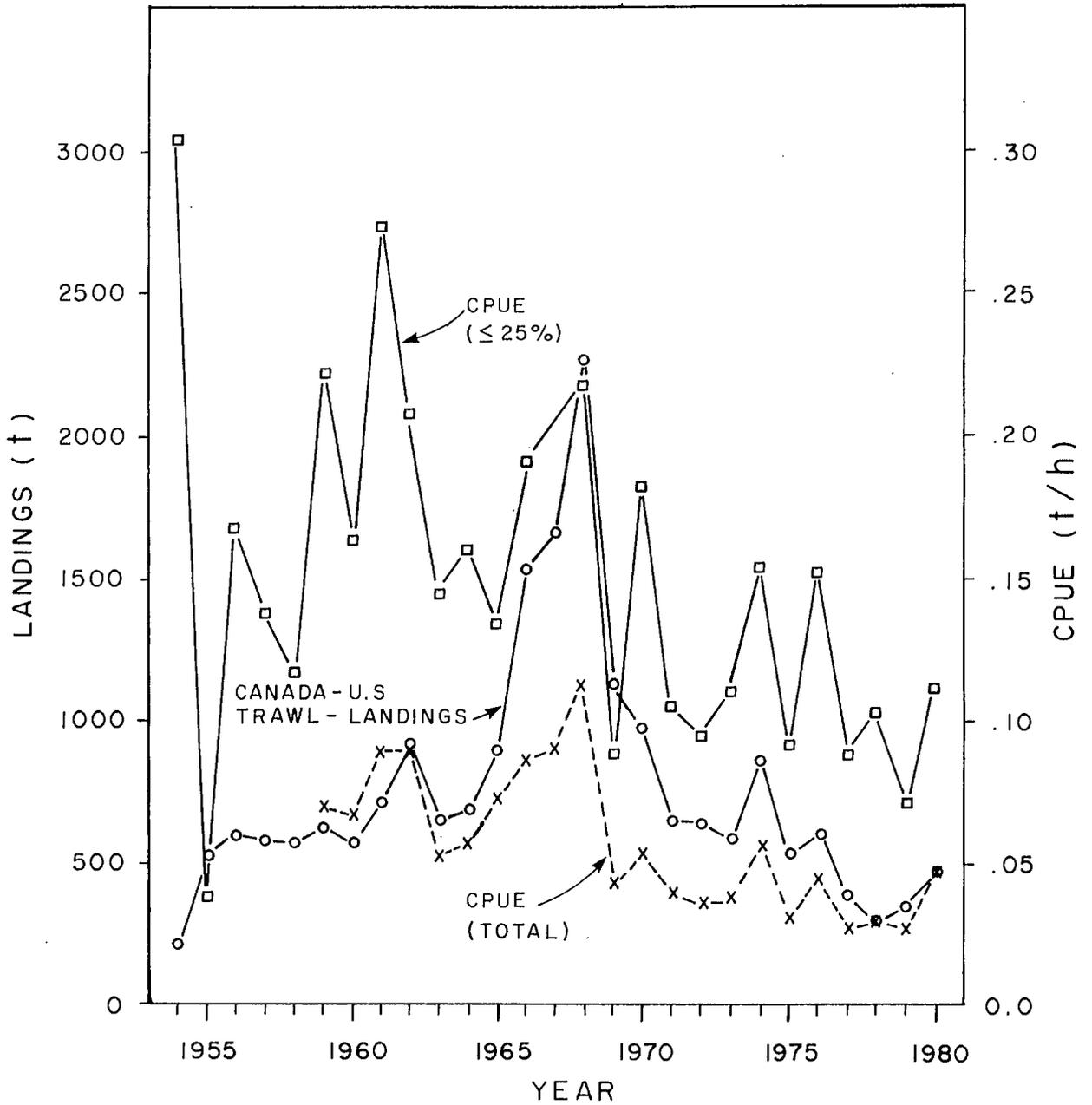
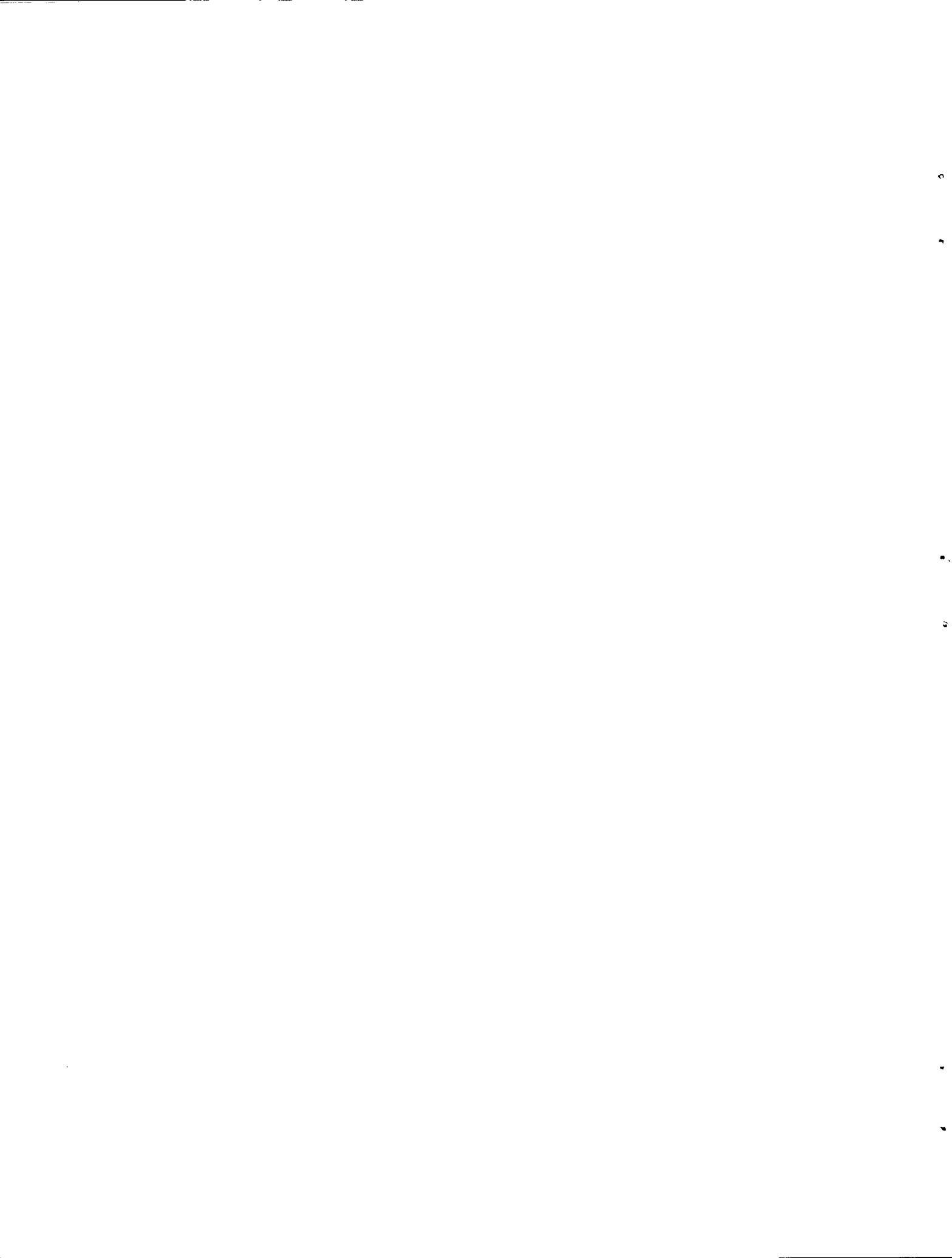


Fig. 5.4.2. Commercial Canada-U.S. lingcod trawl landings and CPUE estimates from Queen Charlotte Sound (Area 5A & 5B) 1954-80.



5.5 Rock sole

5.5.1 Introduction

The rock sole (Lepidopsetta bilineata) has been a minor component of the trawl fishery in Queen Charlotte Sound in recent years. Commercially exploited stocks are located on Goose Island Ground and Cape Scott Ground.

In this assessment, surplus production models are presented and used to estimate stock productivity, maximum sustainable yields, corresponding effort levels and recommended TACs for 1982.

For the purpose of this analysis the rock sole resource is viewed as two discrete units or stocks, namely Goose Island and Cape Scott.

5.5.2 Trends in landings and CPUE

A measure of abundance based on the qualified catch-per-unit-effort (CPUE) was used for this assessment. Abundance of rock sole in Queen Charlotte Sound was estimated using the 50% qualified CPUE from interviewed catch data. Estimates of effort were obtained by dividing annual qualified CPUEs into annual total landings.

The results for the Queen Charlotte Sound stocks are summarized in Table 5.5.1. On the Goose Island and Cape Scott grounds, rock sole production showed moderate fluctuations. The landings for Goose Island Ground peaked in 1966 at 773 t. Landings were generally low from 1977-79 but increased to 410 t in 1980. Lower landings were generally recorded for Cape Scott Ground. A rebounding to moderate landings of around 200 t occurred in 1979-80.

CPUE has fluctuated moderately in Goose Island since 1954. The peak of 0.59 t/h in 1954 was followed by an irregular decline to 0.22 t/h in 1964. Another peak year occurred in 1978 when CPUE was 0.52 t/h. For Cape Scott CPUE remained notably stable showing no particular trends.

5.5.3 Yield

The relationship between catch and effort for the years 1954-80 was examined using surplus production models (Westrheim 1980).

Tables 5.5.2 and 5.5.3 present the results of the parameter estimates obtained for Goose Island Ground and Cape Scott Ground respectively. The best fits to the data were obtained by the Gulland linear regression model with $K = 3$. However, the resulting estimates have to be viewed with caution, since the correlations between abundance and average effort were very low ($r = -0.455$ and $r = -0.305$). The estimates for MSY are 592 t and 335 t for Goose Island and Cape Scott, respectively. Estimates of the corresponding optimal fishing efforts were 3,094 h and 2,136 h giving an optimal CPUE of 0.19 t/h and 0.16 t/h.

The analysis using the dynamic Schaefer model produced negative parameter estimates, indicating that past information predicts catch levels poorly for the Queen Charlotte Sound rock sole stocks.

5.5.4 Yield forecast and recommendations

With the large uncertainty about parameter estimates, it is difficult to forecast rock sole yield for Goose Island and Cape Scott. Even though the Gulland analysis indicates that stocks in the Queen Charlotte Sound show relatively high abundance, these conclusions have to be viewed with caution since the effort data stemming from multi-species exploitation may be questionable. Despite these short-comings it is anticipated that for 1981 present stock abundance should yield about 200 t in each area. Assuming no major departures from projections in the 1981 fishery the recommended TACs for 1982 are 200 t for Goose Island Ground and 200 t for Cape Scott Ground. Should considerable deviations from current fishing patterns occur, these figures may be altered accordingly in early 1982.

Table 5.5.1. Canada-U.S. rock sole landings (t), CPUE (t/h), and calculated effort (h) for Goose Island Ground and Cape Scott Ground 1954-80.

Year	Goose Island Ground			Cape Scott Ground		
	Total ^a landings (t)	CPUE ^b (t/h)	Effort ^c (h)	Total landings (t)	CPUE (t/h)	Effort (h)
1954	203	0.59	344	52	0.17	306
1955	267	0.39	685	118	0.30	393
1956	265	0.40	663	528	0.28	1,886
1957	199	0.29	686	524	0.23	2,278
1958	379	0.24	1,579	504	0.22	2,291
1959	350	0.32	1,094	213	0.18	1,183
1960	503	0.28	1,796	397	0.21	1,890
1961	423	0.22	1,923	237	0.21	1,129
1962	535	0.24	2,229	198	0.15	1,320
1963	533	0.26	2,050	161	0.17	947
1964	483	0.22	2,195	160	0.20	800
1965	568	0.28	2,029	157	0.18	872
1966	773	0.32	2,416	329	0.30	1,097
1967	745	0.33	2,258	253	0.22	1,150
1968	393	0.27	1,456	448	0.26	1,723
1969	652	0.22	2,964	296	0.18	1,644
1970	245	0.23	1,065	167	0.19	879
1971	373	0.21	1,776	134	0.23	583
1972	382	0.33	1,158	58	0.22	264
1973	324	0.27	1,200	61	0.82	74
1974	371	0.24	1,546	75	0.26	288
1975	408	0.37	1,103	37	0.10	370
1976	368	0.32	1,150	181	0.31	584
1977	188	0.26	723	84	0.21	400
1978	216	0.52	415	80	0.15	533
1979	208	0.21	990	201	0.28	718
1980	410	0.44	932	238	0.23	1,035

^aData sources: Canada - sales slips and trip logs.
U.S. - 1954-75 Ketchen (1976)
- 1976-79 supplied by Washington State Department
of Fisheries.

^bFrom trip logs (50 percent qualification level)

^cTotal landings/CPUE

Table 5.5.2. Parameter estimates for Goose Island Ground rock sole.

I. Parameter estimates for Gulland's (1961) linear regression model.

	K = 3	K = 4	K = 5
<u>Biological:</u>			
a	0.383	0.366	0.368
b	6.190×10^{-5}	5.19×10^{-5}	5.200×10^{-5}
<u>Fishery:</u>			
MSY (t)	592	645	651
f_{opt} (h)	3,094	3,526	3,538
<u>Correlation:</u>			
r	-0.455	-0.369	-0.333

II. Parameter estimates from dynamic Schaefer model.

<u>Biological:</u>	<u>Fishery:</u>	<u>"Variance":</u>
	negative parameters	

Table 5.5.3. Parameter estimates for Cape Scott Ground rock sole.

I. Parameter estimates from Gulland's (1961) linear regression model.

	K = 3	K = 4	K = 5
<u>Biological:</u>			
a	0.314	0.313	0.297
b	7.350×10^{-5}	7.330×10^{-5}	5.810×10^{-5}
<u>Fishery:</u>			
MSY (t)	335	334	449
f_{opt} (h)	2,136	2,135	2,556
<u>Correlation:</u>			
r	-0.305	-0.281	-0.205

II. Parameter estimates from dynamic Schaefer model.

<u>Biological:</u>	<u>Fishery:</u>	<u>"Variance":</u>
	negative parameters	

6. HECATE STRAIT (5C AND 5D) STOCK ASSESSMENTS

Principal species (based on a 5-yr average) in the Canadian landings from Hecate Strait are Pacific cod (3,967 t), walleye pollock (1,200 t), turbot (1,196 t), rock sole (1,088 t), Other rockfish (984 t), and English sole (944 t) (Table 6.1). Secondary species are Dover sole (618 t), and Pacific ocean perch (517 t).

In the following sections stock assessments are presented for Pacific cod, walleye pollock, turbot, rock sole, English sole, Dover sole, Other rockfish, and Pacific ocean perch.

Table 6.1. British Columbia groundfish landings (t) by main species in the Hecate Strait and Dixon Entrance (Areas 5C and 5D), 1976-80.

Species	Canadian Landings (t)					5-yr average
	1976	1977	1978	1979	1980	
Pacific cod	4,991.8	3,509.5	2,099.5	4,694.4	4,539.7	3,967.0
Walleye pollock	819.9	583.3	1,706.9	1,804.2	1,084.5	1,199.8
Turbot	1,050.5	1,023.2	1,365.2	1,527.5	1,013.7	1,196.0
Rock sole	1,435.4	841.6	873.5	1,314.3	976.3	1,088.2
Other rockfish	849.7	804.6	957.5	1,466.4	843.4	984.3
English sole	1,126.9	1,177.2	559.1	862.9	994.2	944.1
Dover sole	1,021.4	475.0	356.2	632.8	606.2	618.3
Pacific ocean perch	85.6	73.7	78.4	268.3	2,079.4	517.1

6.1 Pacific cod

6.1.1 Introduction

During 1976-80, Pacific cod comprised 35% of the Canada-U.S. trawl landings of groundfish, and ranked first (Table 6.1). Canadian vessels have dominated the fishery since 1971 (Fig. 6.1.2). Historically, the three principal trawling grounds for Pacific cod have been Two Peaks-Butterworth (5D), Horseshoe (5C) and White Rocks-Bonilla (5D) (Fig. 6.1.1). Together, these three grounds produced 83% of the Pacific cod landed from Hecate Strait during 1958-78 (Westrheim 1980). During April-September, Two Peaks-Butterworth Ground produced 78% of the 1956-78 annual landings of Pacific cod from Area 5D, while Horseshoe Ground accounted for 78% of the corresponding annual landings from Area 5C. During October-March, White Rocks-Bonilla Ground produced 59% of the 1956-78 annual landings from Hecate Strait (Area 5C and 5D) (Westrheim 1980, Table 4.8).

Detailed data on landing statistics and age composition (derived from length-frequencies) are available for the three principal grounds, and are utilized for stock assessment in this report. More refined analyses are scheduled, at a later date, which will incorporate pertinent data from secondary grounds.

6.1.2 Landing statistics

Landing statistics for Two Peaks-Butterworth (April-September), Horseshoe (April-September), and White Rocks-Bonilla (October-March) were processed using the Option-2 method (see Section 4.2.2 for description), and are shown in Figs. 6.1.3-5 and Tables 6.1.1-2.

Fishing effort exhibited different trends among grounds (Fig. 6.1.3; Tables 6.1.1-2). On Two Peaks-Butterworth Ground, effort has gradually increased from about 1,000-2,000 h during 1958-66, to 2,700-4,400 h during 1976-80. On Horseshoe Ground, effort has fluctuated at 200-2,100 h without evident trend. On White Rocks-Bonilla Ground, effort was relatively high during 1958-67 (2,000-5,600 h), and relatively low during 1968-80 (600-2,200 h). Labour disputes reduced effort during April-September 1967 and 1978.

Landings followed trends similar to effort on each ground (Fig. 6.1.4; Table 6.1.1). For Two Peaks-Butterworth Ground, landings have remained relatively high during 1972-80. The decreased landings during April-September 1967 were compensated for by larger landings during October-March on White Rocks Ground. For Horseshoe and White Rocks-Bonilla grounds, landings fluctuated more or less synchronously.

LPUE fluctuations were similar for Pacific cod landed from Two Peaks-Butterworth and Horseshoe grounds (Fig. 6.1.5; Table 6.1.1). Substantial fluctuations were evident with peaks occurring during 1958-59, 1963-67, and 1973-75. No long-term trend is evident for either array. In contrast, LPUE for White Rocks-Bonilla exhibited negligible fluctuations, but no trend. As in Area 3C, LPUE for the winter fishery failed to reflect the substantial fluctuations in abundance noted in the landings and LPUEs of the spring-summer fishery (and the landings during October-March). Anecdotal evidence from fishermen and others suggest that cod behaviour (availability) is different during the spawning season.

Pacific cod landing statistics for Hecate Strait during April-March 1958-80 are shown in Fig. 6.1.6. October-March effort was derived by dividing Area 5C and 5D October-March landings by Area 5C and 5D April-September LPUE. White Rocks-Bonilla LPUE was deemed unrepresentative of Pacific cod abundance during October-March, because it did not reflect fluctuations in LPUE during April-September, or October-March landings from White Rocks-Bonilla Ground.

Effort generally ranged between 4,000 and 8,000 h, and exhibited a slight upward trend. Values ranged from 4,200-6,600 h during 1958-65, and 6,500-9,700 h during 1975-80 (Table 6.1.2; Fig. 6.1.6). Landings ranged from 1,200-9,000 t without trend. Peaks occurred in 1958-59, 1965-67 and 1974-76. LPUEs ranged from 0.155-1.345 t/h, also without trend, with peaks in 1958-60, 1964-67, and 1973-76. Notable are the relatively large effort values during 1975-80 despite the decline in landings.

6.1.3 Mortality rates

A new method has been employed to estimate age composition of Canadian landings of Pacific cod by computer-processing of length-frequency samples, and is an application of the generalized method of Schnute and Fournier (1980). A report describing the application is in preparation. A time series (1956-80) of Pacific cod length-frequencies has been processed, for the important seasons, on the three major fishing grounds in Hecate Strait. Validation of the method has not been established. Therefore, conclusions based on these age-compositions must be regarded as tentative.

Total mortality rate (Z) was calculated for each year-class (1956-74) based on numbers landed per hour trawled (ages 3-5 and 3-6) during April-September, for Two Peaks-Butterworth and Horseshoe grounds (Table 6.1.3). Age composition data for White Rocks-Bonilla Ground during October-March was deemed not usable, because LPUEs did not reflect April-September LPUE fluctuations. Estimates of Z based on ages 3-6 were deemed more consistent, because they included fewer anomalous values.

Relationship between year-class abundance (Σ LPUE) and Z is shown in Fig. 6.1.7. In general, Z values were maximal on the year-classes following strong year-classes, and were relatively high for all of the 1970-74 year-classes, irrespective of their relative abundance. Evidently, the fishery reacts belatedly to the appearance of strong year-classes of Pacific cod. This phenomenon was also reflected in trends of effort, in relation to landings in Figs. 6.1.3-4 and 6.1.6.

Interestingly, more strong year-classes are evident on Horseshoe Ground (1960-63; 1969-72) than on Two Peaks-Butterworth Ground (1961-62; 1969-71). The significance of this phenomenon is unknown.

Natural mortality rate (M) was estimated by regressing Z on April-March fishing effort for each year class, except 1959, 1967, and 1968, which were deemed anomalous. Fishing mortality rate (F) was estimated by subtraction, $\bar{Z} - M$.

Regressing Z on fishing effort yielded the formula $\hat{Y} = 0.38 + 0.0000333X$ ($r = 0.595$), where the intercept 0.38 is an estimate of M (Fig. 6.1.8; Table 6.1.4). Then $\hat{F} = \bar{Z} - \hat{M} = 1.05 - 0.38 = 0.67$.

6.1.4 Stock assessment

Landing statistics indicate that Pacific cod abundance continues to fluctuate without trend, although fishing effort during recent years may be approaching a level detrimental to stock reproduction. Similarly, total mortality rate (Z) is currently at a relatively high level, and fishing mortality rate (F) may well be a substantial proportion of Z. Scheduled refinements in the analysis of landing statistics may clarify the situation.

The substantial increase in effort in Area 5D may well be detrimental to secondary species, such as English sole and rock sole, which share some of the grounds with Pacific cod.

6.1.5 Recommendation

No TAC, or other restraint, is recommended at this time (May 1981) for Pacific cod in Hecate Strait. A mid-season review will be undertaken.

Table 6.1.1. Canada-U.S. landing statistics for Pacific cod from Area 5D (April-Sept), 5C (April-Sept) and 5C + 5D (Oct-Mar), and 1958-80.

Year	Two Peaks-Butterworth				Horseshoe				5C + 5D		White Rocks	
	5D Landings (t)	Landings (t)	Effort (h)	LPUE (kg/h)	5C Landings (t)	Landings (t)	Effort (h)	LPUE (kg/h)	Landings (t)	Landings (t)	Effort (h)	LPUE (kg/h)
1958	1,372	1,236	1,890	684	1,146	836	634	1,318	-	-	-	-
1959	1,244	1,203	1,716	701	806	645	648	995	3,184	2,486	5,613	443
1960	902	744	1,428	521	400	392	1,231	319	1,466	1,306	3,656	357
1961	574	543	1,332	408	33	33	270	122	1,089	825	2,591	318
1962	1,097	531	1,048	507	158	99	289	343	913	771	3,331	231
1963	810	755	1,606	470	722	628	528	1,190	1,301	985	2,843	346
1964	1,874	1,773	1,245	1,424	1,705	1,232	933	1,321	1,126	684	2,021	338
1965	3,296	2,368	1,556	1,522	3,036	2,215	1,994	1,111	2,745	1,615	2,755	586
1966	3,209	2,554	2,237	1,142	4,023	2,990	2,114	1,415	2,537	1,244	2,874	433
1967	1,229	866	697	1,243	1,554	1,085	1,360	798	1,728	859	2,421	355
1968	1,742	908	2,879	315	1,049	595	1,754	339	3,333	1,410	3,384	417
1969	1,171	642	1,800	357	669	357	1,423	251	1,159	351	1,728	203
1970	485	434	2,318	187	94	29	389	75	731	368	737	499
1971	600	486	2,855	170	322	138	527	262	608	280	1,097	255
1972	2,291	1,189	2,200	540	636	577	750	770	386	138	595	232

(cont'd.)

Table 6.1.1 (cont'd.)

Year	5D Landings (t)	Two Peaks-Butterworth			5C Landings (t)	Horseshoe			5C + 5D Landings (t)	White Rocks		
		Landings (t)	Effort (h)	LPUE (kg/h)		Landings (t)	Effort (h)	LPUE (kg/h)		Landings (t)	Effort (h)	LPUE (kg/h)
1973	1,579	1,270	1,596	786	1,527	1,297	943	1,376	976	476	1,016	469
1974	2,663	1,560	1,251	1,247	1,361	1,284	1,004	1,279	714	389	1,016	383
1975	2,691	1,673	1,940	862	961	771	1,323	583	1,222	719	1,213	593
1976	2,063	1,233	2,695	458	1,157	880	1,226	718	1,741	1,063	2,147	495
1977	2,408	1,859	3,953	470	402	274	638	429	946	565	2,190	258
1978	977	603	2,134	283	579	458	818	560	652	312	1,151	271
1979	2,429	2,082	4,422	471	1,520	1,260	1,603	786	740	487	1,239	393
1980	-	1,466	3,784	387	-	977	1,679	582	1,550	802	1,790	448
1958-79												
\bar{x}	1,668	1,205			1,085	822			1,402	824		
S.D.	855	630			947	716			838	544		
C.V.	51	52			87	87			60	66		
%Inter-												
viewed		72				76				59		

Source: 1956-78 Canada-U.S. landings from PMFC groundfish Data Series
1979-80 Canada-U.S. from unpublished data
1956-80 Canada interviewed landings and effort from PBS computer files

Table 6.1.2. Canada-U.S. landing statistics for Pacific cod from Hecate Strait (5C + 5D), April-March, 1958-80.

Year	Landings (t)			Effort (h)			Apr-Sep LPUE (kg/h)
	Apr-Sep	Oct-Mar	Total	Apr-Sep	Oct-Mar ^a	Total	
1958-59	2,518	3,184	5,702	2,933	3,707	6,640	859
1959-60	2,050	1,466	3,516	2,450	1,751	4,201	837
1960-61	1,302	1,089	2,391	2,942	2,458	5,400	433
1961-62	607	913	1,520	1,685	2,536	4,221	360
1962-63	1,255	1,301	2,556	2,644	2,739	5,383	475
1963-64	1,532	1,126	2,658	2,479	1,822	4,301	618
1964-65	3,579	2,745	6,324	2,660	2,041	4,701	1,345
1965-66	6,332	2,537	8,869	5,309	2,127	7,436	1,193
1966-67	7,232	1,728	8,960	5,729	1,369	7,098	1,262
1967-68	2,783	3,333	6,116	2,982	3,572	6,554	933
1968-69	2,791	1,159	3,950	9,087	3,775	12,862	307
1969-70	1,840	731	2,571	5,997	2,381	8,378	307
1970-71	579	608	1,187	3,741	3,923	7,664	155
1971-72	922	386	1,308	4,727	1,979	6,706	195
1972-73	2,927	967	3,894	5,013	1,656	6,669	584
1973-74	3,106	714	3,820	3,255	748	4,003	954
1974-75	4,024	1,222	5,246	3,268	993	4,261	1,231
1975-76	3,652	1,741	5,393	4,554	2,171	6,725	802
1976-77	3,220	946	4,166	6,071	1,785	7,856	530
1977-78	2,810	652	3,462	5,997	1,390	7,387	469
1978-79	1,556	740	2,296	4,439	2,108	6,547	351
1979-80	3,949	1,550	5,499	6,990	2,743	9,733	565

^a Oct-Mar Effort = (Oct-Mar Landings) ÷ (Apr-Sep LPUE) X 1,000

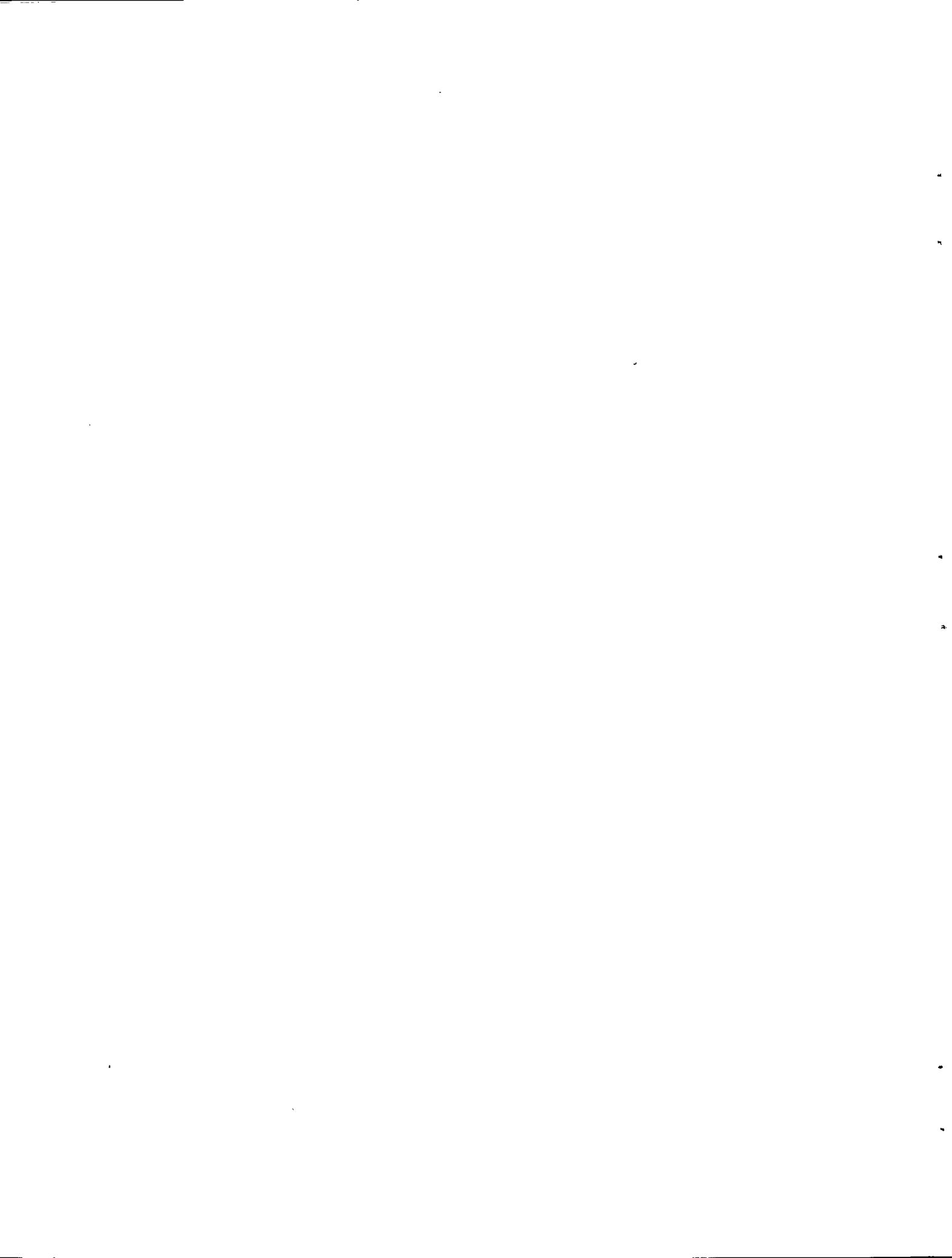
Table 6.1.3. Pacific cod year-class abundance (Σ LPUE) and total mortality rate (Z) for Two Peaks-Butterworth, and Horseshoe grounds, April-September, 1959-80 (Anomalous values in parentheses).

Year class	Two Peaks-Butterworth				Horseshoe			
	Age 3-5		Age 3-6		Age 3-5		Age 3-6	
	Σ LPUE (n/h)	Z						
1956	120	1.35	132	0.77	464	1.70	464	1.93
1957	161	(0.50)	167	0.80	118	2.30	130	0.94
1958	147	0.90	160	0.68	24	-	38	(0.35)
1959	164	(0.10)	171	0.67	154	-	170	0.82
1960	172	(0.40)	176	0.89	502	0.85	548	0.66
1961	382	0.97	390	0.99	754	0.70	770	1.06
1962	445	1.15	452	1.28	551	0.90	553	1.66
1963	171	0.61	176	0.83	398	2.00	402	1.57
1964	160	(0.20)	162	0.73	171	1.00	171	1.48
1965	92	1.25	94	1.34	147	2.25	152	1.30
1966	38	(0.50)	38	0.93	52	-	52	(0.45)
1967	42	0.85	58	(0.18)	40	-	48	-
1968	44	-	53	(0.09)	69	(0.20)	79	(0.30)
1969	146	(0.05)	148	1.01	313	(0.40)	330	0.70
1970	264	(0.40)	268	1.09	425	1.40	432	1.32
1971	167	0.95	170	1.27	262	0.95	265	1.32
1972	121	1.90	123	1.35	326	1.75	332	1.40
1973	106	0.80	109	1.05	227	0.95	230	1.26
1974	112	0.70	115	0.99	201	0.65	208	0.92

Table 6.1.4. Canada-U.S. effort (h) and total mortality rate (Z) for Pacific cod landed from Hecate Strait (5C + 5D), for year-classes 1956-74, during April-March.

Year class	Age			Total Effort (3-6)	Z (3-6)
	(3-4)	(4-5)	(5-6)		
1956	4,201	5,400	4,221	13,822	.96
1957	5,400	4,221	5,383	15,004	.72
1958	4,221	5,383	4,301	13,905	.65
1959	5,383	4,301	4,701	14,385	(.45)
1960	4,301	4,701	7,436	16,438	.64
1961	4,701	7,436	7,098	19,235	1.05
1962	7,436	7,098	6,554	21,088	1.34
1963	7,098	6,554	12,862	26,514	1.23
1964	6,554	12,862	8,378	27,794	1.27
1965	12,862	8,378	7,664	27,904	1.33
1966	8,378	7,664	6,706	22,748	.85
1967	7,664	6,706	6,669	21,039	(.29)
1968	6,706	6,669	4,003	17,378	(.33)
1969	6,669	4,003	4,261	14,933	.69
1970	4,003	4,261	6,725	14,989	1.23
1971	4,261	6,725	7,856	18,842	1.31
1972	6,725	7,856	7,387	21,966	1.43
1973	7,856	7,387	6,547	21,790	1.12
1974	7,387	6,547	9,733	23,667	.92
mean ^a = 1.05					

^a excluding 1959, 1967, and 1968



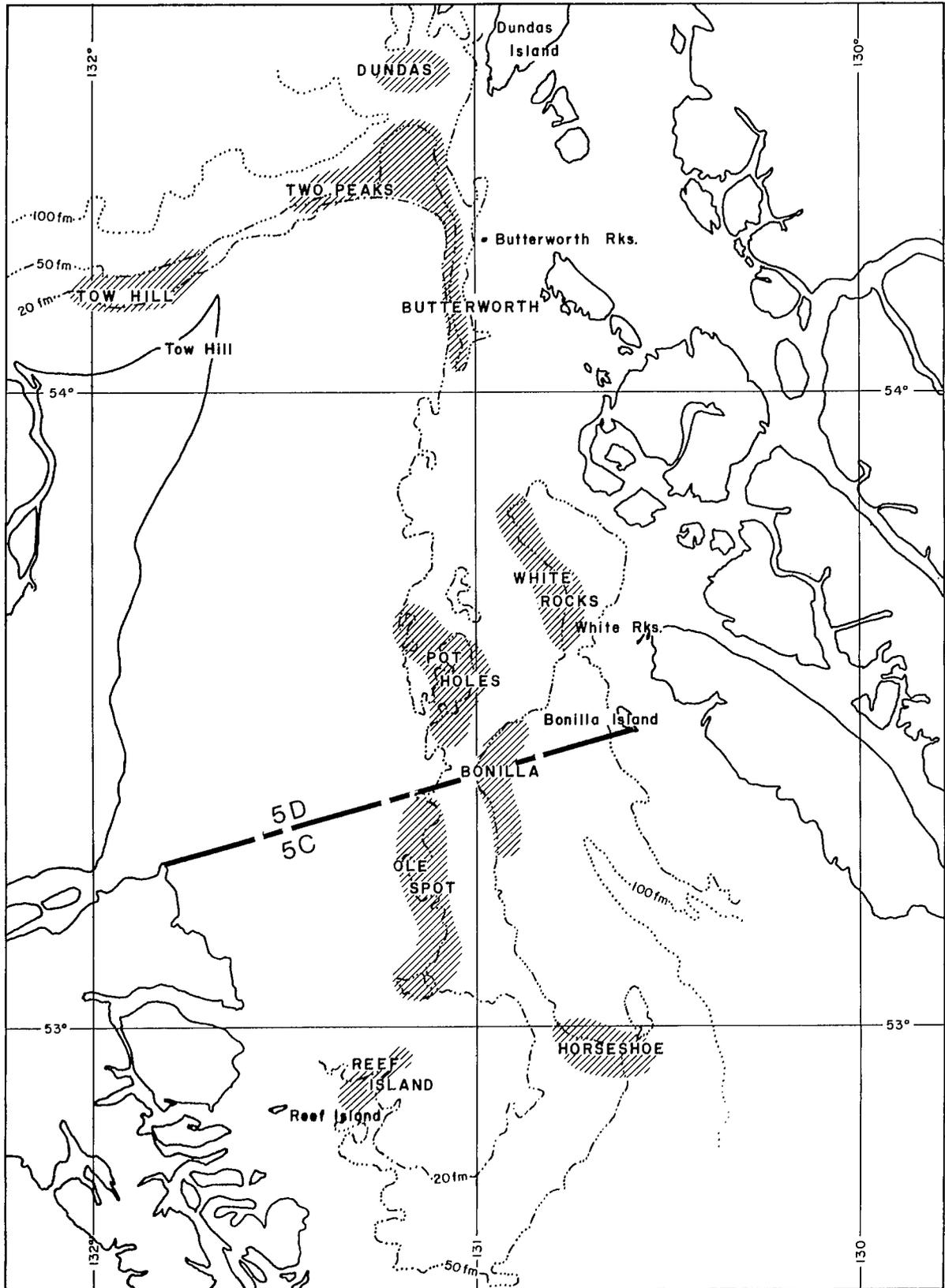
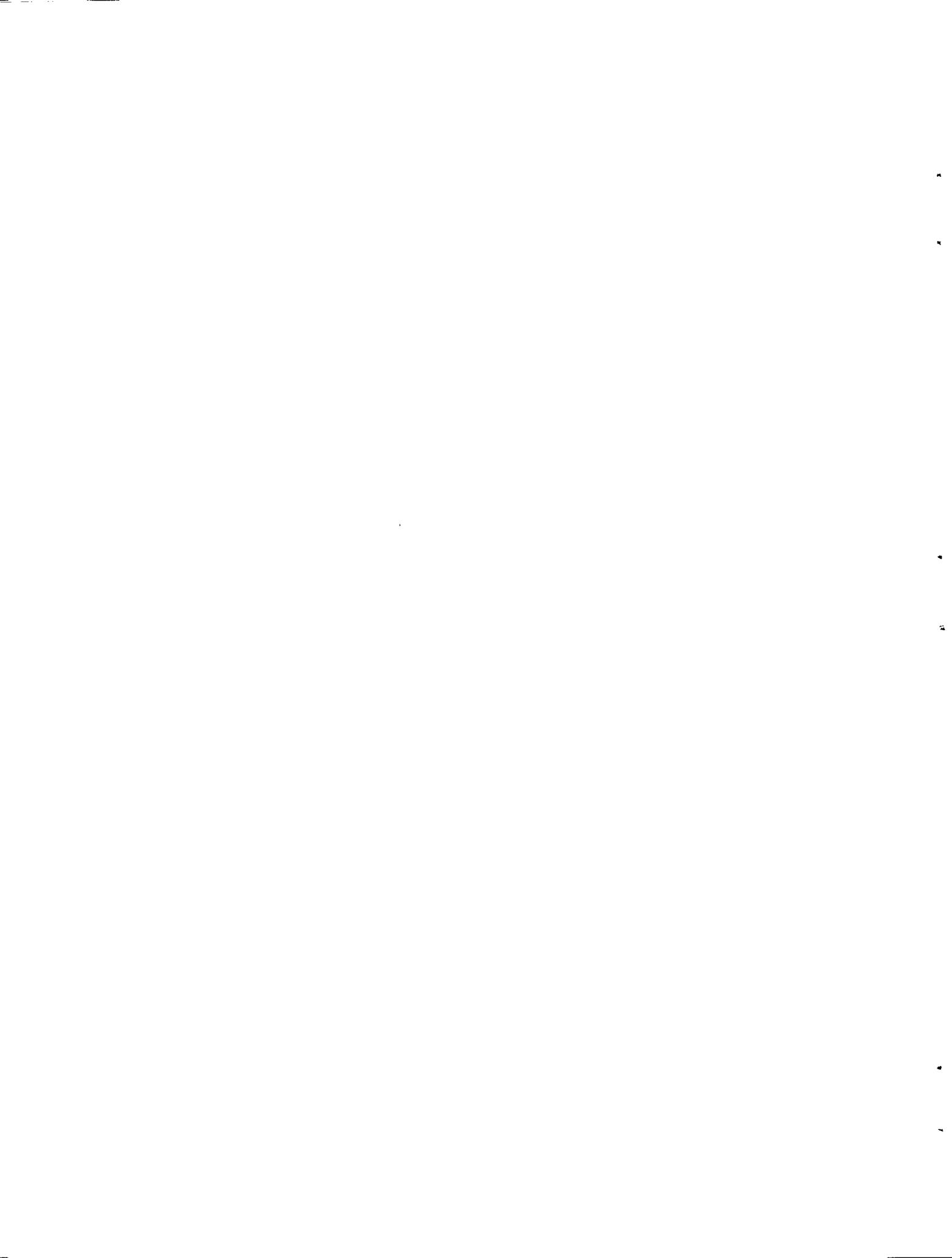


Fig. 6.1.1. Trawling grounds in Hecate Strait.



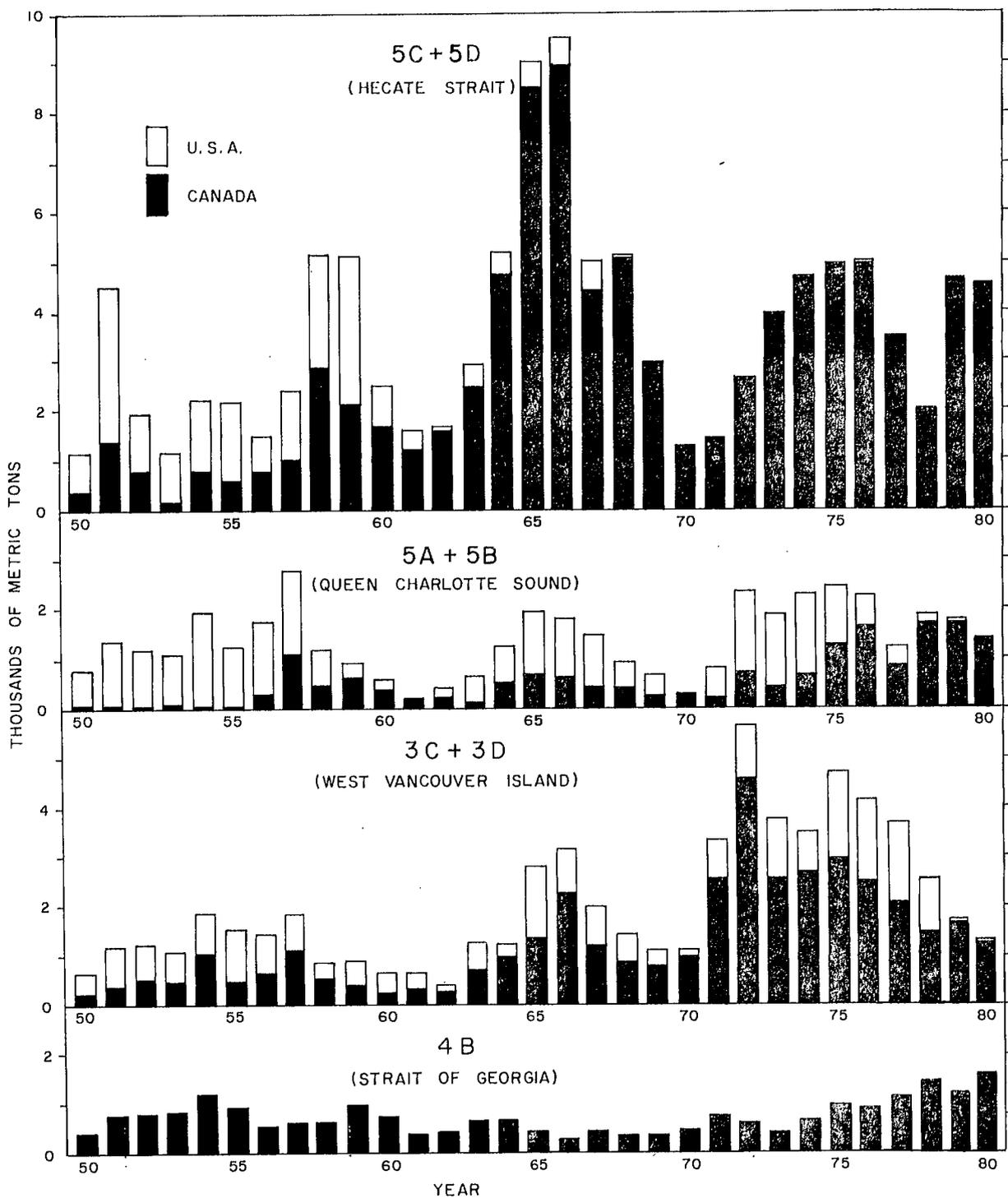
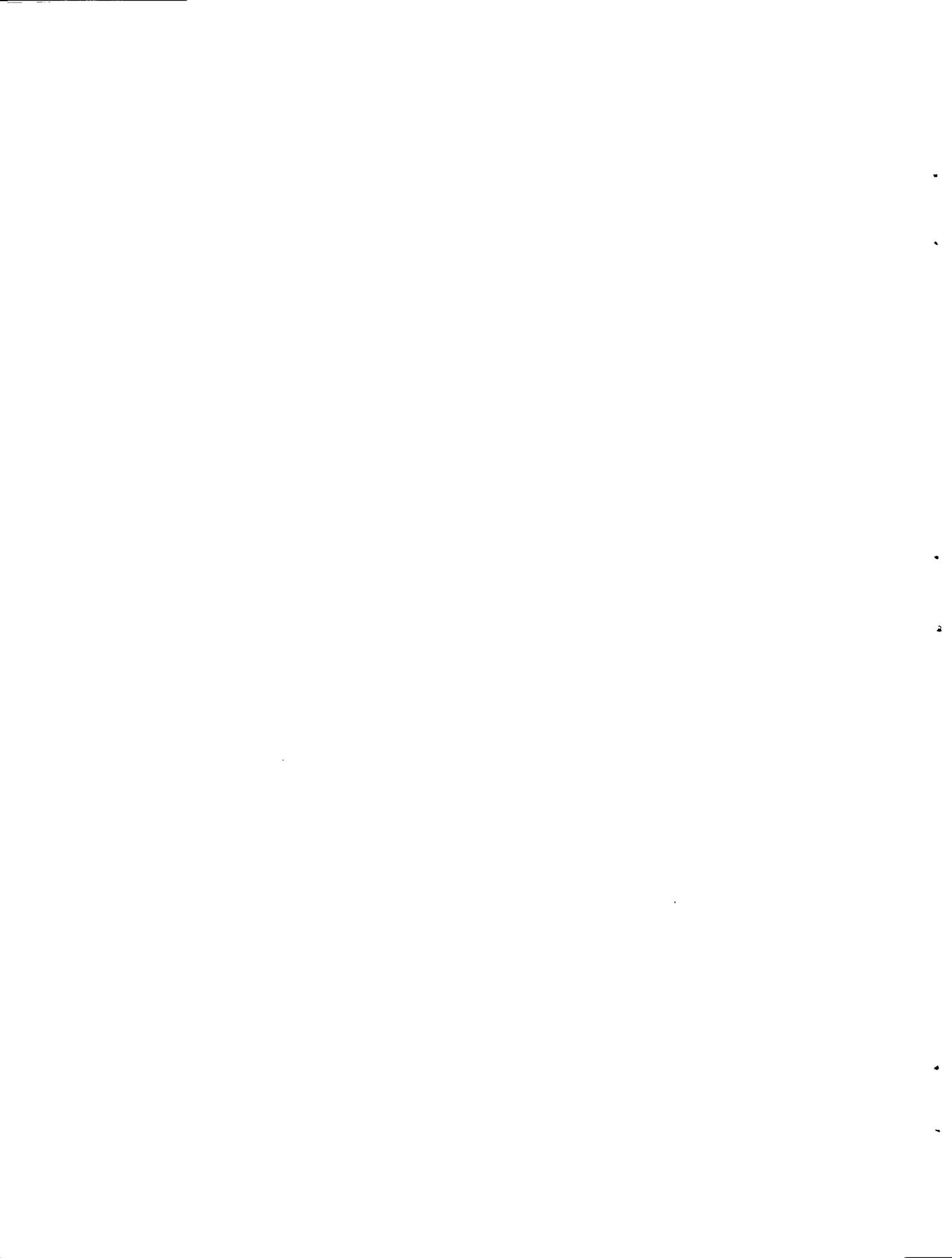


Fig. 6.1.2. Canada-U.S. trawl landings (t) of Pacific cod by region, 1950-80. (Shaded area = Canadian landings.)



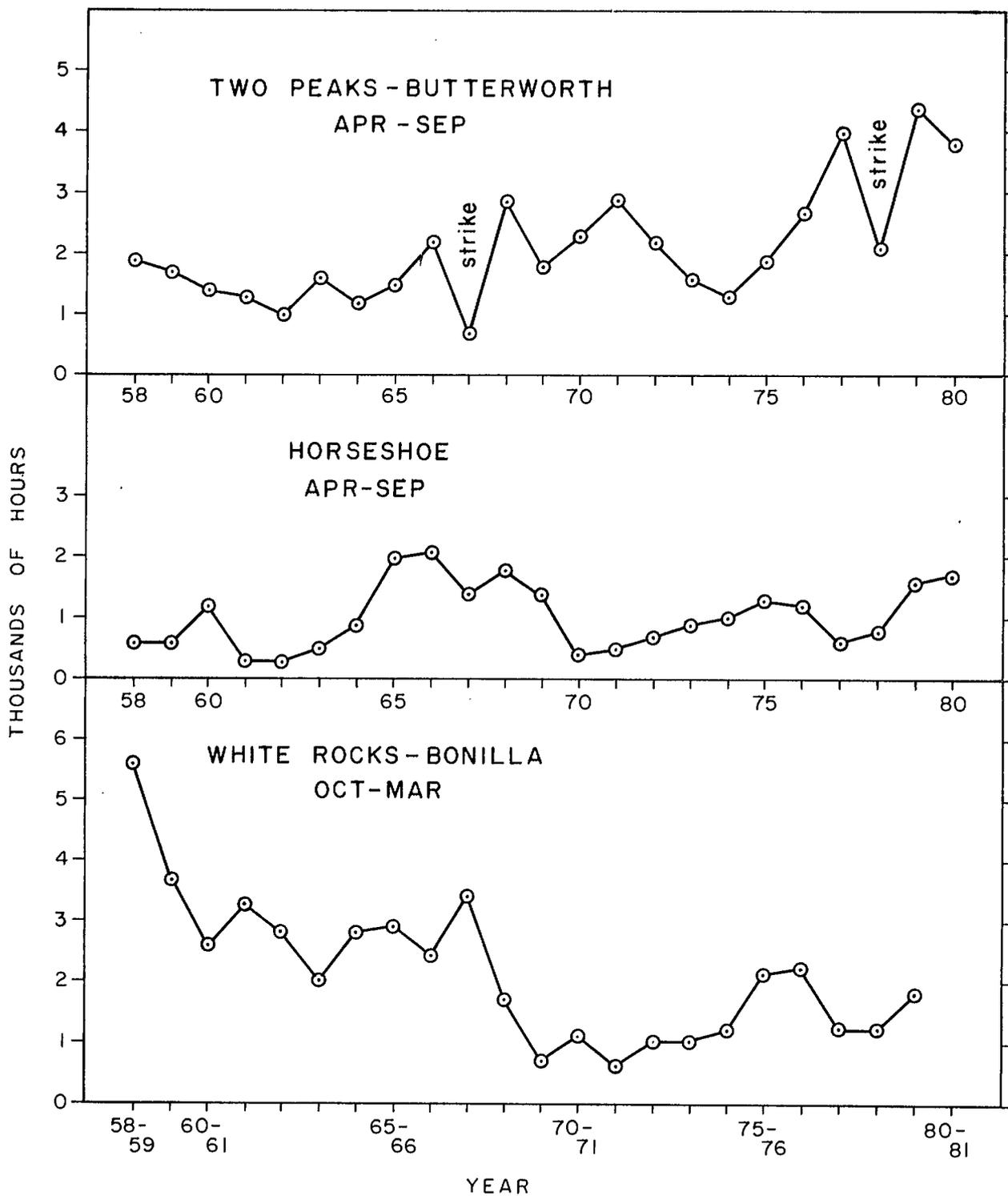
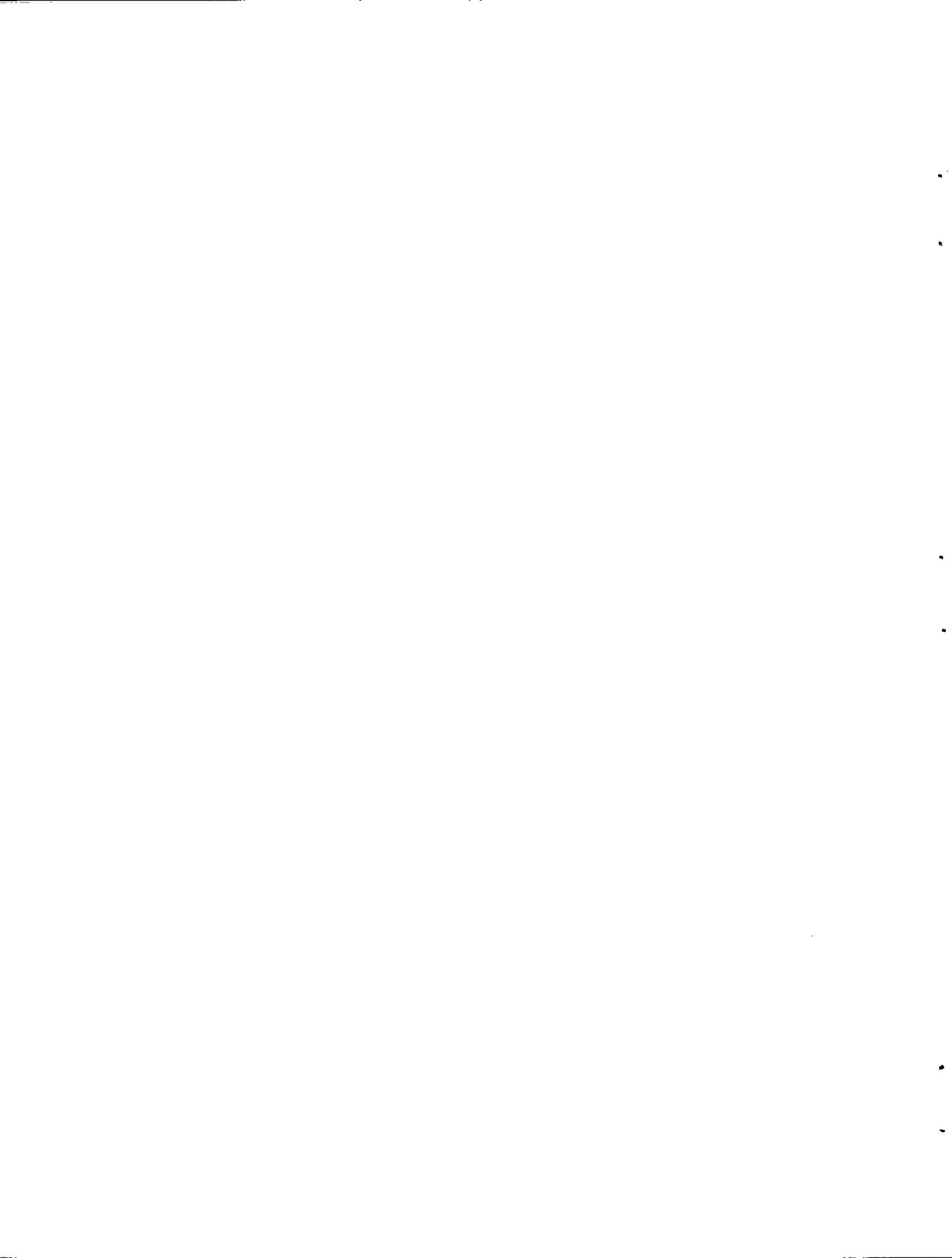


Fig. 6.1.3. Canada-U.S. trawling effort (h) expended for Pacific cod on Two Peaks-Butterworth (Apr.-Sep.), Horseshoe (Apr.-Sep.), and White Rocks-Bonilla (Oct.-Mar.) grounds, 1958-80.



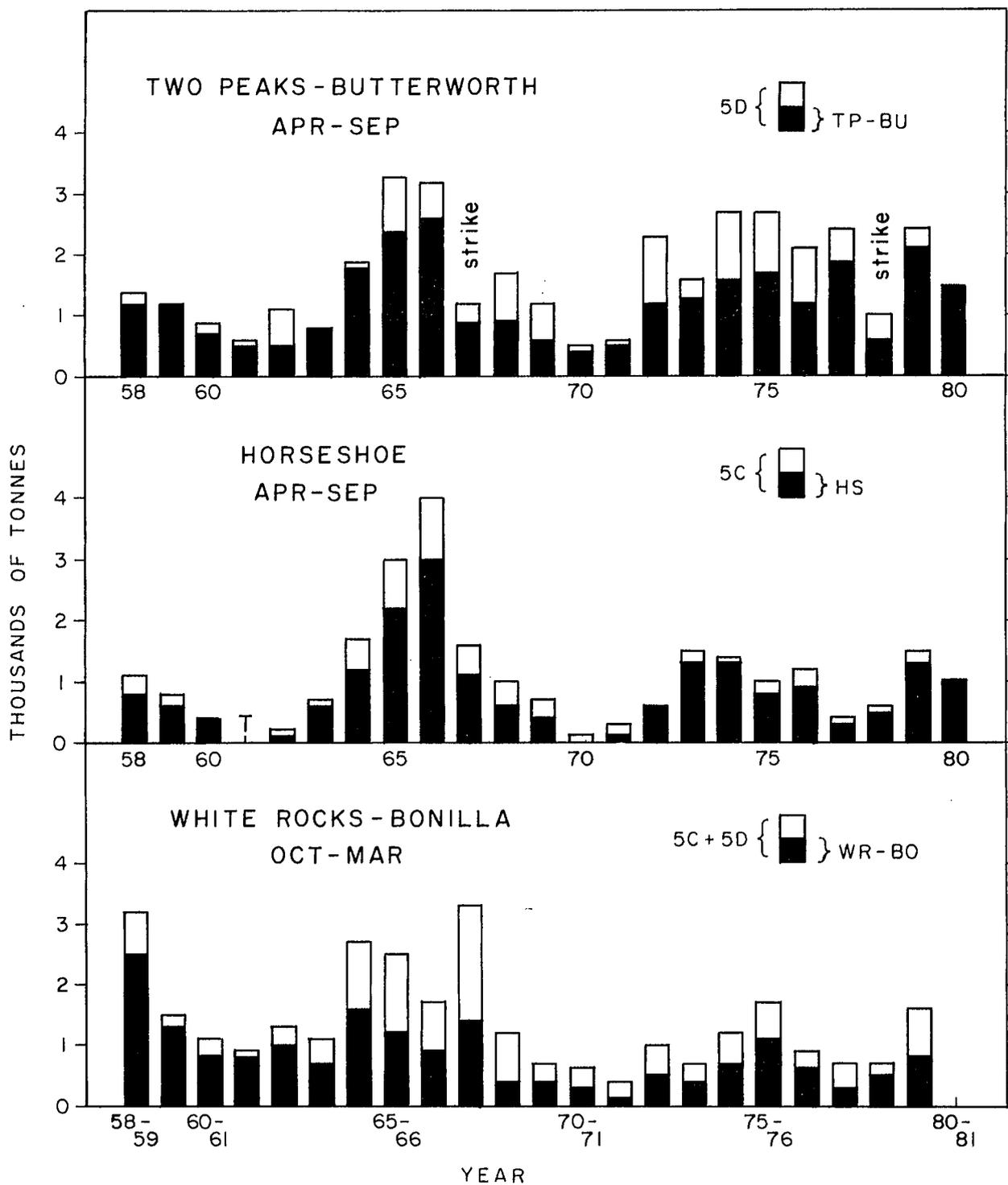
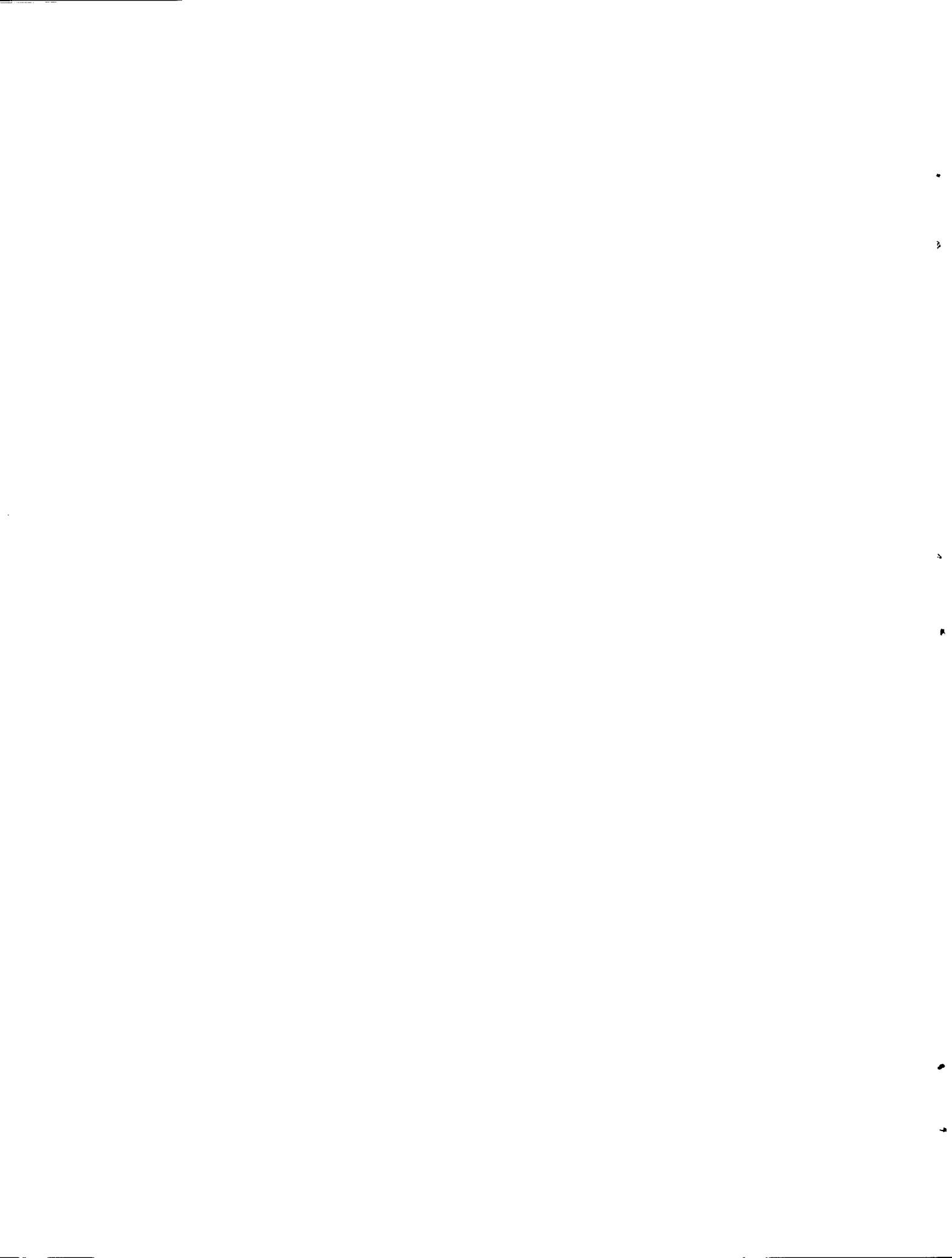


Fig. 6.1.4. Canada-U.S. trawl landings (t) of Pacific cod from Two Peaks-Butterworth (Apr.-Sep.), Horseshoe (Apr.-Sep.), and White Rocks-Bonnilla (Oct.-Mar.) grounds, 1958-80.



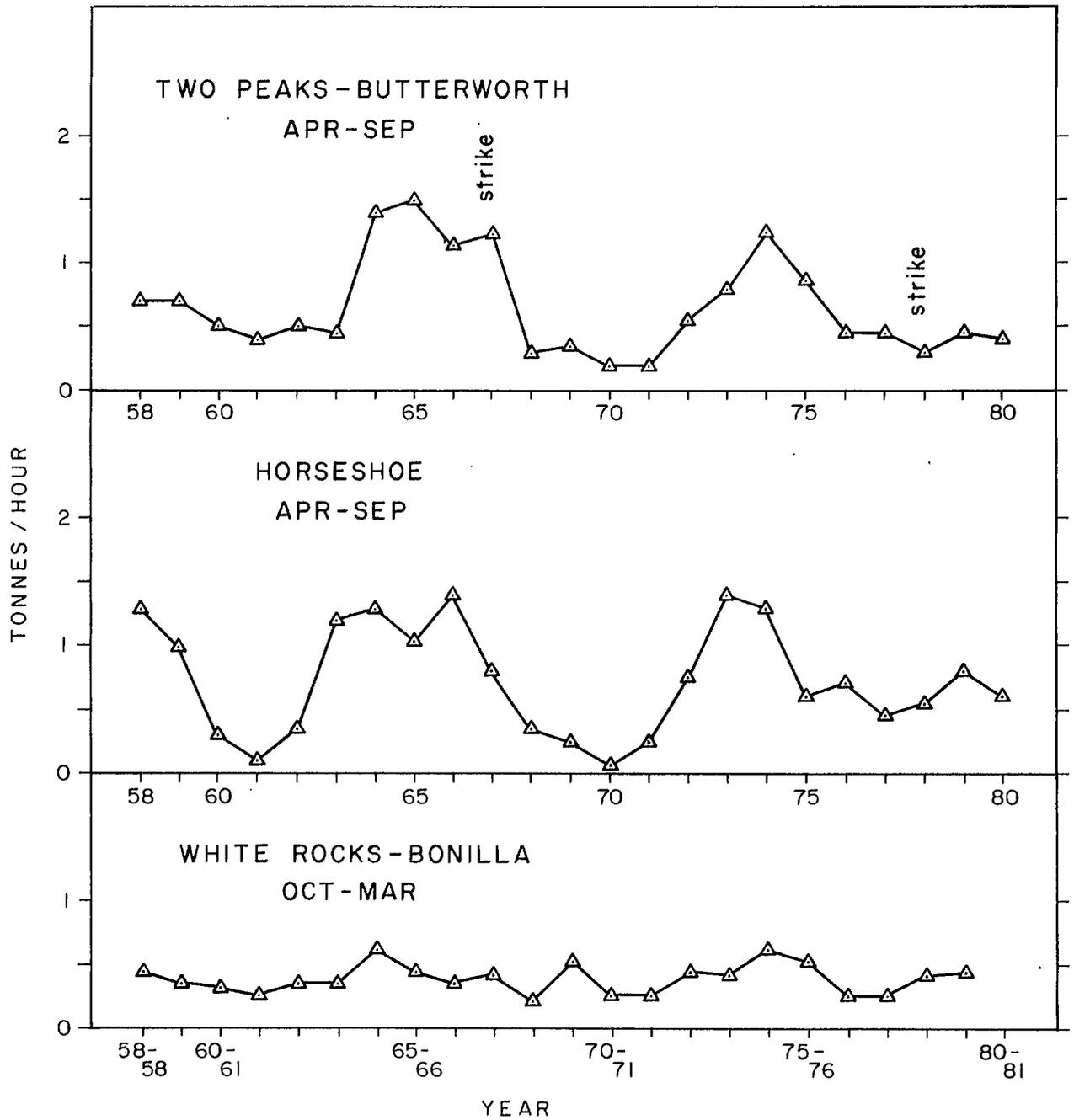


Fig. 6.1.5. Canada-U.S. LPUE (t/h) of Pacific cod from Two Peaks-Butterworth (Apr.-Sep.), Horseshoe (Apr.-Sep.), and White Rocks-Bonilla (Oct.-Mar.) grounds, 1958-80.



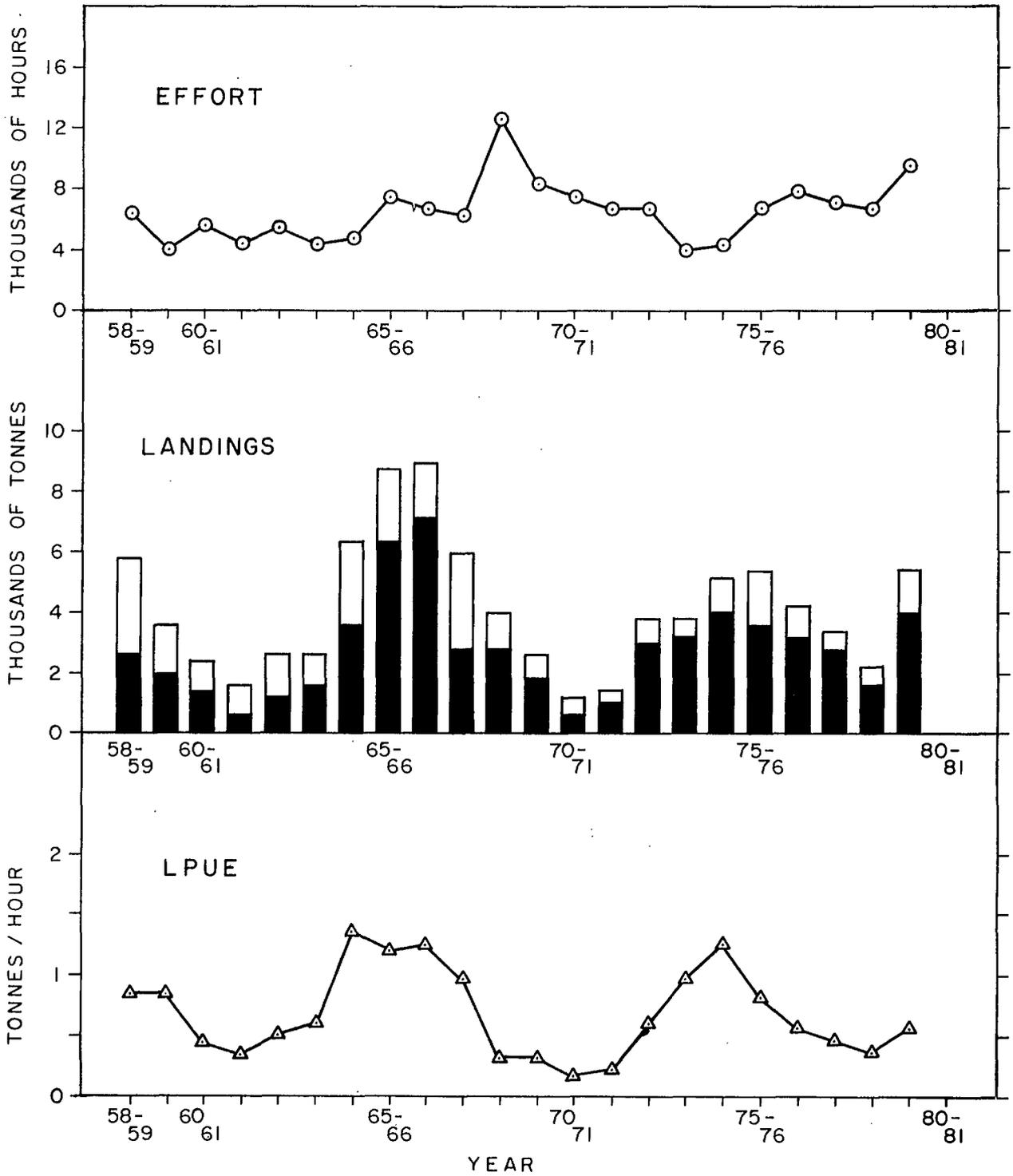
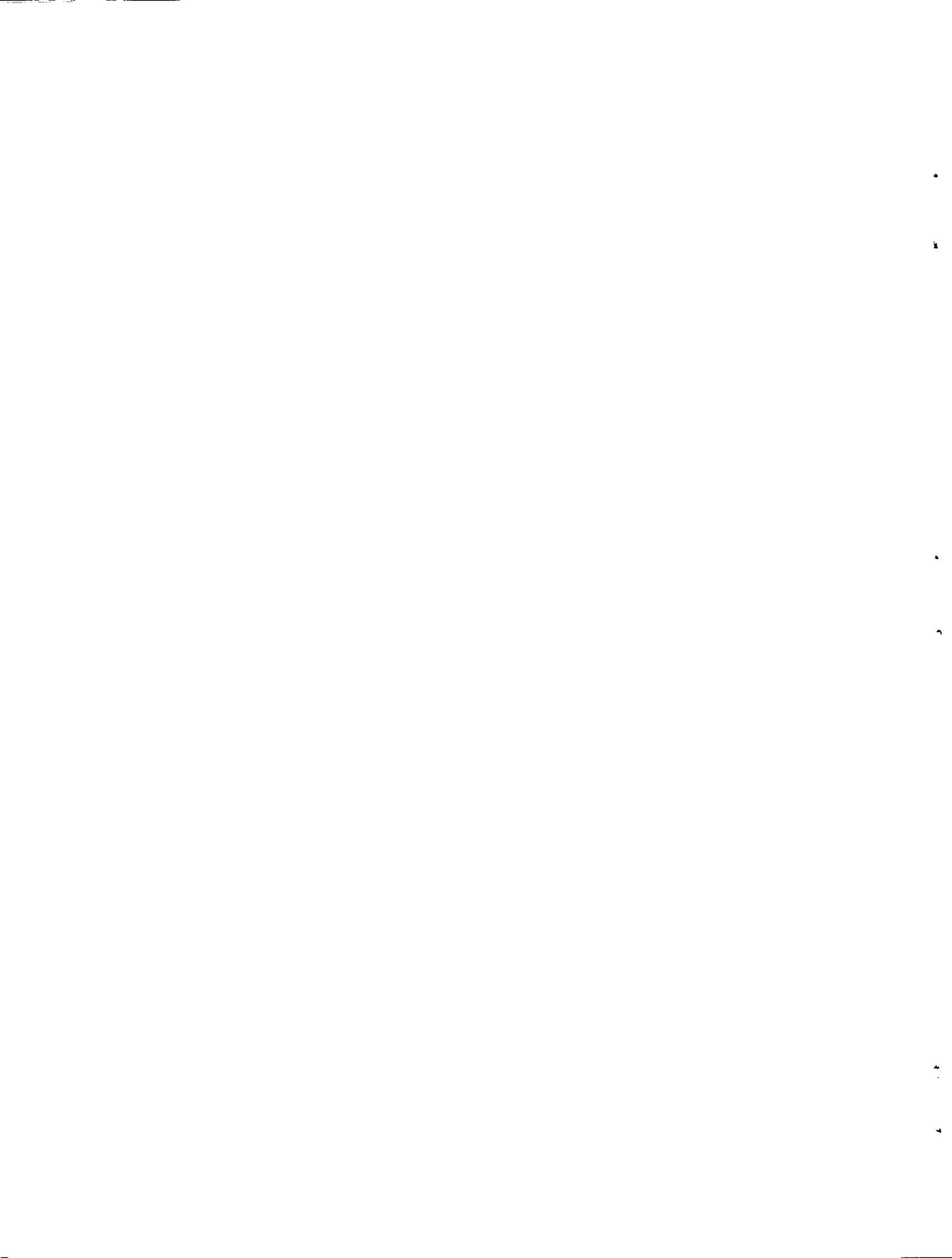


Fig. 6.1.6. Canada-U.S. landing statistics for Pacific cod from Hecate Strait (Area 5C & 5D), April-March 1958-80. (Shaded area = April-September landings.)



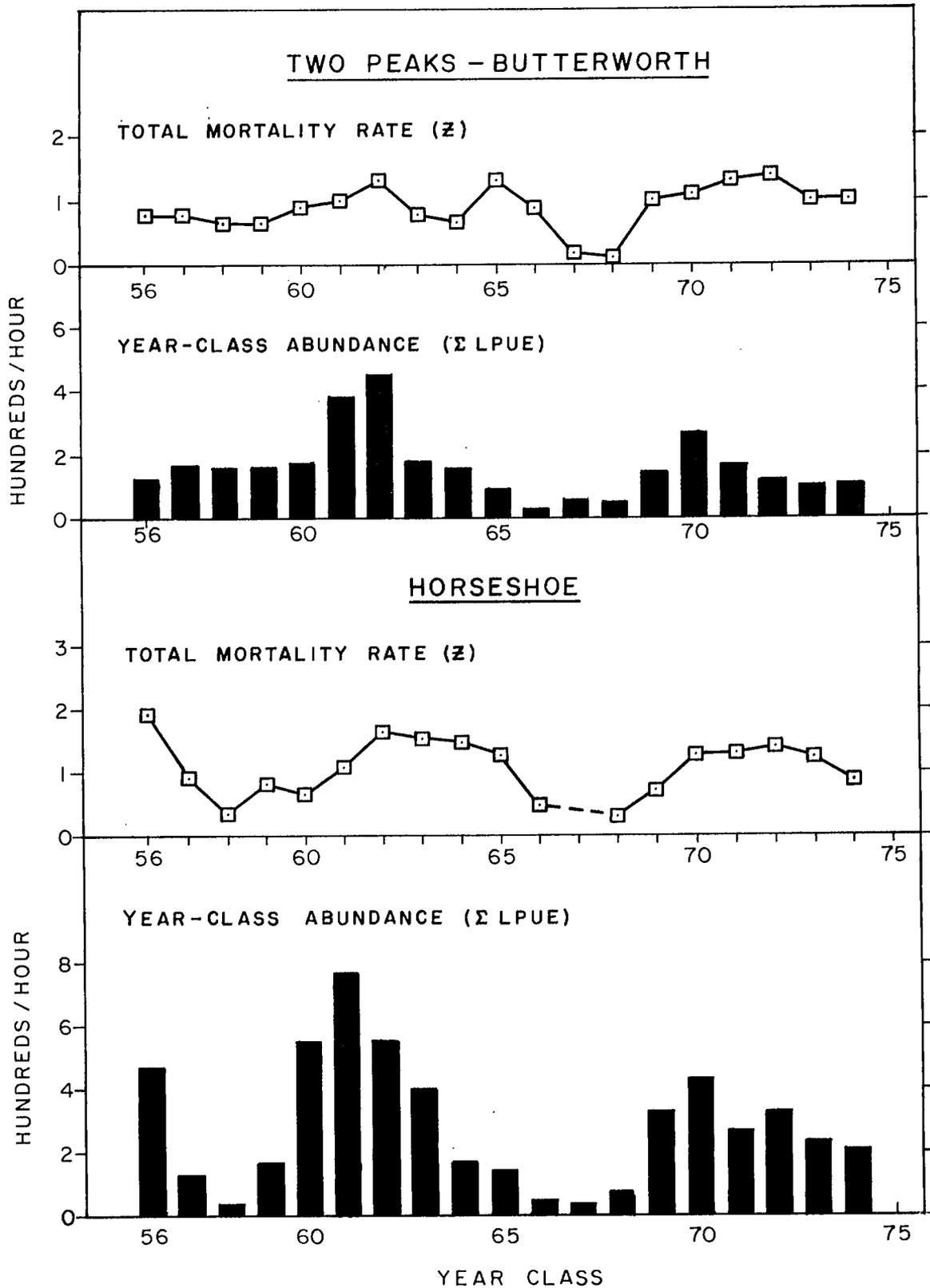


Fig. 6.1.7. Pacific cod total mortality rate (Z) and relative abundance (Σ LPUE) for year-classes 1956-74, at ages 3-6, on Two Peaks-Butterworth and Horseshoe grounds, April-September.



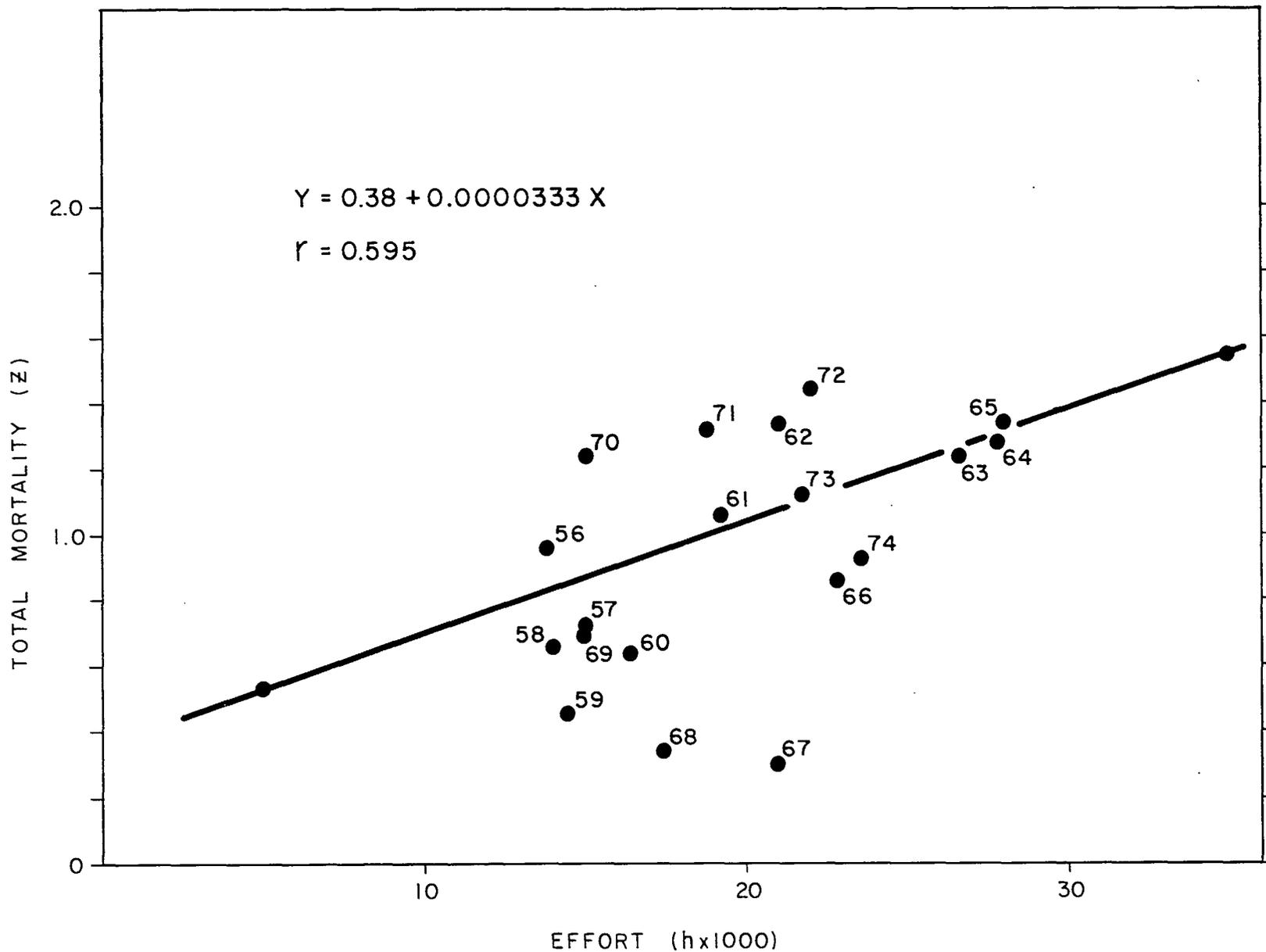
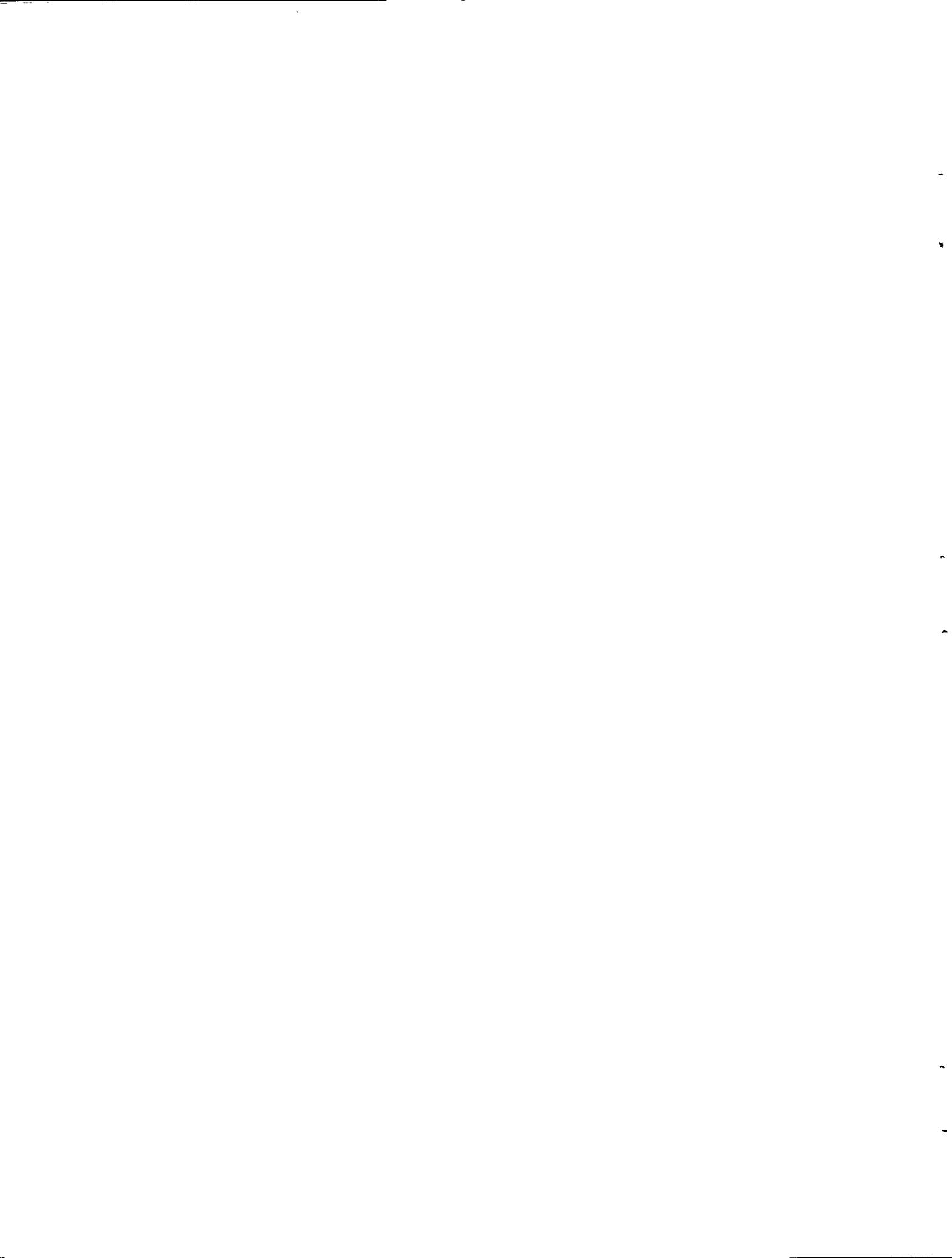


Fig. 6.1.8. Regression of Pacific cod total mortality rate (Z) on total trawling effort (h) for year-classes 1956-74, at ages 3-6, in Hecate Strait, April-March. (Year-classes 1950, 1967 and 1968 excluded from computations.)



6.2 Walleye pollock

6.2.1 Introduction

Relatively little pollock was landed from Hecate Strait until 1976 (Table 6.2.1), when adults larger in size than pollock in the Strait of Georgia were fished for fillets. An experimental roe fishery developed in 1978. Research into the biology of pollock in Hecate Strait and Dixon Entrance began in 1977.

6.2.2 Landing statistics

Annual pollock landings from Major Areas 5C and 5D (combined) rose from 820 t in 1976, to a peak of 1,804 t in 1979 (Table 6.2.1). Most of the landings originated from grounds in eastern Dixon Entrance-northern Hecate Strait (Major Area 5D), where landings have declined since the 1978 high of 1,700 t.

Since 1978, landings were made predominantly from midwater trawl catches during the period of the winter roe fishery in eastern Dixon Entrance (first quarter), and from bottom trawl catches during the spring-summer-autumn multi-species fishery in Hecate Strait (Table 6.2.2). Landings from 5D during the last three quarters were equal to first quarter landings in 1979, and double the size of first quarter landings in 1978 and 1980. Landings during the period of the roe fishery peaked at 712 t in 1979, then fell to 317 t in 1980, and 47 t in 1981. Failure of the roe fishery is largely attributed to decline in average size, high incidence of immature pollock, and decline in abundance of adults.

6.2.3 Stock identity

Midwater trawl surveys of spawning pollock during March 1978 and March 1979 revealed that the stock fished in eastern Dixon Entrance could range into southeastern Alaska. Older, late-ripening adults with age and length frequencies similar to those sampled from commercial catches were found off Cape Chacon and in southeast Alaska channels during March of both years, but were not found on eastern Dixon Entrance fishing grounds where they had formed midwater schools in January-February of both years (Fig. 6.2.1). These midwater and near bottom schools supplied most of the 1978-81 landings from Major Area 5D. The most conservative assumption is that the pollock present at McIntyre Bay-Two Peaks-Dundas-Butterworth form a discrete stock, but it should be realized that stock identities and movements in the area are not well understood.

Small, adult pollock were found in inlets off Hecate Strait and Dixon Entrance during the spawning survey in 1978-79. Ageing of samples collected in 1979, while not complete, has revealed that the small pollock in Selwyn and Dana Inlets (east coast of Moresby Island) were 2-4-yr-olds. The mean lengths of these spawning adults appeared to be slightly smaller than juveniles of similar age at Two Peaks-Butterworth (Fig. 6.2.2). Small adults were also found in Portland Inlet. Very few pollock in these inlets were immature. The remaining samples will be aged to provide stock identity information on the basis of differences or similarities in growth curves between these areas.

6.2.4 Stock assessment

The following discussion draws on results of ageing pollock by methods which have not been fully validated. Identification of the various year-classes could be inaccurate by one and possibly 2 yr, but there is no doubt that relatively low recruitment occurred.

Age and length frequencies show that the Two Peaks stock is recovering from two years of relatively low recruitment which took place in 1978-79. When the midwater trawl roe fishery began in February 1978 on adults preparing to spawn, 6-7-yr-old adults (1971-72 year-classes) dominated catches (Figs. 6.2.3, 6.2.4). Although pollock in this area spawn for the first time at 3-5 yr of age and would be expected to recruit during or before the roe fishery, these age groups were not strongly represented. The 1978 year-class recruited poorly relative to the 1971-72 year-classes, and the 1975-76 year-classes seem to be even weaker. By 1980-81 the 1971-72 year-classes largely passed out of the stock, as a consequence of fishing pressure and normally high natural mortality. The relatively stronger 1977 year-class now predominates, but will not obtain the larger average body size which attracted the fleet in 1978 until 1982-83.

Since the parents of the missing year-classes were not heavily exploited, as indicated by low landings prior to 1976 (Table 6.2.1), the low recruitments in 1978-79 were not caused by overfishing. Possible causes include emigration of the missing year-classes to refuge areas in southeast Alaska or the west coast of the Queen Charlotte Islands, but since larger, older pollock did not re-enter the fishery in 1980 or 1981, it is safer to assume that the Dixon Entrance stock is discrete and in low abundance relative to 1978. There is no historical information to determine whether the stock has dropped to below normal abundance levels, or whether the current condition is closer to long-term average abundance for pollock in the region.

Landings of the incoming recruits were small in 1979, but increased to 1,600 t in 1980. Reported discards of pollock in 1980 were 73 t. Assuming that all were 3-yr-olds and would experience a high natural mortality rate (45%/yr), this means that more than 40 t of 5-yr-olds would be lost from the potential 1982 fishery, which could be significant if actual discards were several times higher. Many of the recruits were immature in 1980-81 and were caught before they spawned for the first time (Fig. 6.2.5).

Since there is too little information to predict estimates of stock-recruitment parameters for this stock, and since year-class fluctuations have not been measured, it is not yet possible to determine precisely the probability that the stock can be overfished if the TAC recommended in previous assessments for Major Area 5D (2,550 t; Westrheim 1980) is taken in 1982. Since some of the present stock of adults were caught before spawning, only 1-2 year-classes of young adults comprise most of the stock, and smaller pollock produce fewer eggs (Fig. 3.2.3), the probability of recruitment impairment could be high.

6.2.5 Recommendations

A conservative TAC of 1,000 t is recommended for Major Area 5D; this TAC could be raised in mid-season if older pollock, identifiable by length, reappear in the fishery.

No TAC is recommended for Major Area 5C, where catches remain small and no intensive roe fishery has developed.

It is recommended that a directed fishery for juveniles should be prevented because of our uncertainty about the stock-recruitment relationship in this species.

Table 6.2.1. Canadian landings (t) of walleye pollock by major statistical area, 1954-81.

Year	Pollock landing (t)									Total
	4B	3B	3C	3D	5A	5B	5C	5D	5E	
1954	147	0	3	0	13	1	0	0	0	164
1955	418	0	5	0	1	0	0	3	0	426
1956	380	0	52	0	5	0	0	14	0	451
1957	248	0	4	0	3	0	0	7	0	262
1958	121	0	0	0	0.3	0	0	14	0	145
1959	260	0	8	0	0.4	0	0	2	0	270
1960	95	0	5	0	1	3	0	10	0	114
1961	115	0	0.1	0	1	0	0.3	7	0	123
1962	49	0	6	0	0	0	0	12	0	67
1963	13	0	7	0	6	0	0	4	0	29
1964	33	0	2	0	5	0	0	2	0	42
1965	26	0	10	0	0	0	0	9	0	45
1966	37	0	0.4	0	1	0.1	0.4	82	0	121
1967	33	1	0	0	1	0	7	48	0	90
1968	16	0	2	0	7	0	4	13	0	42
1969	30	0	14	0	33	0	0	47	0	125
1970	45	0	0	0	0	0	0	8	0	52
1971	80	0	5	0	0	0	0	0	0	85
1972	71	0	0.3	0	172	0	0	1	0	244
1973	9	0	0.1	0	62	9	0.4	13	0	93
1974	11	0	0	0	6	6	2	47	0	72
1975	1	0	0	0	21	10	1	70	0	104
1976	26	0	5	2	69	400	193	627	0.2	1,322
1977	50	0	10	0	61	175	16	568	12	891
1978	380	0	6	0.4	106	187	11	1,700	21	2,411
1979	1,341	0	31	0.3	72	71	238	1,566	67	3,385
1980	1,056	0	(3) ^a	3	12	23	83	1,104	18	(2,303) ^a
1981 ^b	(1,458)	(0)	(0)	(0)	(0)	(0)	(1)	(48)	(0)	(506)

^a excludes estimated 1,800 t caught in hake fishery

^b to April 23 1981, preliminary estimates

Table 6.2.2. Walleye pollock landings in Major Areas 5C and 5D by Canadian vessels (by gear and quarter, 1978-81).

	Major Area 5C			Major Area 5D		
	QI	QII-IV	Total	QI	QII-IV	Total
<u>1976</u>						
MWT	0	127	127	0	265	265
BT	1	64	65	5	357	362
UK	0	0	0	1	0	1
TOTAL	1	191	192	6	621	628
<u>1967</u>						
MWT	0	0	0	1	0	1
BT	1	15	16	35	499	534
UK	0	0	0	0	33	33
TOTAL	1	15	16	36	532	568
<u>1978</u>						
MWT	0	1	1	451	370	821
BT	1	9	10	81	786	867
UK	0	0	0	0	12	12
TOTAL	1	10	11	532	1,168	1,700
<u>1979</u>						
MWT	0	0	0	664	63	727
BT	0	237	237	48	748	796
UK	0	0	0	0	43	43
TOTAL	0	237	237	712	854	1,566
<u>1980</u>						
MWT	0	1	1	201	270	471
BT	1	81	82	116	510	626
UK	0	0	0	0	6	6
TOTAL	1	82	83	317	786	1,103
<u>1981</u>						
MWT	0	-	-	44	-	-
BT	0.1	-	-	3	-	-
UK	-	-	-	-	-	-
TOTAL	-	-	-	-	-	-

MWT = midwater trawl

BT = bottom trawl

UK = unknown gear



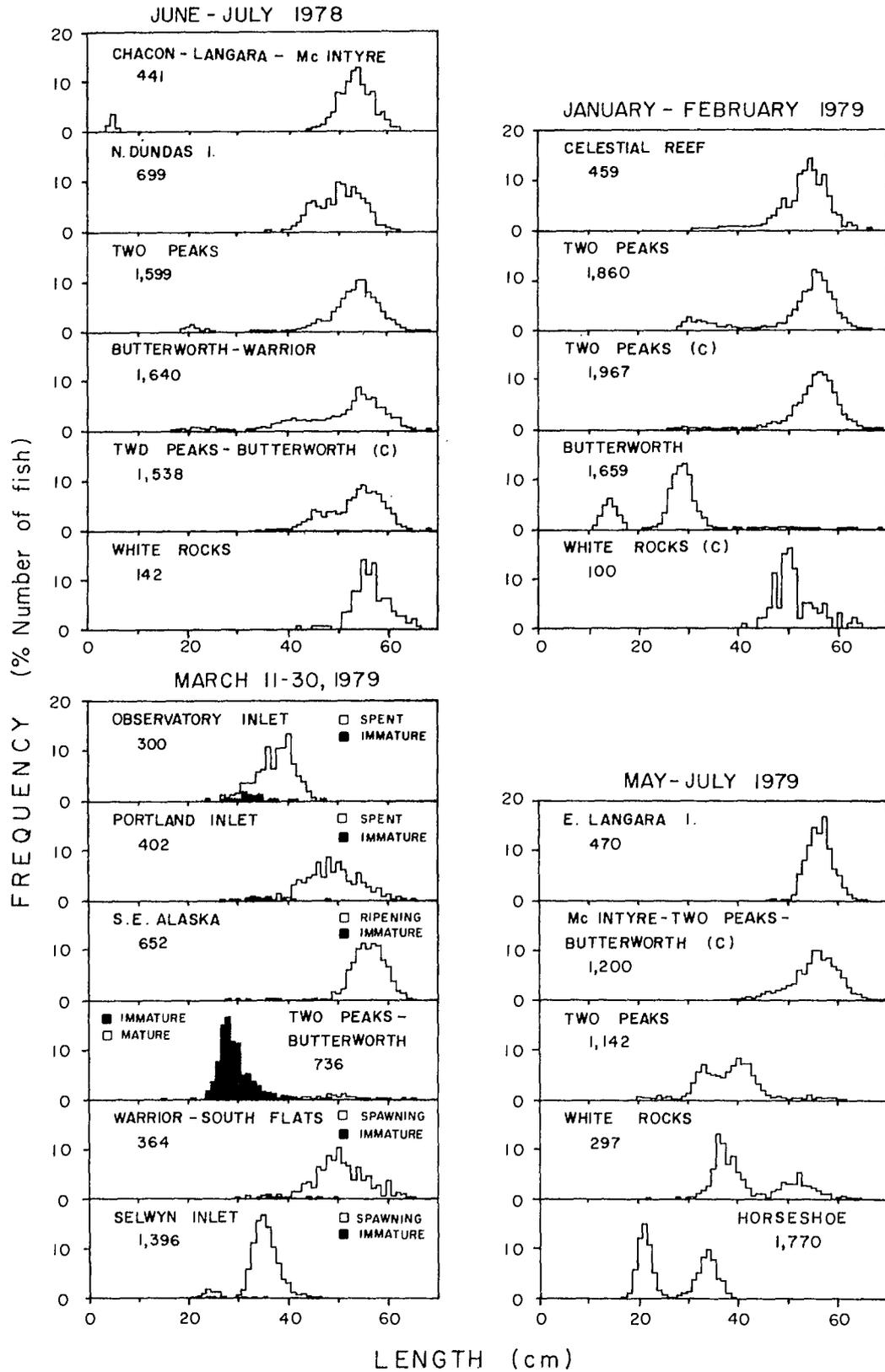


Fig. 6.2.1. Length frequencies of walleye pollock in the vicinity of Dixon Entrance before, during and after spawning.



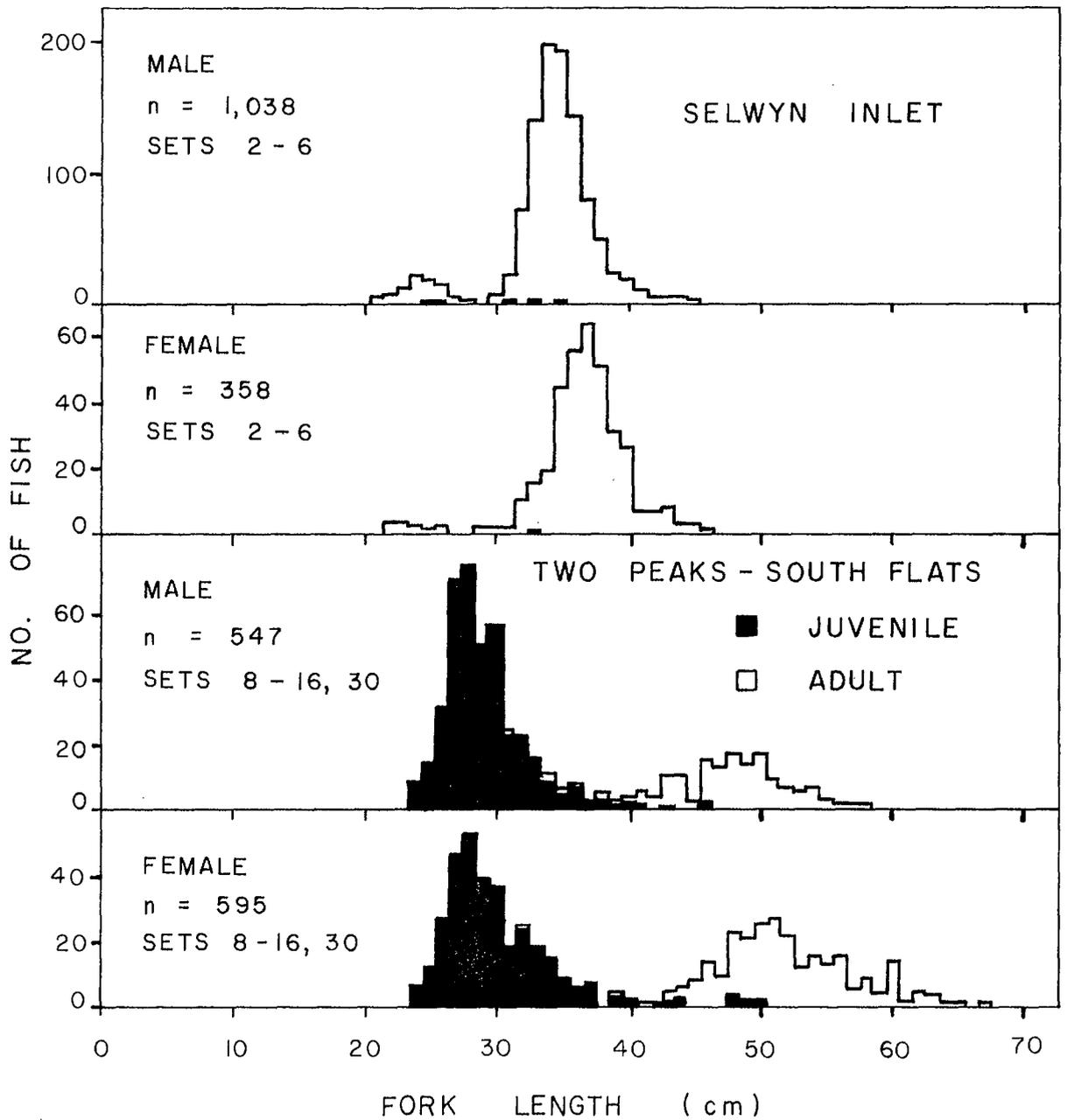


Fig. 6.2.2. Length frequencies of immature and mature walleye pollock in Selwyn Inlet (top) and at Two Peaks-Butterworth (bottom) in March 1979.



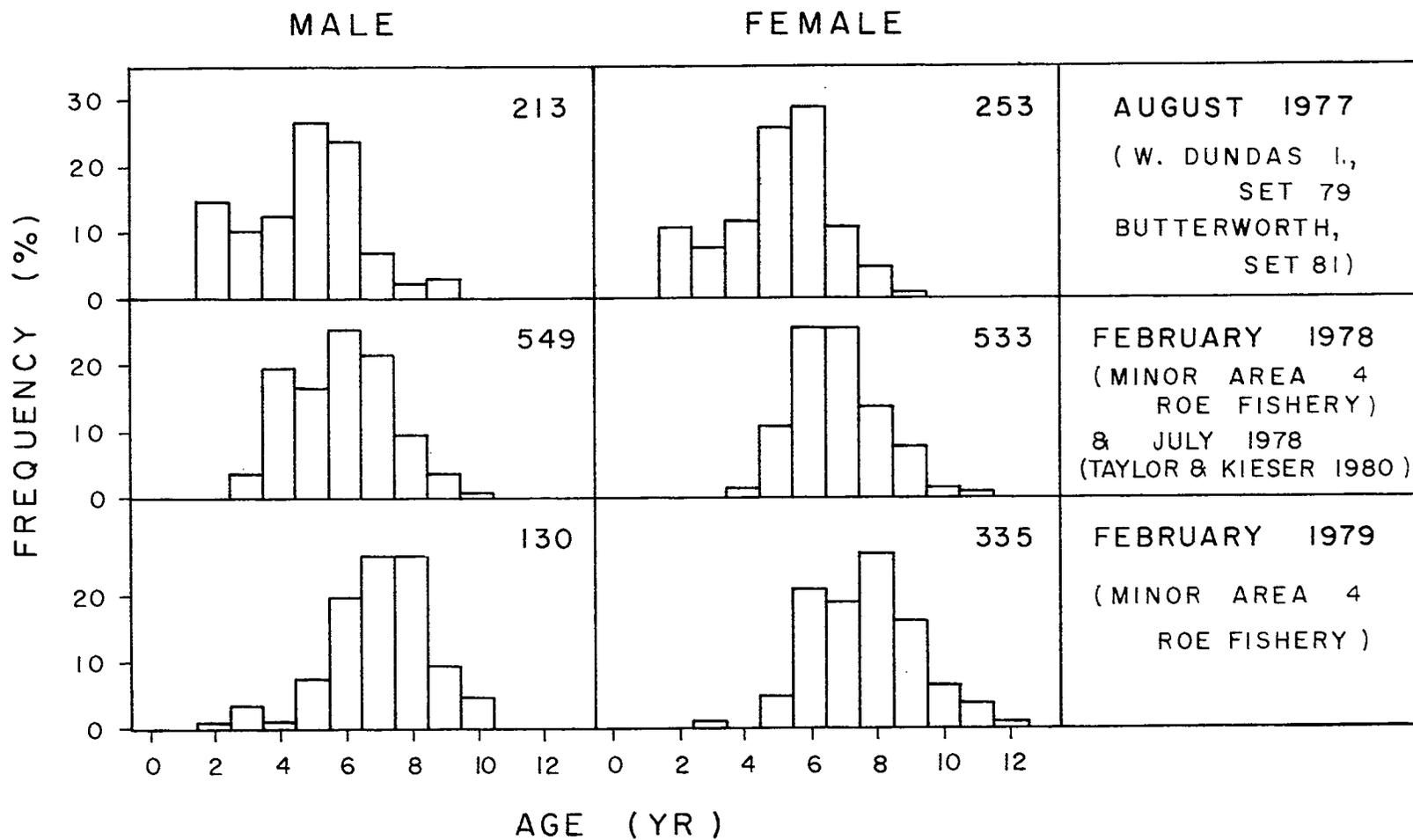


Fig. 6.2.3. Walleye pollock age frequencies in Dixon Entrance.



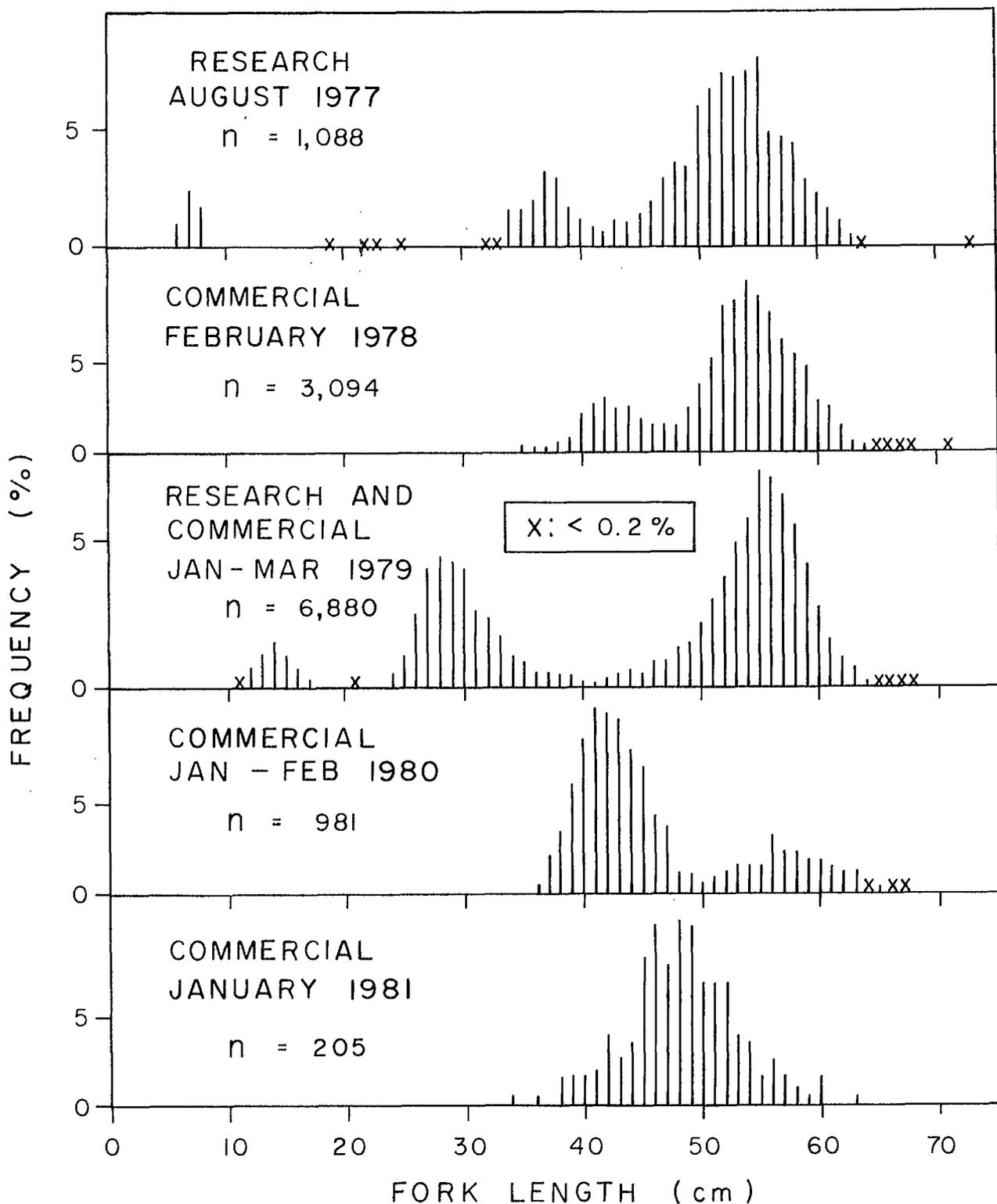
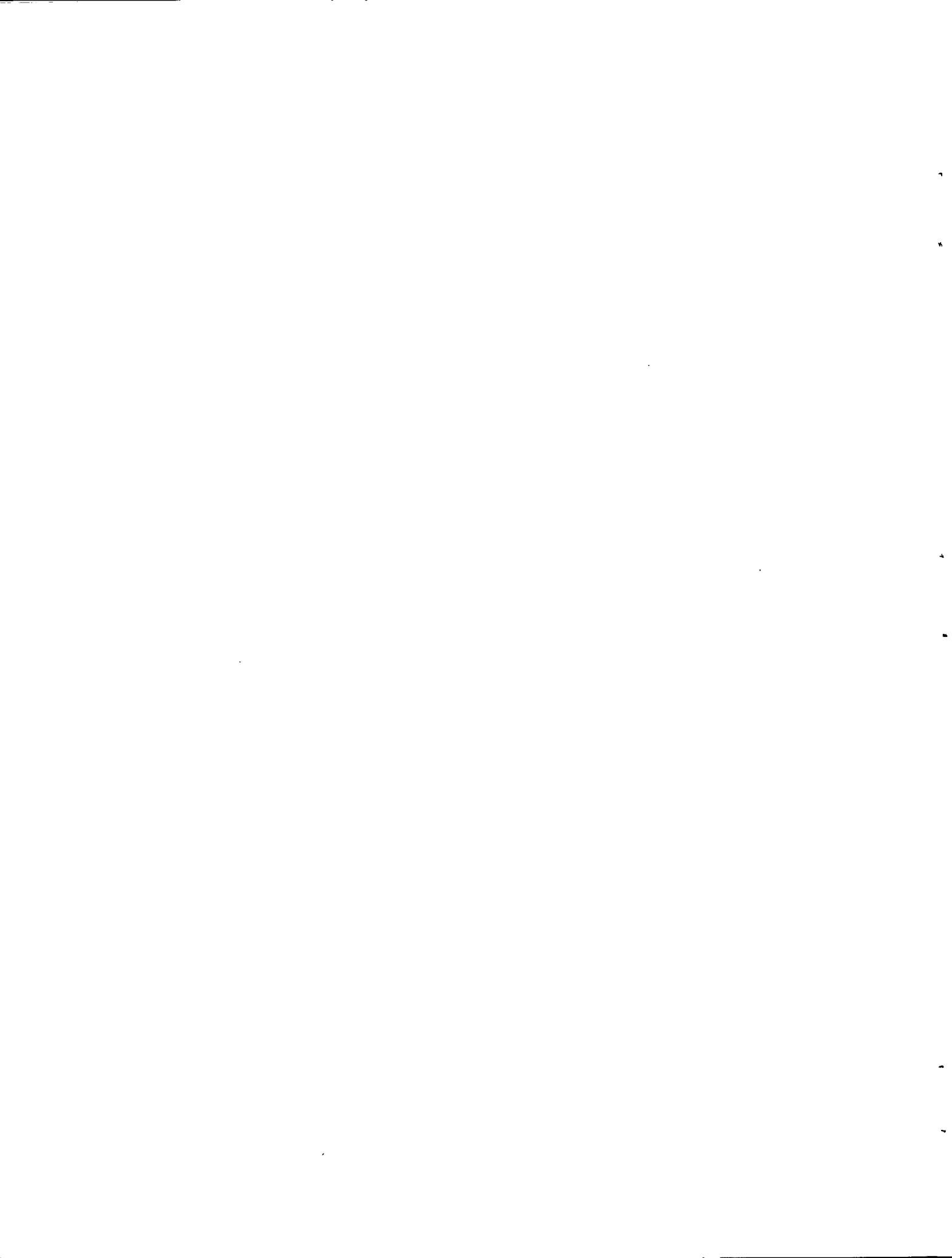


Fig. 6.2.4. Length frequencies of walleye pollock in Dixon Entrance-north Hecate Strait (vicinity of Two Peaks and Butterworth).



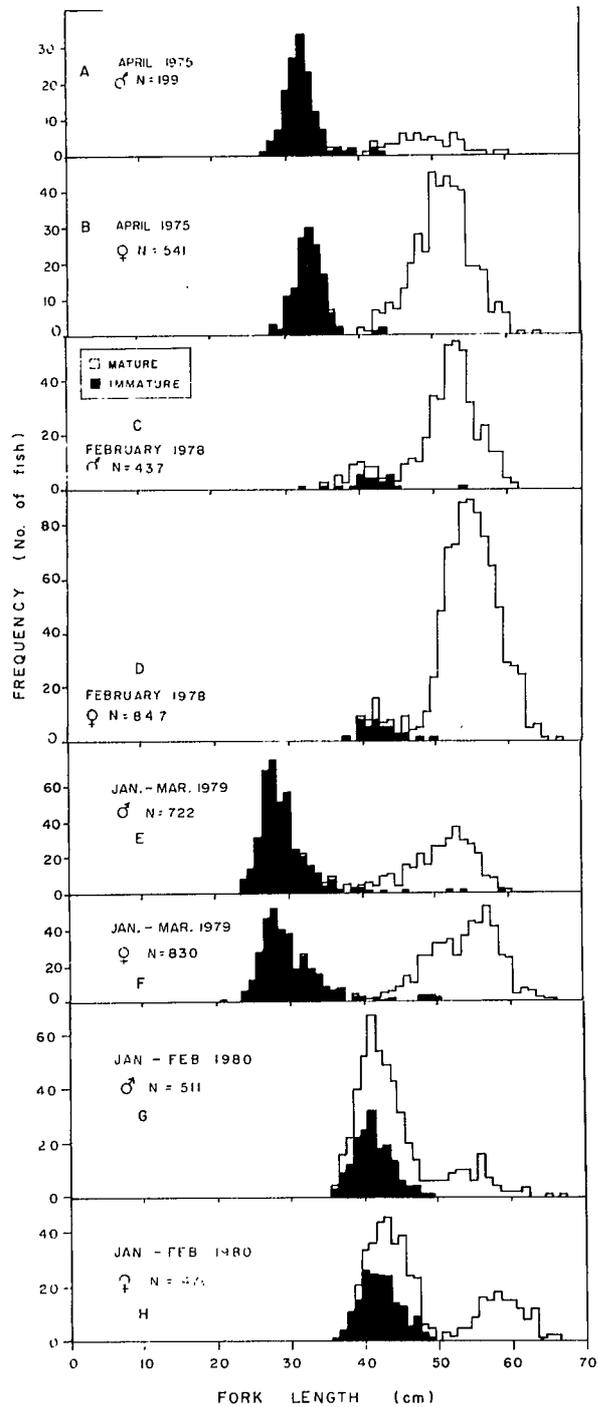
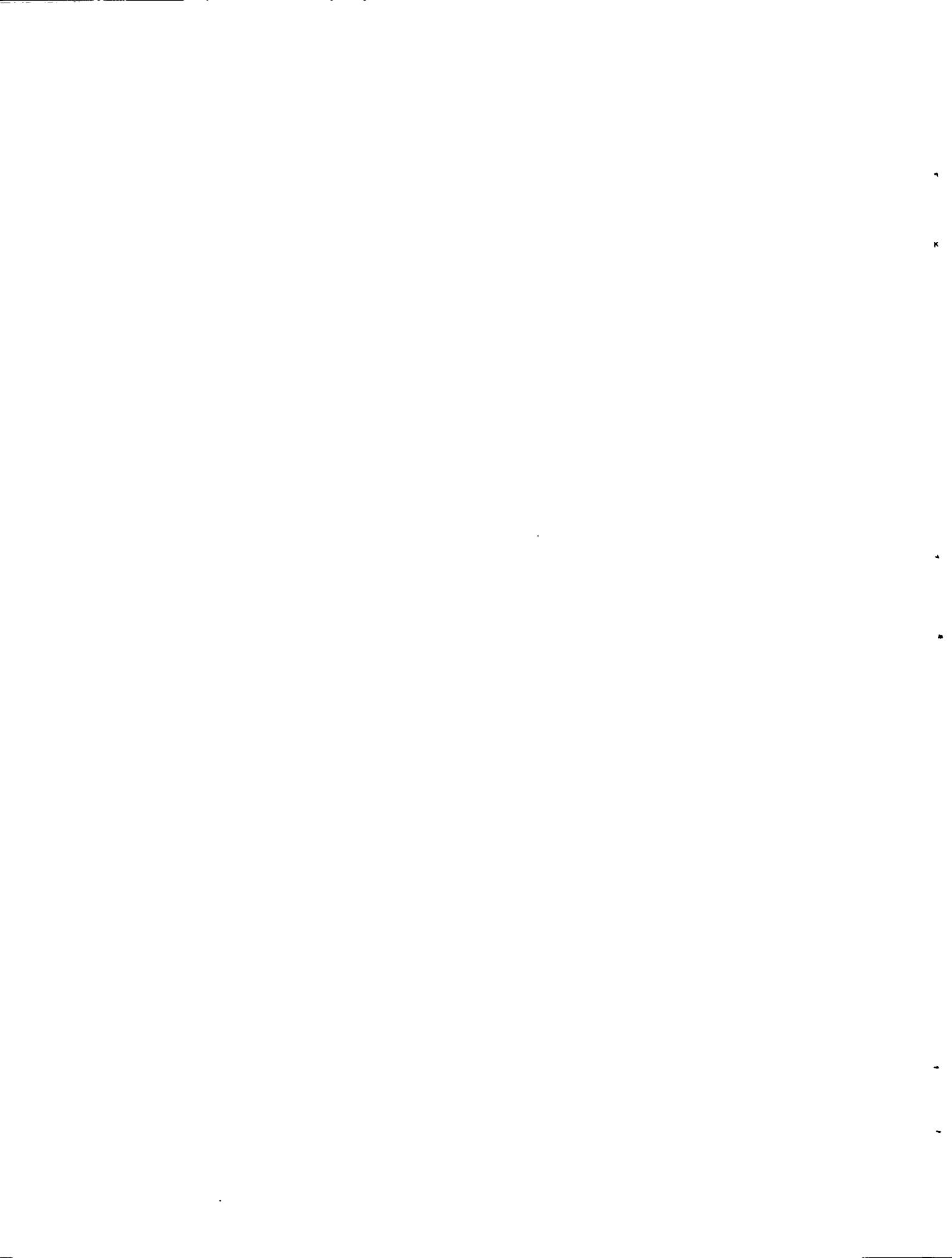


Fig. 6.2.5. Length frequencies of immature and mature walleye pollock in Major Area 5D during the spawning season.



6.3 Arrowtooth flounder (turbot)

6.3.1 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 1940s, 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 900 m (500 fm). 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 statistical areas 5C and 5D.

6.3.2 Catch statistics

Significant landings of turbot as animal food began in 1951, rising rapidly to a peak of 2,500 t in 1956 when most of the production originated from grounds off southwest Vancouver Island (Area 3C) and on the Cape Scott Ground (Area 5A) (Table 6.3.1). 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, turbot production expanded rapidly in northern Hecate Strait. Production from that area reached a peak of 1,295 t in 1978 (Table 6.3.2). Landings have declined to 844 t in 1980. This decline may be reflective of current market conditions.

6.3.3 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 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.

6.3.4 Recommendations

Recommended TACs for 1982 are 200 t for Area 5C and 2,000 t for Area 5D.

Pending final analysis of the turbot biomass survey conducted in 1980 these figures may be altered in early 1982.

Table 6.3.1. Historical record of landings (t) of arrowtooth flounder by Canadian trawlers operating along the British Columbia coast, 1948-80.

Year	Landing (t)		Year	Landing (t)	
	Animal food	foodfish ^a		Animal food	foodfish ^a
1948	2	-	1964	830	2
1949	20	-	1965	578	99
1950	9	-	1966	687	27
1951	102	-	1967	1,675	-
1952	429	-	1968	933	4
1953	434	-	1969	2,017	-
1954	499	-	1970	316	7
1955	1,518	-	1971	106	-
1956	2,499	-	1972	172	130
1957	578	-	1973	36	539
1958	399	-	1974	-	364
1959	851	-	1975	-	953
1960	1,114	-	1976	-	1,205
1961	2,360	-	1977	-	1,591
1962	1,482	6	1878	-	2,317
1963	668	5	1979	-	1,826
			1980	-	1,448

^a Human consumption

Table 6.3.2. Canadian landings (t) and calculated efforta(h) for arrowtooth flounder for areas 5C and 5D, 1972-80.

Year	5C		5D	
	Landings (t)	Effort (h)	Landings (t)	Effort (h)
1972	Tr ^b	10	210	1,750
1973	20	166	437	2,185
1974	18	360	251	1,673
1975	40	667	591	3,110
1976	69	209	981	4,087
1977	35	125	988	3,407
1978	80	160	1,295	3,500
1979	250	1,042	1,280	6,095
1980	170	2,833	844	4,220

^aCalculated effort = landings/CPUE at 0% qualification level.

^bTr = trace

6.4 Rock sole

6.4.1 Introduction

The rock sole (Lepidopsetta bilineata) is an important component of the Hecate Strait trawl fishery. Since the early 1950s, rock sole has been the dominant flatfish in trawl landings from Hecate Strait, and production has varied between 447 t and 2,563 t with an average of 1,219 t/yr (Table 6.4.1). The principal fishing grounds are Two Peaks-Butterworth and Ole Spot.

For the purpose of this assessment the rock sole resource is viewed as two discrete units or stocks (Fig. 6.4.1): Northern Hecate Strait (southern boundary 53°50'N), and Middle Hecate Strait (northern boundary 53°50'N). These delineations are based on earlier tagging studies (Forrester and Thomson 1969), length frequency analyses, and examination of catch and effort time-series.

6.4.2 Northern Hecate Strait Rock Sole

In this assessment, results are presented for growth studies, yield analysis, sequential population analysis, and surplus production model analysis.

6.4.2.1 Growth

Von Bertalanffy growth curves were fitted to average mean length of ages 5-15 male and female rock sole in 1945-78 commercial samples from northern Hecate Strait. Research vessel data of ages 1-4 allowed refinement of otherwise biased growth estimates.

The following parameter estimates were obtained:

Parameter	Males	Females
K	0.296	0.206
t ₀	-0.027	-0.125
L _∞	40.6 cm	50.7 cm
W _∞	0.85 kg	1.87 kg

The growth parameter estimates show sexual dimorphism in growth of rock sole. Females are larger than males beginning with age 5. Growth parameter estimates were used in yield simulation models.

6.4.2.2 Yield

The growth parameters above were used to derive a Beverton-Holt (1957) yield-per-recruit isopleth diagram for female rock sole (Fig. 6.4.2). A natural mortality (M) of 0.16 was employed for the calculations. This estimate was obtained by regressing effort on total mortality (Z) for the period 1954-78 using the method developed by Paloheimo (1961).

Yield-per-recruit increases rapidly over a range of fishing mortality of 0.1-0.6 as the age of recruitment increases from 2 to 8 years. This observation implies that younger age rock sole should not be caught. Very little yield is gained by increasing the age of recruitment beyond the age of 5.

The maximum yield estimated from yield-per-recruit calculation, at recruitment age, of about 800 t is similar to MSY estimates obtained using the dynamic Schaefer model (see Section 6.4.2.4). This estimate is derived by multiplying average numbers of age 4 recruits (males and females) by greatest yield per recruit for age 4 recruitment.

6.4.2.3 Stock reconstruction

The catch at age data in Table 6.4.2 were analysed using the stochastic stock reconstruction model developed by Fournier and Archibald (in press). The model incorporates fishing effort information and a stock-recruitment relationship. Natural mortality (M) was assumed to be 0.15. Results of the calculations include estimates of population size, fishing mortality, fishing intensity effort relationship, and stock-recruitment parameters.

Population estimates of female rock sole age 4 and older fluctuated around 4 million fish from 1954-66, then declined steadily to around 1 million by 1972 (Table 6.4.3). This decline was followed by a population increase to 2.5 million by 1978.

Recruitment, measured in numbers of age 4 females ($N_{i+4,4}$), is given in Table 6.4.3. Spawning success has been highly variable, and there appears to be a density dependent effect over the observed population size range (Fig. 6.4.3). Recruitment was generally low in the 1970s; strong year-classes observed in the 1950s and 1960s have notably been absent in recent years.

Parameters of a Ricker type spawner-recruit function were estimated by the stock reconstruction model. The functional form assumes density dependent recruitment:

$$N_{i+4,4} = \alpha \left[\begin{array}{c} 15 \\ \Sigma \\ j=5 \end{array} N_{i,j} \cdot f_j \right] e^{-\beta \left[\begin{array}{c} 15 \\ \Sigma \\ j=5 \end{array} N_{i,j} \cdot f_j \right]}$$

where

$N_{i+4,4}$ = 4-yr-old recruits in year $i+4$ in thousands
of females,

$N_{i,j}$ = spawners age 5-15 in thousands of females,

f_j = age dependent reproductive potential,

α, β = spawner-recruit parameters.

The α and β parameters were estimated as 1.507 and 5.310×10^{-4} , respectively. The fitted relationship is shown in Fig. 6.4.3. The arched relationship indicates maximum productivity at around 1.8 million spawners.

The stock reconstruction model assumes an age dependent fishing mortality represented by a flattened curve. Estimates of fishing mortality rates are shown in Table 6.4.4. Fishing mortalities fluctuated widely from 1954-78. Estimates indicate mean F of ages 6-15 was lowest in 1959 with peaks occurring in 1955, 1966, 1968 and 1971. F -values for ages 7-10 were considerably higher than the means. F of 4-yr-olds was negligible except for peak years.

Means of the F -values at ages 6-15 in each year fluctuate in relation to fluctuations in annual effort in northern Hecate Strait (Fig. 6.4.4).

The 1978 population estimates (Table 6.4.3) are taken as the starting condition for projections of relative yield for a 50-yr simulation period using POPSIM (Walters 1969). The forward simulations, in relation to age of recruitment and fishing mortality, use the spawner-recruit parameters, and age dependent fishing mortality rates estimated by the stock reconstruction model.

The potential yield isopleths are depicted in Fig. 6.4.5. The simulation model predicts best age of recruitment and fishing rate similar to those predicted by the Beverton-Holt yield equation. Yield increases rapidly over a range of fishing mortality of 0.1-0.4 as the age of recruitment increases from 4-7 years. As with the Beverton-Holt yield isopleths, this implies that younger age rock sole should not be fished. Best yields for given age of recruitment are not very sensitive to F -values indicated by the flat shape of curve A in Fig. 6.4.5. Similarly, best yields for given F -values are not sensitive to age of recruitment. This is in contrast to the Beverton-Holt results where these responses are quite sensitive.

6.4.2.4 Surplus production model analyses

A measure of abundance based on the qualified catch-per-unit-effort (CPUE) was used for these analyses. Abundance of rock sole for northern Hecate Strait was estimated using the 25% qualified CPUE from interviewed catch data (Table 6.4.5). Estimates of effort were obtained by dividing annual CPUE into annual total landings. CPUE in northern Hecate Strait has fluctuated widely since 1954. Rock sole abundance in this important fishing area peaked in 1960-61 and 1965, and gradually declined to a low of 0.28 t/h in 1972. In recent years, CPUE has fluctuated around 0.40 t/h.

The relationship between catch and effort for the years 1954-80 was examined using surplus production models (Westrheim 1980: 184).

Table 6.4.6 presents the results of the parameter estimates for the northern Hecate Strait rock sole stock. The best fit to the data (as determined by the correlation coefficient; $r = -0.738$) was obtained by the Gulland linear regression model with $K = 5$. The resulting estimate of MSY is 732 t with a corresponding optimal fishing effort of 1,033 h for an optimal CPUE of 0.71 t/h. The current CPUE is only 34% of the calculated optimum.

Using the same graphical method as in the assessment document for 1980 (Westrheim 1980), the TAC for 1981 is determined at 250 t. This low catch level is reflective of the current low population level of the stock.

6.4.2.5 Recommendations

Under the assumption that there are no drastic upward trends in the northern Hecate Strait rock sole stock, such as unusually high recruitment or reduced fishing mortality for 1981, continued conservation measures are recommended for 1982. In the best interest of conservation of rock sole a TAC of 250 t is recommended for 1982. This low catch level can be achieved by again putting a year-round 25,000-lb trip limit into effect. It is further recommended to avoid the removal of any rock sole less than 30 cm in length by avoiding fishing in shallow areas and voluntarily fishing with larger mesh sizes.

If information from the 1981 fishery departs considerably from projections, the recommendations may be altered accordingly in early 1982.

6.4.3 Middle Hecate Strait Rock Sole

In this assessment, surplus production models are presented and used to estimate stock productivity, maximum sustainable yields, corresponding effort levels and recommended TAC for 1982.

6.4.3.1 Trends in catch and CPUE

A measure of abundance based on the qualified catch-per-unit-effort (CPUE) was used for this assessment. Abundance for middle Hecate Strait rock sole was estimated using the 25% qualified CPUE from interviewed catch data. Estimates of effort were obtained by dividing annual CPUEs into annual total landings.

Production in middle Hecate Strait has been quite variable. Landings peaked in 1957 and were generally high from 1966-1970. In recent years landings have increased and CPUE has fluctuated around 0.40 t/h (Table 6.4.7).

6.4.3.2 Yield

The relationship between catch and effort for 1954-80 was examined using surplus production models (Westrheim 1980).

Table 6.4.8 presents the results of the parameter estimates for the middle Hecate Strait rock sole stock. The best fit to the data (as determined by the failure rate index; $I = 0.86$) was obtained from the dynamic Schaefer model analysis (Schnute 1977). The resulting estimate of MSY is 628 t with a

corresponding optimal fishing effort of 1,385 h for an optimum CPUE of 0.45 t/h. The 1980 CPUE is 89% of the calculated optimum. The dynamic Schaefer model gives a good fit to historical data of the middle Hecate Strait rock sole fishery, as shown in Fig. 6.4.6.

Fig. 6.4.7 shows the catch-effort history of the middle Hecate Strait rock sole fishery. There have been periods of decline and increase in this stock. Particularly heavy exploitation has been recorded in the late 1960s. Currently, the stock seems near optimum levels.

The estimates of the biological, fishery, and variance parameters were used to predict 1981 yield. These estimates combined with information on most recent catch and effort (C_{80} , E_{80}) were used to predict 1981 catch levels for the existing non-equilibrium situation (Schnute 1977). Present stock abundance would yield close to MSY in 1981 if fished at a similar effort level observed during 1980. To continue rebuilding strategies, a catch level below that of MSY is projected for 1982; assuming removals in 1981 will be similar to those in 1980.

6.4.3.3 Recommendations

Based on the described analysis a TAC of 500 t is recommended for the middle Hecate Strait rock sole stock. Continued closure of the suspected spawning area, and a year round 25,000-lb trip limit (as recommended by the fishing industry) will help to achieve the recommended TAC.

If information from the 1981 fishery departs considerably from projections, the recommendations may be altered accordingly in early 1982.

Table 6.4.1. Canada-U.S. rock sole landings (t) for Hecate Strait (5C and 5D), 1954-80.

Year	Landings ^a (t)	Year	Landings ^a (t)
1954	926	1968	2,430
1955	1,559	1969	2,427
1956	1,282	1970	1,405
1957	1,250	1971	1,528
1958	1,280	1972	505
1959	447	1973	504
1960	1,135	1974	623
1961	795	1975	1,264
1962	832	1976	1,436
1963	914	1977	847
1964	792	1978	877
1965	880	1979	1,315
1966	2,563	1980	908
1967	2,198		

^aData Sources: Canada - sales slips and trip logs
U.S. - 1954-75 Ketchen (1976)
1976-79 supplied by Washington State
Department of Fisheries.

Table 6.4.2. Age composition of commercial catches of northern Hecate Strait female rock sole, 1954-78 (Chilton et al. 1979, Chilton and Smith 1972, Forrester 1966).

Year	Estimated total no. caught (x1000)	Observed proportion at age											
		4	5	6	7	8	9	10	11	12	13	14	15
1954	818.7	0.098	0.433	0.306	0.108	0.032	0.012	0.004	0.005	0.001	0.000	0.000	0.000
1955	1,362.1	0.017	0.215	0.355	0.228	0.104	0.040	0.023	0.011	0.005	0.003	0.000	0.000
1956	417.2	0.094	0.127	0.268	0.241	0.145	0.079	0.026	0.008	0.007	0.002	0.002	0.000
1957	199.9	0.117	0.108	0.218	0.219	0.167	0.090	0.052	0.023	0.005	0.000	0.000	0.000
1958	982.4	0.041	0.674	0.135	0.062	0.031	0.037	0.009	0.008	0.002	0.002	0.000	0.000
1959	165.4	0.000	0.008	0.517	0.393	0.059	0.013	0.008	0.001	0.000	0.000	0.000	0.000
1960	946.6	0.000	0.010	0.338	0.517	0.094	0.024	0.009	0.003	0.002	0.003	0.001	0.000
1961	1,022.9	0.000	0.046	0.507	0.364	0.068	0.005	0.005	0.000	0.000	0.000	0.002	0.000
1962	552.7	0.000	0.014	0.164	0.537	0.224	0.041	0.018	0.002	0.000	0.000	0.000	0.000
1963	757.8	0.040	0.086	0.135	0.314	0.283	0.108	0.033	0.000	0.000	0.000	0.000	0.000

(cont'd.)

Table 6.4.2. (cont'd.)

Year	Estimated total no. caught (x1000)	Observed proportion at age											
		4	5	6	7	8	9	10	11	12	13	14	15
1964	528.2	0.195	0.215	0.111	0.166	0.197	0.082	0.020	0.011	0.002	0.000	0.000	0.000
1965	299.5	0.114	0.271	0.204	0.151	0.143	0.068	0.027	0.016	0.005	0.000	0.000	0.000
1966	1,992.6	0.033	0.327	0.297	0.136	0.088	0.054	0.033	0.021	0.008	0.001	0.001	0.000
1967	1,125.8	0.029	0.303	0.259	0.259	0.085	0.039	0.014	0.008	0.002	0.000	0.000	0.002
1968	1,417.7	0.130	0.248	0.425	0.137	0.035	0.015	0.008	0.003	0.000	0.000	0.000	0.000
1969	1,131.5	0.357	0.294	0.199	0.112	0.024	0.009	0.004	0.000	0.000	0.000	0.000	0.001
1970	539.7	0.011	0.137	0.291	0.309	0.093	0.097	0.029	0.024	0.002	0.004	0.002	0.000
1971	833.9	0.020	0.219	0.349	0.173	0.148	0.071	0.017	0.003	0.000	0.000	0.000	0.000
1972	290.9	0.144	0.194	0.236	0.159	0.135	0.070	0.029	0.022	0.012	0.000	0.000	0.000
1973	174.4	0.267	0.169	0.122	0.145	0.122	0.070	0.041	0.041	0.023	0.000	0.000	0.000
1974	240.6	0.414	0.500	0.039	0.008	0.000	0.016	0.016	0.008	0.000	0.000	0.000	0.000
1975	608.6	0.026	0.082	0.252	0.258	0.191	0.109	0.047	0.015	0.006	0.003	0.009	0.003
1976	504.6	0.149	0.244	0.423	0.119	0.045	0.020	0.000	0.000	0.000	0.000	0.000	0.000
1977	378.3	0.173	0.347	0.234	0.168	0.039	0.018	0.008	0.006	0.006	0.000	0.000	0.000
1978	419.1	0.228	0.200	0.149	0.132	0.096	0.062	0.060	0.026	0.021	0.018	0.005	0.003

Table 6.4.3. Estimated population numbers at age for northern Hecate Strait "female" rock sole.

Year	Population number at age (x 1000)												Total
	4	5	6	7	8	9	10	11	12	13	14	15	
1954	873	1,339	854	386	138	57	22	14	5	0	1	0	3,689
1955	469	701	937	495	195	66	26	11	9	3	0	0	2,912
1956	831	348	386	344	135	47	15	7	5	4	1	0	2,123
1957	2,323	670	246	228	178	66	22	8	5	3	2	1	3,752
1958	1,471	1,948	533	182	160	122	45	16	6	3	2	2	4,490
1959	1,954	1,172	1,327	294	86	71	52	21	9	4	2	1	4,993
1960	1,060	1,664	977	1,075	233	67	55	41	17	8	3	2	5,202
1961	564	871	1,246	645	645	135	38	33	29	12	5	2	4,225
1962	551	461	642	799	373	358	73	22	23	20	8	4	3,334
1963	1,049	457	356	449	518	235	221	47	16	17	14	6	3,385

(cont'd.)

Table 6.4.3. (cont'd.)

Year	Population number at age (x 1000)												Total
	4	5	6	7	8	9	10	11	12	13	14	15	
1964	1,920	848	326	214	237	260	114	117	31	10	11	9	4,097
1965	1,914	1,575	632	213	127	135	145	68	81	21	7	7	4,925
1966	1,919	1,616	1,279	487	158	92	98	107	53	64	17	6	5,896
1967	1,480	1,437	911	492	141	41	22	28	49	24	29	8	4,662
1968	1,228	1,160	931	457	204	54	15	9	16	28	14	16	4,132
1969	1,113	904	621	325	116	45	11	4	4	7	12	6	3,168
1970	476	852	545	272	112	36	13	4	2	2	3	6	2,323
1971	294	382	590	311	134	52	16	7	2	1	1	2	1,792
1972	371	217	205	207	79	30	11	4	3	1	1	1	1,130
1973	803	296	149	115	100	36	13	5	3	2	1	0	1,523
1974	878	664	226	102	73	61	21	8	4	2	1	0	2,040
1975	514	721	496	148	61	41	34	13	6	3	1	1	2,039
1976	638	404	470	251	62	24	15	14	7	3	1	1	1,890
1977	678	490	247	211	89	20	7	5	7	4	2	1	1,761
1978	1,418	537	327	131	94	37	8	3	3	4	2	1	2,565

Table 6.4.4. Estimated fishing mortality (F) for northern Hecate Strait female rock sole, 1954-78.

Year	Fishing mortality at age											Mean F (ages 6-15)	
	4	5	6	7	8	9	10	11	12	13	14		15
1954	0.068	0.207	0.394	0.533	0.590	0.626	0.533	0.310	0.310	0.310	0.310	0.310	0.423
1955	0.148	0.447	0.851	1.152	1.273	1.352	1.150	0.669	0.669	0.669	0.669	0.669	0.912
1956	0.065	0.197	0.376	0.508	0.562	0.597	0.508	0.295	0.295	0.295	0.295	0.295	0.403
1957	0.026	0.080	0.152	0.206	0.228	0.242	0.206	0.120	0.120	0.120	0.120	0.120	0.163
1958	0.077	0.234	0.445	0.602	0.665	0.707	0.601	0.350	0.350	0.350	0.350	0.350	0.477
1959	0.011	0.032	0.061	0.083	0.091	0.097	0.082	0.048	0.048	0.048	0.048	0.048	0.065
1960	0.046	0.140	0.266	0.360	0.398	0.423	0.360	0.209	0.209	0.209	0.209	0.209	0.285
1961	0.051	0.154	0.294	0.398	0.439	0.467	0.397	0.231	0.231	0.231	0.231	0.231	0.315
1962	0.036	0.110	0.209	0.283	0.313	0.332	0.283	0.165	0.165	0.165	0.165	0.165	0.224
1963	0.063	0.189	0.360	0.488	0.539	0.573	0.487	0.283	0.283	0.283	0.283	0.283	0.386

(cont'd.)

Table 6.4.4. (cont'd.)

Year	Fishing mortality at age												Mean F (ages 6-15)
	4	5	6	7	8	9	10	11	12	13	14	15	
1964	0.048	0.144	0.275	0.372	0.411	0.436	0.371	0.216	0.216	0.216	0.216	0.216	0.294
1965	0.019	0.058	0.111	0.150	0.166	0.176	0.150	0.087	0.087	0.087	0.087	0.087	0.119
1966	0.140	0.423	0.805	1.090	1.204	1.279	1.088	0.633	0.633	0.633	0.633	0.633	0.863
1967	1.094	0.283	0.539	0.730	0.807	0.857	0.729	0.424	0.424	0.424	0.424	0.424	0.578
1968	0.157	0.475	0.903	1.223	1.352	1.436	1.222	0.710	0.710	0.710	0.710	0.710	0.969
1969	0.117	0.355	0.676	0.915	1.011	1.074	0.914	0.531	0.531	0.531	0.531	0.531	0.725
1970	0.072	0.217	0.413	0.559	0.617	0.656	0.558	0.324	0.324	0.324	0.324	0.324	0.442
1971	0.156	0.472	0.898	1.215	1.343	1.427	1.214	0.706	0.706	0.706	0.706	0.706	0.963
1972	0.075	0.226	0.431	0.583	0.644	0.684	0.582	0.339	0.339	0.339	0.339	0.339	0.462
1973	0.040	0.120	0.228	0.309	0.341	0.363	0.308	0.179	0.179	0.179	0.179	0.179	0.245
1974	0.047	0.143	0.273	0.369	0.408	0.434	0.369	0.215	0.215	0.215	0.215	0.215	0.293
1975	0.092	0.278	0.528	0.715	0.790	0.839	0.714	0.415	0.415	0.415	0.415	0.415	0.566
1976	0.113	0.343	0.653	0.884	0.977	1.037	0.883	0.513	0.513	0.513	0.513	0.513	0.700
1977	0.084	0.254	0.483	0.654	0.722	0.767	0.653	0.380	0.380	0.380	0.380	0.380	0.518
1978	0.073	0.221	0.421	0.570	0.629	0.669	0.569	0.331	0.331	0.331	0.331	0.331	0.451

Table 6.4.5. Canada-U.S. rock sole landings (t), CPUE (t/h), and calculated effort (h) for northern Hecate Strait (north of 53°50'), 1954-1980.

Year	Total landings ^a (t)	CPUE ^b (t/h)	Effort ^c (h)
1954	835	1.01	827
1955	1,324	0.74	1,789
1956	512	0.63	813
1957	211	0.52	406
1958	797	1.06	752
1959	109	0.83	131
1960	626	1.48	423
1961	660	1.55	426
1962	503	1.18	426
1963	754	1.02	739
1964	484	0.77	629
1965	318	1.54	206
1966	1,468	0.83	1,769
1967	1,045	0.85	1,229
1968	1,386	0.45	3,080
1969	1,230	0.78	1,577
1970	455	0.44	1,034
1971	895	0.39	2,295
1972	230	0.28	821
1973	180	0.46	391
1974	220	0.32	688
1975	562	0.64	878
1976	892	0.55	1,622
1977	427	0.36	1,186
1978	394	0.44	895
1979	361	0.31	1,165
1980	360	0.24	1,500

^aData Sources: Canada - sales slips and trip logs.
 U.S. - 1954-75 Ketchen (1976),
 - 1976-79 supplied by Washington State Department
 of Fisheries.

^bFrom trip logs (25 percent qualification level).

^cTotal landings/CPUE.

Table 6.4.6. Parameter estimates for northern Hecate Strait rock sole

I. Parameter estimates from Gulland's (1961) linear regression model.

	K = 3	K = 4	K = 5
<u>Biological:</u>			
a	1.223	1.299	1.417
b	5.030×10^{-4}	5.770×10^{-4}	6.860×10^{-4}
<u>Fishery:</u>			
MSY (t)	743	731	732
f _{opt} (h)	1,216	1,126	1,033
<u>Correlation:</u>			
r	-0.632	-0.673	-0.738

II Parameter estimates from dynamic Schaefer model.

<u>Biological:</u>		<u>Fishery:</u>		<u>"Variance":</u>
r'a	0.245	MSY(t)	831	σ 0.422
q	2.400×10^{-4}	f _{opt} (h)	510	I 0.917
k(t)	13,576			

a r' = growth parameter

Table 6.4.7. Canada-U.S. rock sole landings (t), CPUE (t/h), and calculated effort (h) for middle Hecate Strait (south of 53°50'), 1954-79.

Year	Total landings ^a (t)	CPUE ^b (t/h)	Effort ^c (h)
1954	91	0.46	198
1955	235	0.74	318
1956	770	0.73	1,055
1957	1,039	0.48	2,165
1958	483	0.49	986
1959	338	0.43	786
1960	509	0.45	1,131
1961	135	0.29	466
1962	329	0.51	645
1963	160	0.40	400
1964	308	0.41	751
1965	562	0.64	878
1966	1,095	0.68	1,610
1967	1,153	0.51	2,261
1968	1,044	0.38	2,747
1969	1,197	0.30	3,990
1970	950	0.28	3,393
1971	633	0.26	2,435
1972	275	0.38	724
1973	324	0.34	953
1974	403	0.48	840
1975	702	0.28	2,507
1976	544	0.29	1,876
1977	420	0.28	1,500
1978	483	0.37	1,305
1979	954	0.52	1,835
1980	548	0.40	1,370

^aData Sources: Canada - sales slips and trip logs.
 U.S. - 1954-75 Ketchen (1976),
 - 1976-79 supplied by Washington State
 Department of Fisheries.

^bFrom trip logs (25 percent qualification level).

^cTotal landings/CPUE

Table 6.4.8. Parameter estimates for middle Hecate Strait rock sole.

I. Parameter estimates from Gulland's (1961) linear regression model.

	K = 3	K = 4	K = 5
<u>Biological:</u>			
a	0.563	0.542	0.553
b	9.360×10^{-5}	8.720×10^{-5}	9.610×10^{-5}
<u>Fishery:</u>			
MSY (t)	846	842	796
f _{opt} (h)	3,007	3,108	2,877
<u>Correlation:</u>			
r	-0.589	-0.566	-0.573

II Parameter estimates from dynamic Schaefer model.

<u>Biological:</u>		<u>Fishery:</u>		<u>"Variance":</u>
r'a	0.391	MSY(t)	628	σ 0.291
q	1.411×10^{-4}	f _{opt} (h)	1,385	I 0.862
k(t)	6,424			

a r' = growth parameter



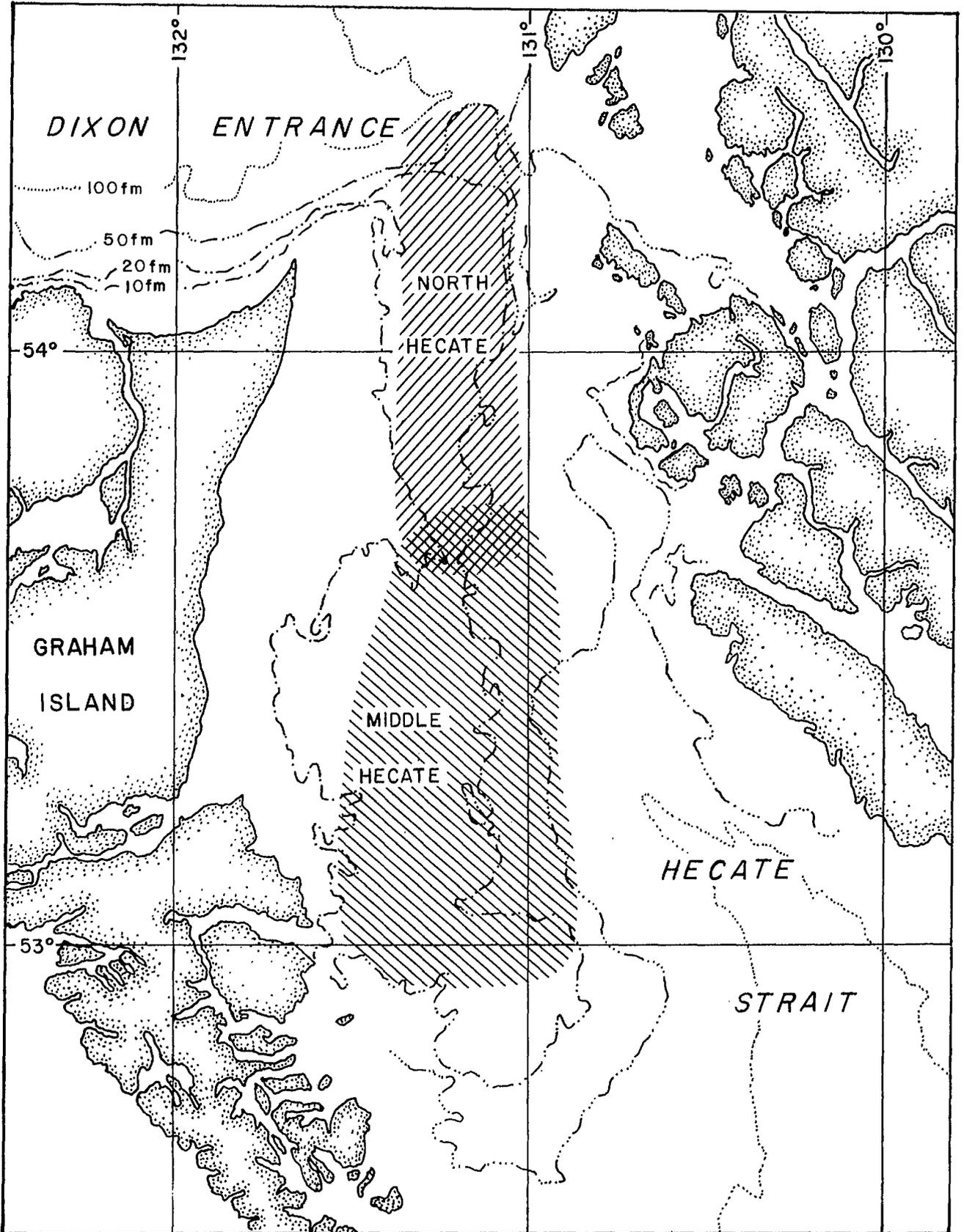
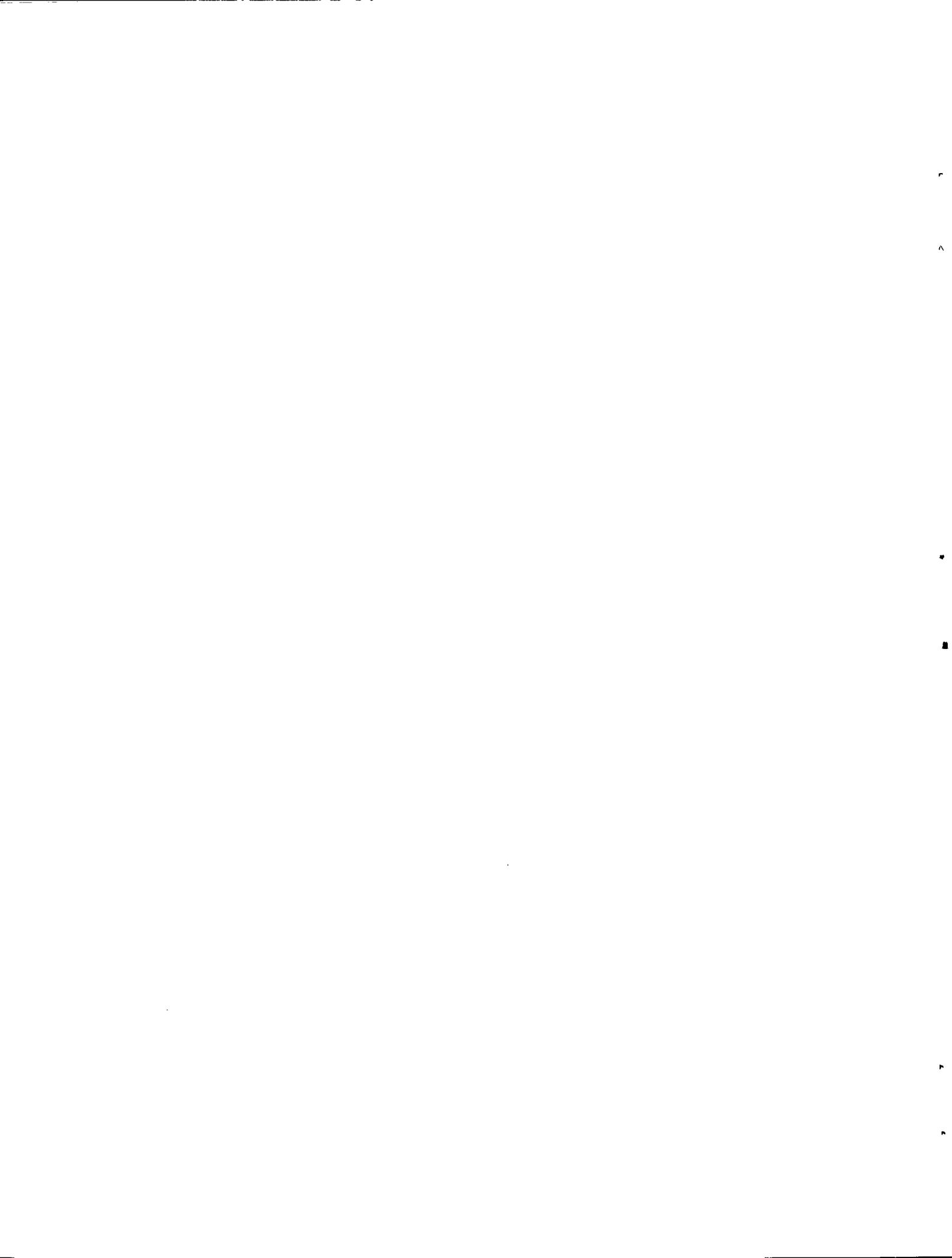


Fig. 6.4.1. Rock sole "stocks" in Hecate Strait.



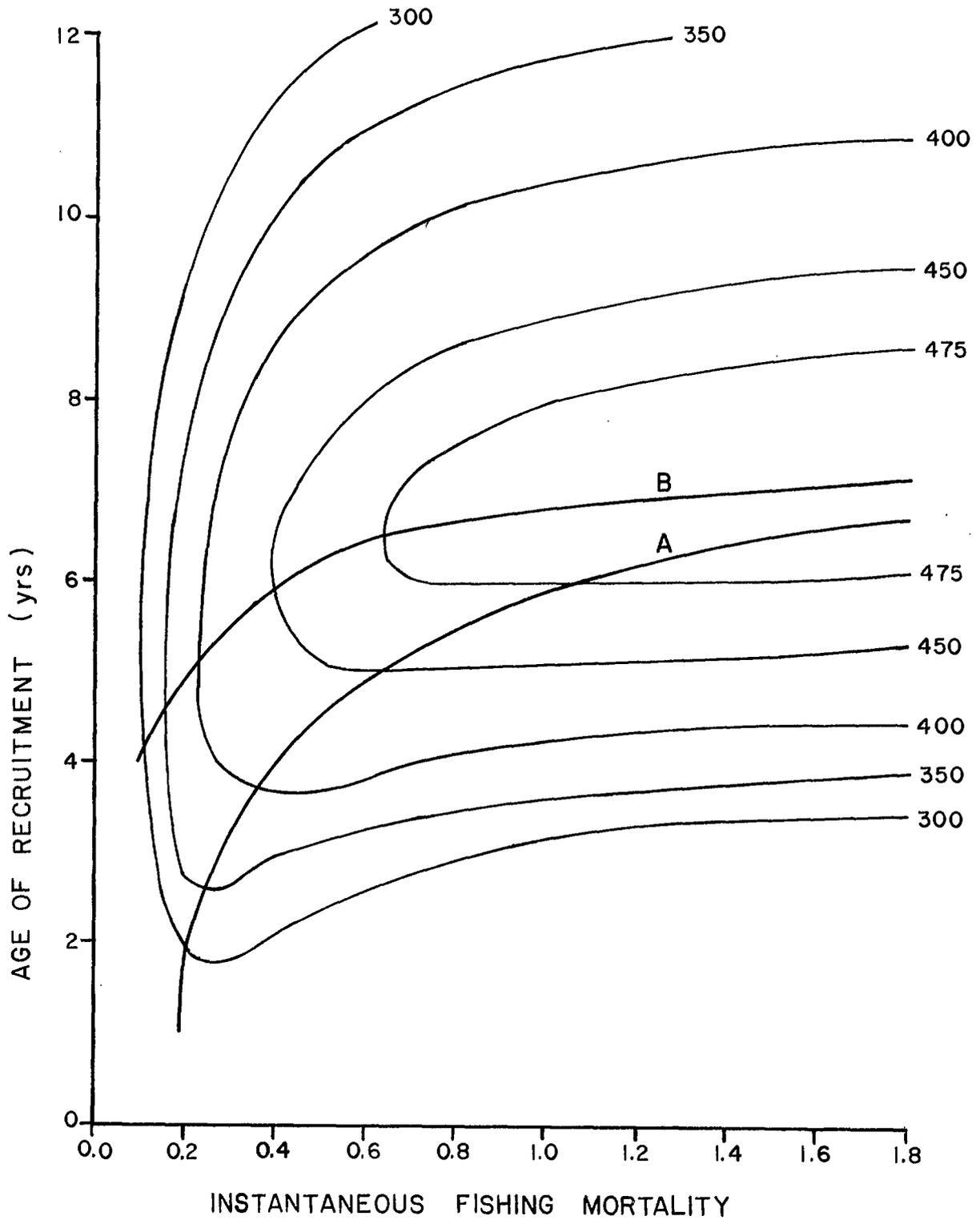


Fig. 6.4.2. Beverton-Holt yield isopleths for northern Hecate Strait female rock sole. Line (A) gives the F with best yield for given ages at recruitment; line (B) gives age at recruitment with best yield for given levels of F . Numbers in body of graph are yields per recruit in grams.



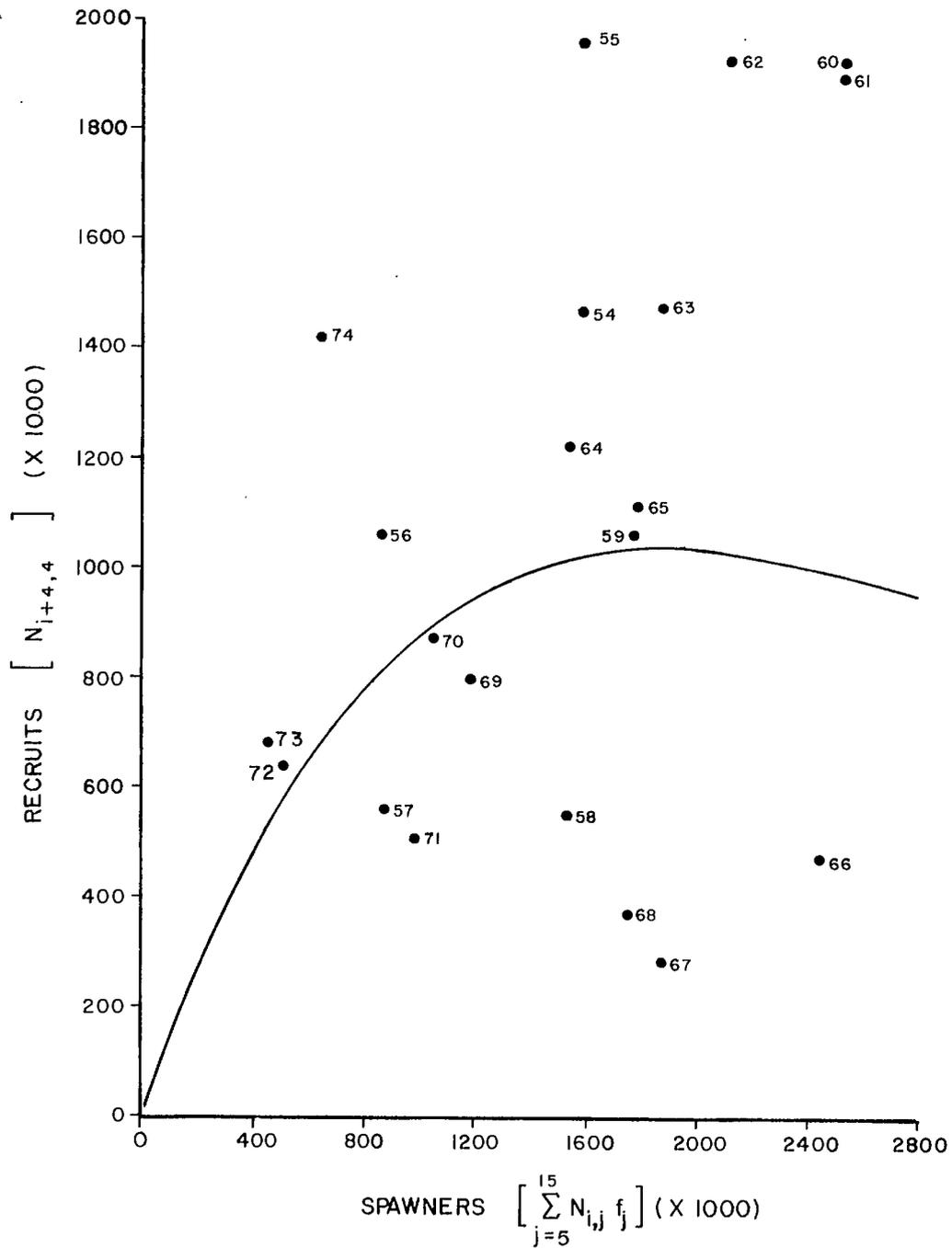


Fig. 6.4.3. Stock-recruitment relationship for northern Hecate Strait female rock sole.



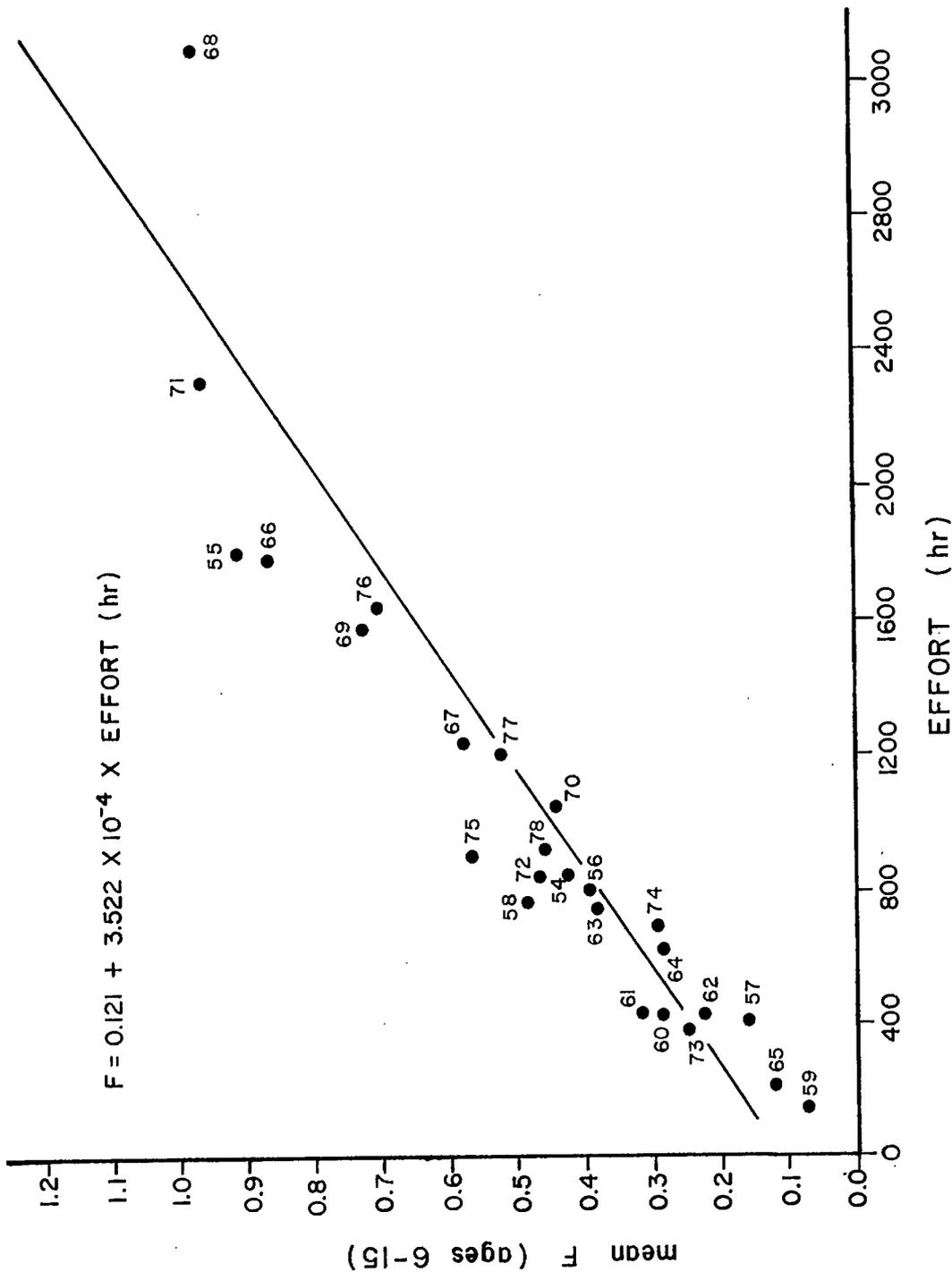


Fig. 6.4.4. Relationship between mean F-values of ages 6-15 and annual effort for northern Hecate Strait rock sole fishery.



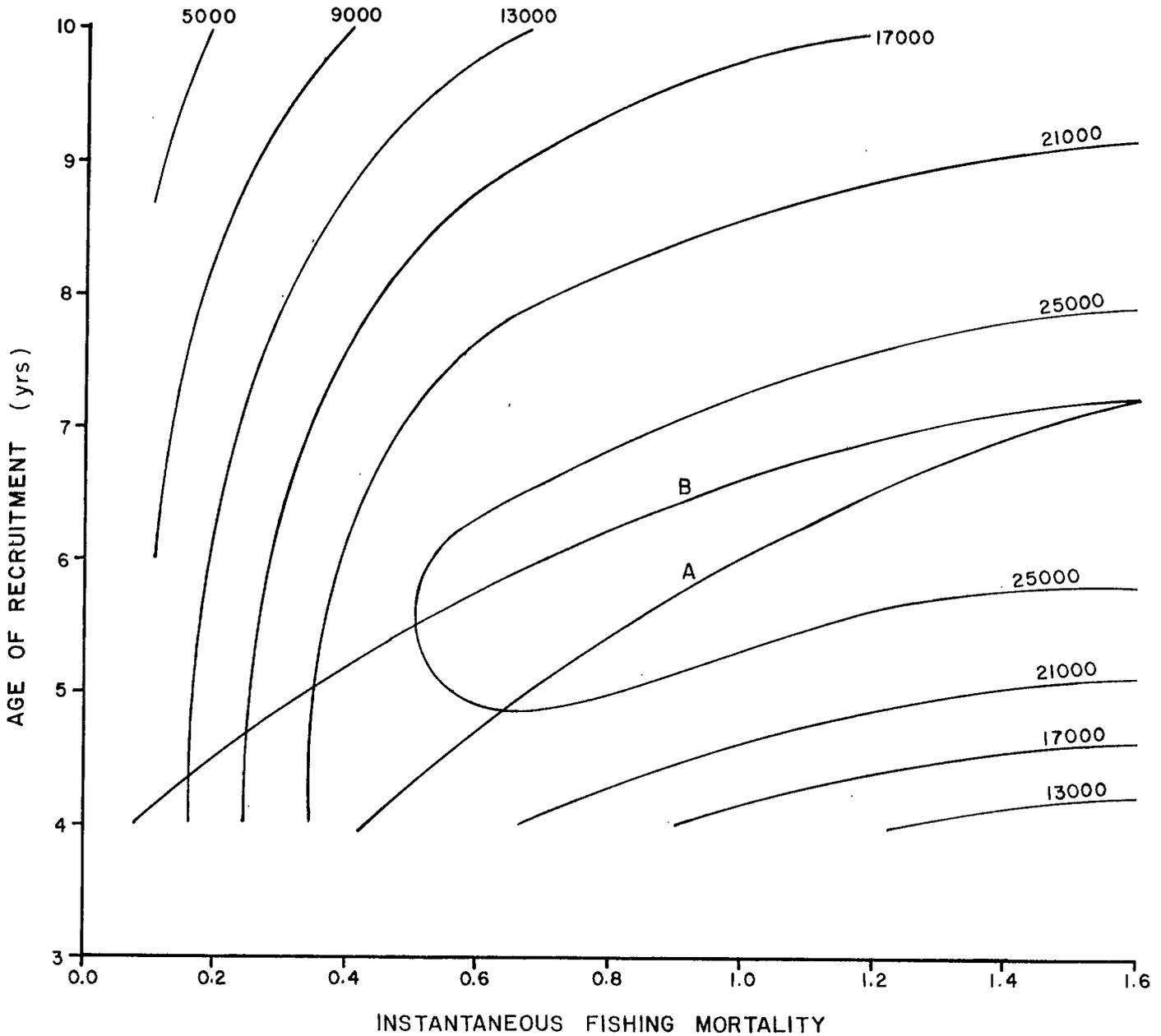
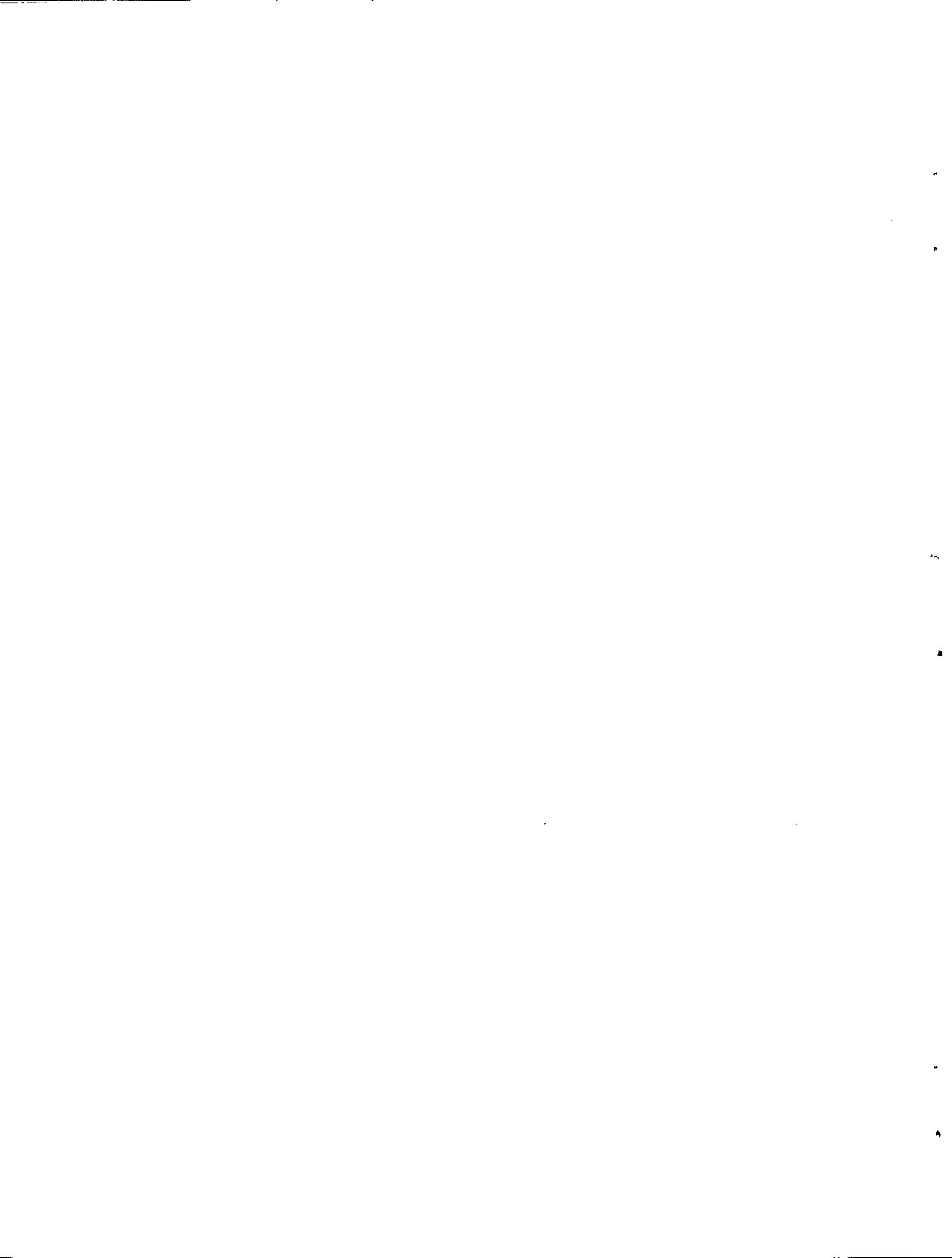


Fig. 6.4.5. Potential yield isopleths from 50-yr forward simulations. Line (A) gives F with greatest potential yield for given ages at recruitment; line (B) gives age at recruitment with best potential yield for given levels of F. Numbers in body of graph are relative potentials in relation to 1000s of fish.



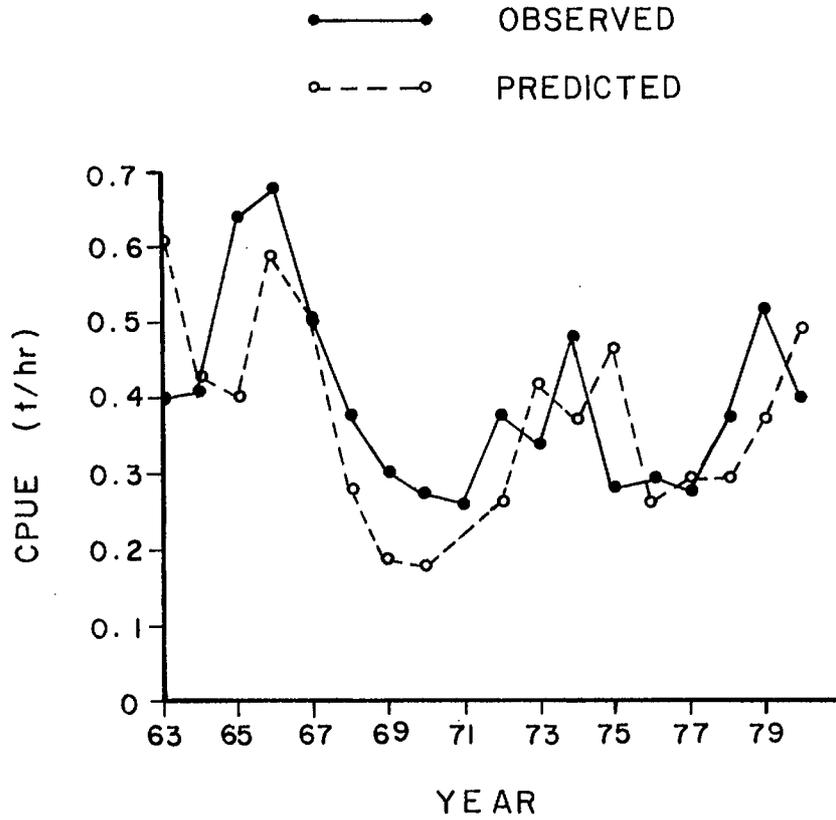
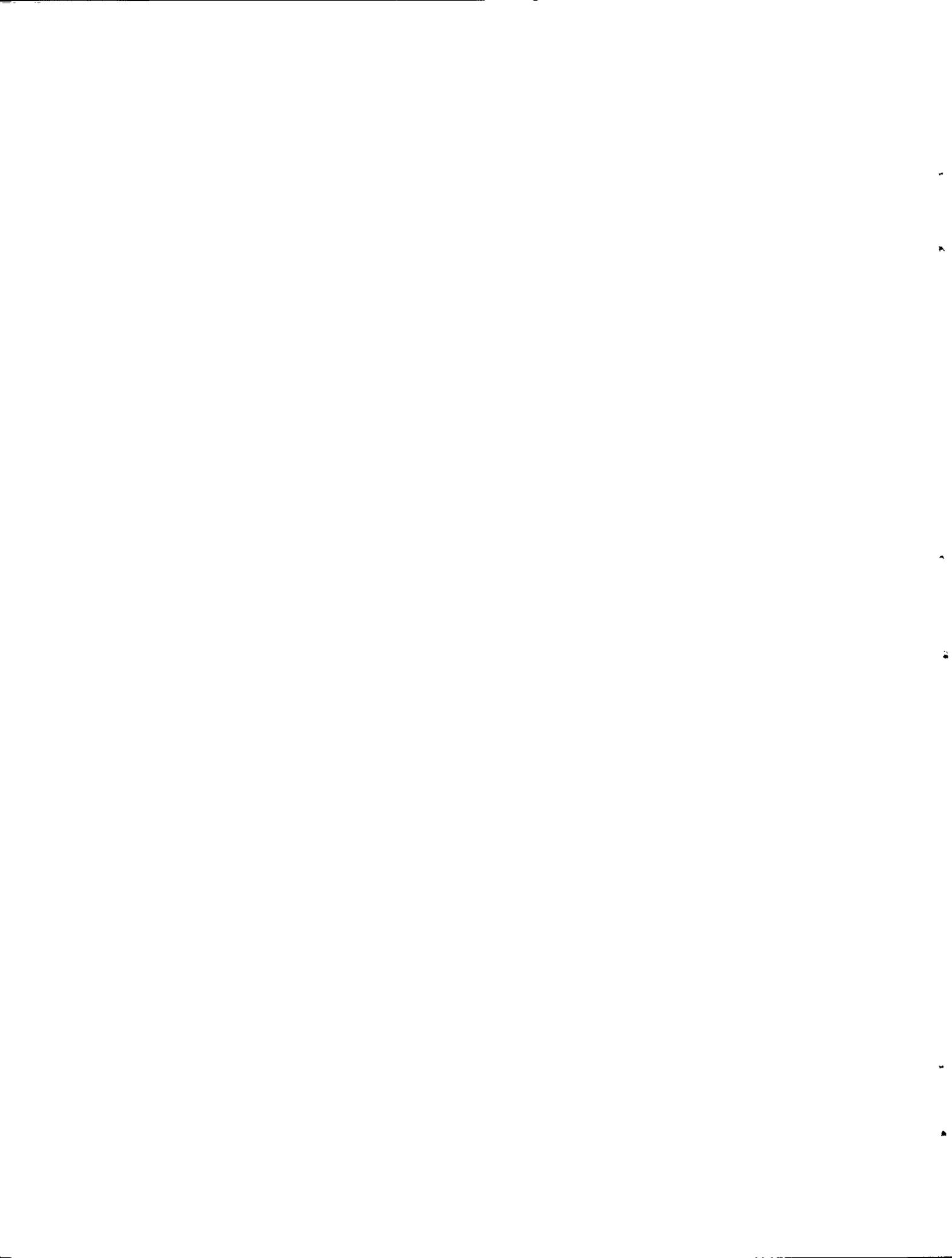


Fig. 6.4.6. Observed and predicted CPUE (t/h) for middle Hecate Strait rock sole, 1963-80.



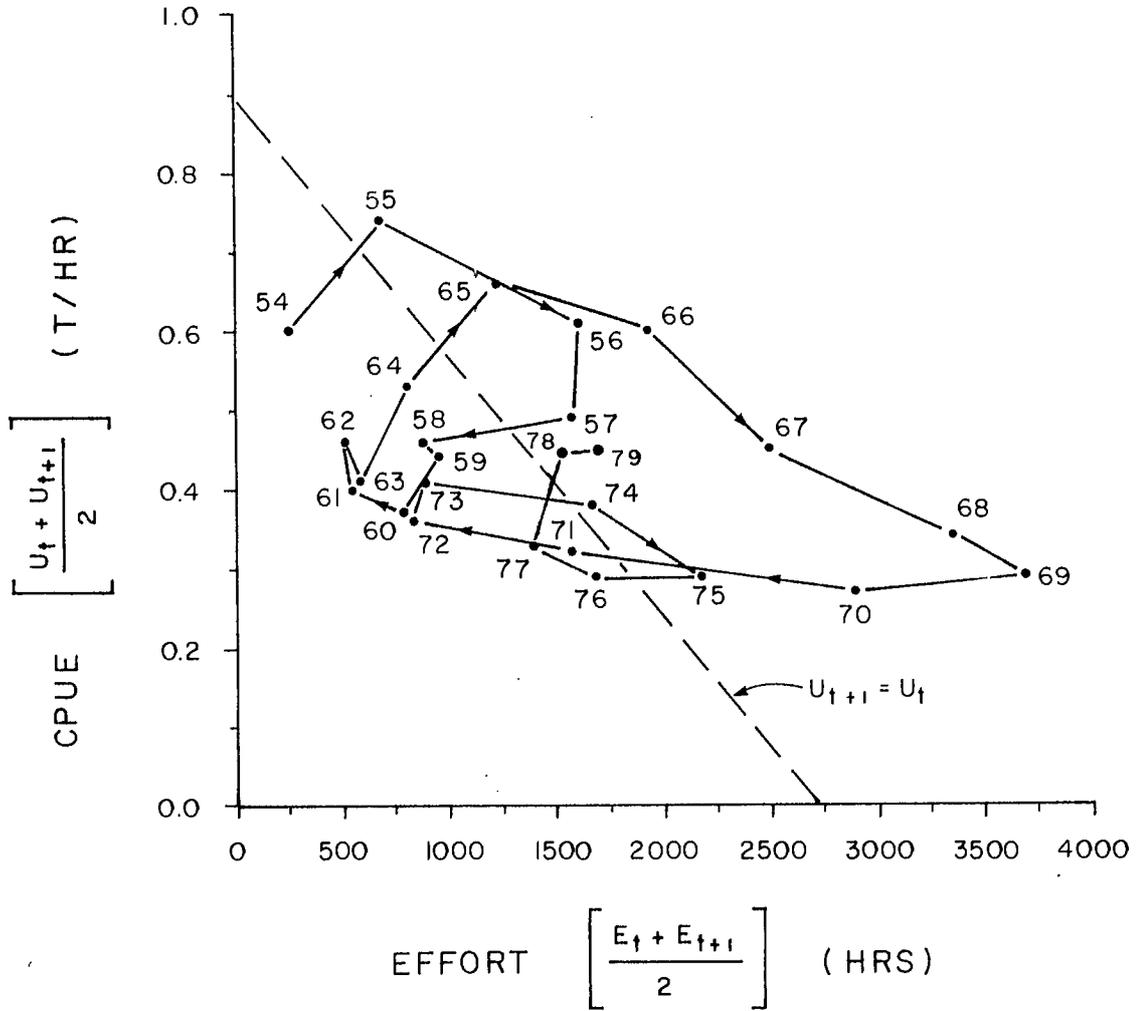


Fig. 6.4.7. Exploitation history of middle Hecate Strait rock sole (1954-80). The dashed line is the isocline generated by Schnute's method.



6.5 English sole

6.5.1 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 second and third quarters along the Butterworth-Warrior Edge and on the Two Peaks, during the post-spawning migration (Ketchen 1956).

6.5.2 Trends in landings and effort statistics for Area 5D

Landings have varied substantially over the years, rising from 632 t in 1954 to a peak of 1,086 t in 1960 followed by an irregular downward trend to 340 t in 1966 (Table 6.5.1). Between 1967 and 1980 there was considerable fluctuation, with landings of more than 900 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-1960s with a highly irregular upward trend thereafter.

6.5.3 Yield

The relationship between catch and effort for northern Hecate Strait English sole was examined using surplus production model analysis (Westrheim 1980). The analysis provides estimates of biological, fisheries, and variance parameters.

Table 6.5.2 presents results of the parameter estimates for northern Hecate Strait English sole. The best fit to the data (as determined by a low value for the failure index; $I = 0.486$) was obtained from the dynamic Schaefer model analysis (Schnute 1977). Using this method the MSY was estimated to be 766 t with a corresponding optimal effort level (f_{opt}) of 1,983 h. A CPUE of 0.39 is predicted to be the optimal level. Observed and predicted CPUEs for the northern Hecate Strait English sole fishery are shown in Fig. 6.5.1.

Fig. 6.5.2 shows the exploitation history of northern Hecate Strait English sole. The data are closely grouped around the optimal equilibrium CPUE of 0.39 t/h. The current CPUE of 0.28 t/h is only 72% of the optimal level.

6.5.4 Yield forecast

The estimates of the biological and variance parameters combined with most recent catch information (C_{80} , E_{80}) were used to predict 1981 catch levels in relation to expected effort levels (Schnute 1977). The catch predictions and 95% confidence limits are shown in Fig. 6.5.3. Present stock abundance would yield about 80% of the MSY in 1981 if fished at the predicted optimal effort level (f_{opt}). Assuming that there will be no considerable departure from predictions of the 1981 fishery, the 1982 TAC should be set at 590 t for northern Hecate Strait English sole.

6.5.5 Recommendations

For the northern Hecate Strait stock, a TAC of 590 t is recommended for 1982. This recommendation is based on surplus production analysis performed in April 1981. Once age-structured population analyses are complete this figure may change, and appropriate recommendations will be made in late 1981. Recommended TAC for southern Hecate Strait, where English sole is mainly an incidental species is 70 t.

Table 6.5.1. Canada-U.S. English sole landings (t) and effort (h) statistics for northern Hecate Strait (5D), 1954-79.

Year	Total landings ^a (t)	CPUE ^b (t/h)	Effort ^c (h)
1954	632	0.37	1,708
1955	853	0.43	1,984
1956	943	0.39	2,418
1957	537	0.26	2,065
1958	642	0.34	1,888
1959	908	0.32	2,837
1960	1,086	0.33	3,291
1961	879	0.29	3,031
1962	439	0.26	1,688
1963	374	0.20	1,870
1964	436	0.28	1,557
1965	391	0.26	1,504
1966	340	0.25	1,360
1967	509	0.37	1,376
1968	634	0.31	2,045
1969	720	0.38	1,895
1970	918	0.34	2,700
1971	480	0.20	2,400
1972	353	0.24	1,471
1973	595	0.36	1,653
1974	458	0.43	1,065
1975	948	0.51	1,859
1976	943	0.32	2,947
1977	972	0.30	3,240
1978	494	0.27	1,830
1979	745	0.34	2,191
1980	796	0.28	2,843

^aData Sources: Canada - sales slips and trip logs.
U.S. - 1954-75 Ketchen (1976),
- 1976-79 supplied by Washington State
Department of Fisheries.

^bFrom trip logs (25 percent qualification level).

^cTotal landings/CPUE.

Table 6.5.2. Parameter estimates for northern Hecate Strait (5D) English sole.

I. Parameter estimates from Gulland's (1961) linear regression model.

	K = 3	K = 4	K = 5
<u>Biological:</u>			
a	0.443	0.478	0.495
b	6.230×10^{-5}	8.020×10^{-5}	8.810×10^{-5}
<u>Fishery:</u>			
MSY (t)	788	712	695
f_{opt} (h)	3,555	2,980	2,809
<u>Correlation:</u>			
r	-0.403	-0.461	-0.438

II Parameter estimates from dynamic Schaefer model.

<u>Biological:</u>		<u>Fishery:</u>		<u>"Variance":</u>
$r'a$	1.739	MSY(t)	766	σ 0.228
q	4.385×10^{-4}	f_{opt} (h)	1,983	I 0.486
k(t)	1,763			

a r' = growth parameter

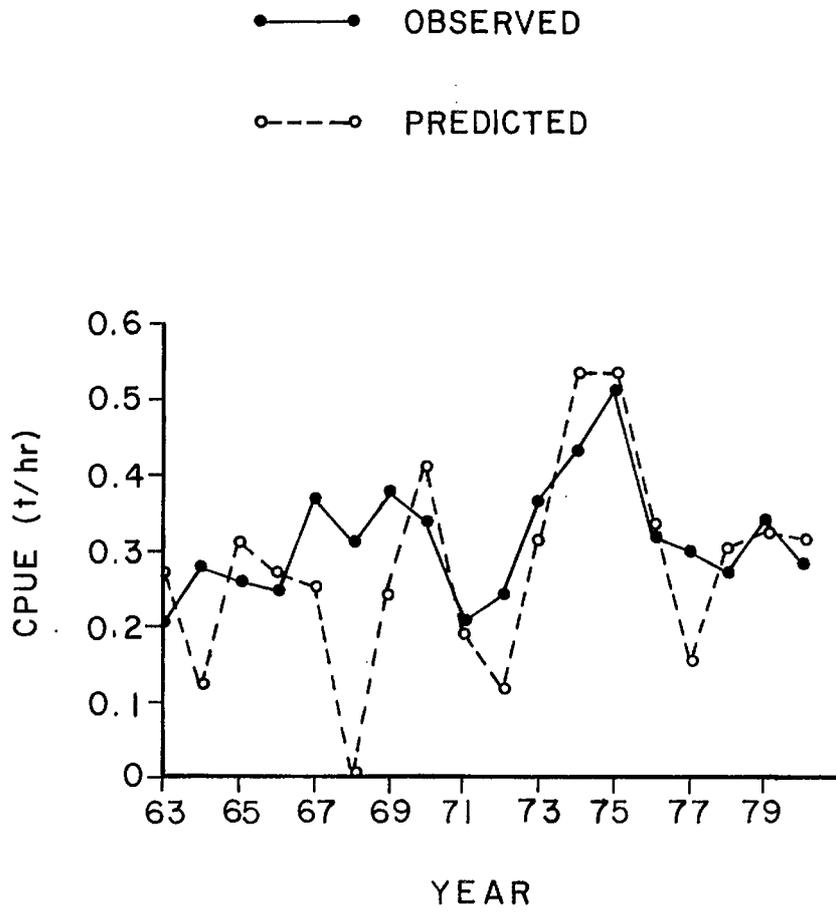
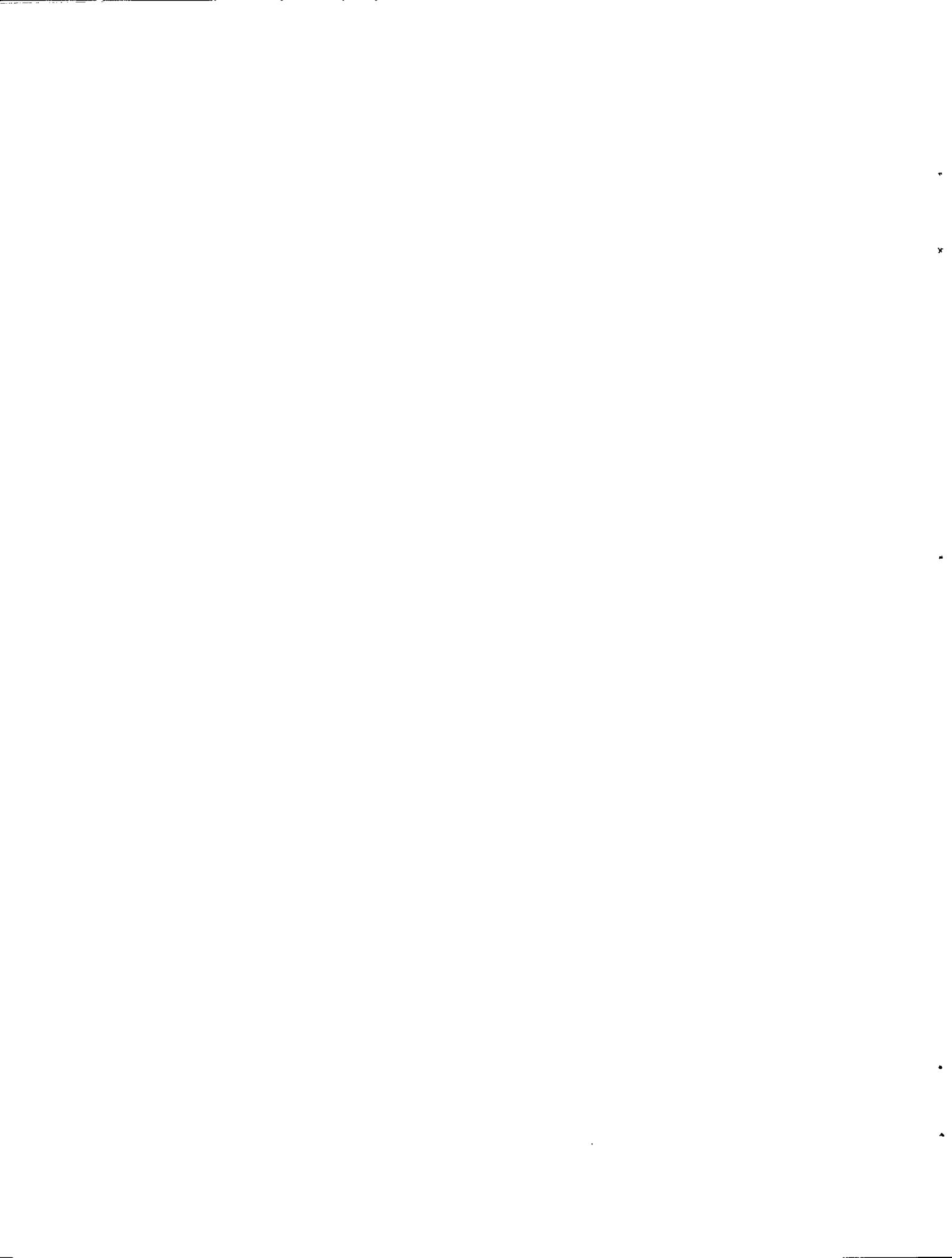


Fig. 6.5.1. Observed and predicted CPUE (t/h) for North Hecate Strait English sole, 1963-80.



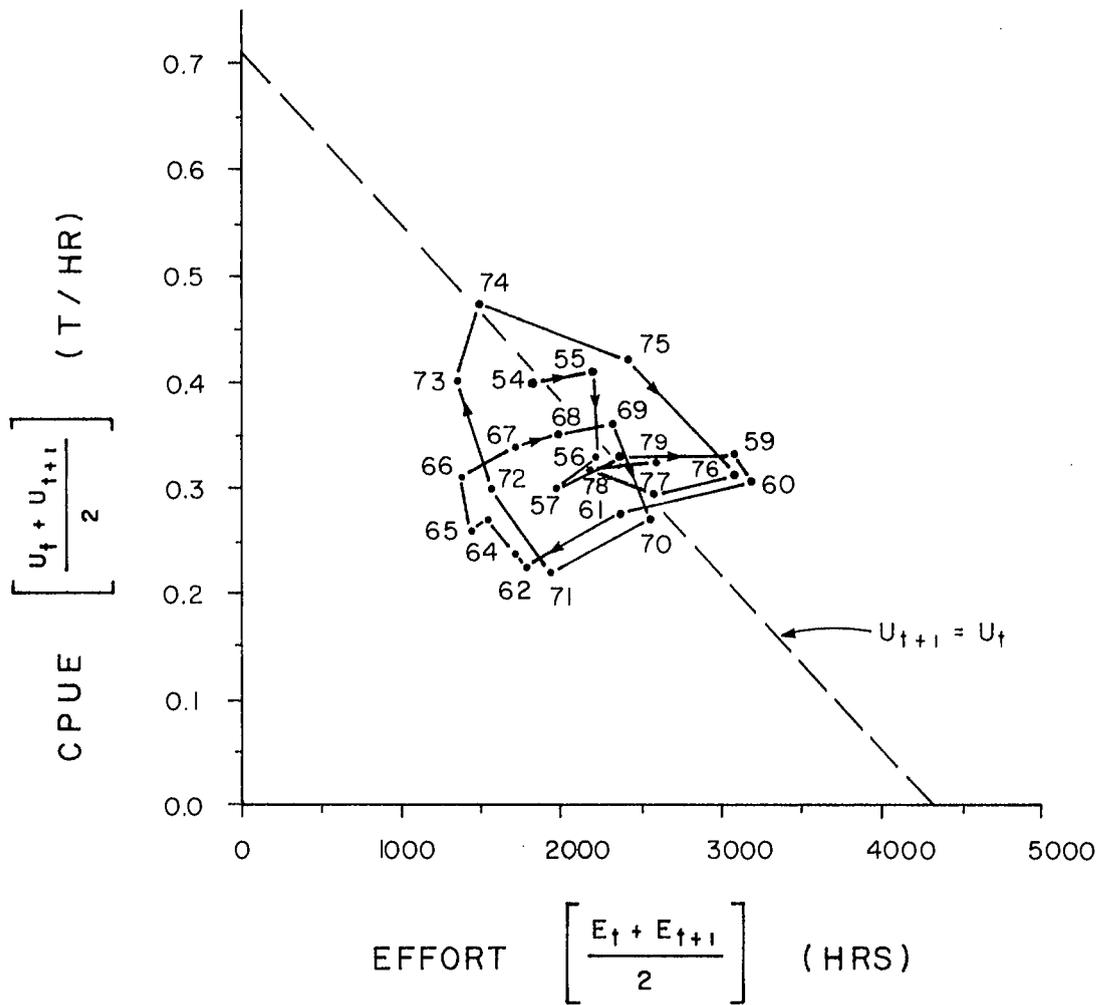
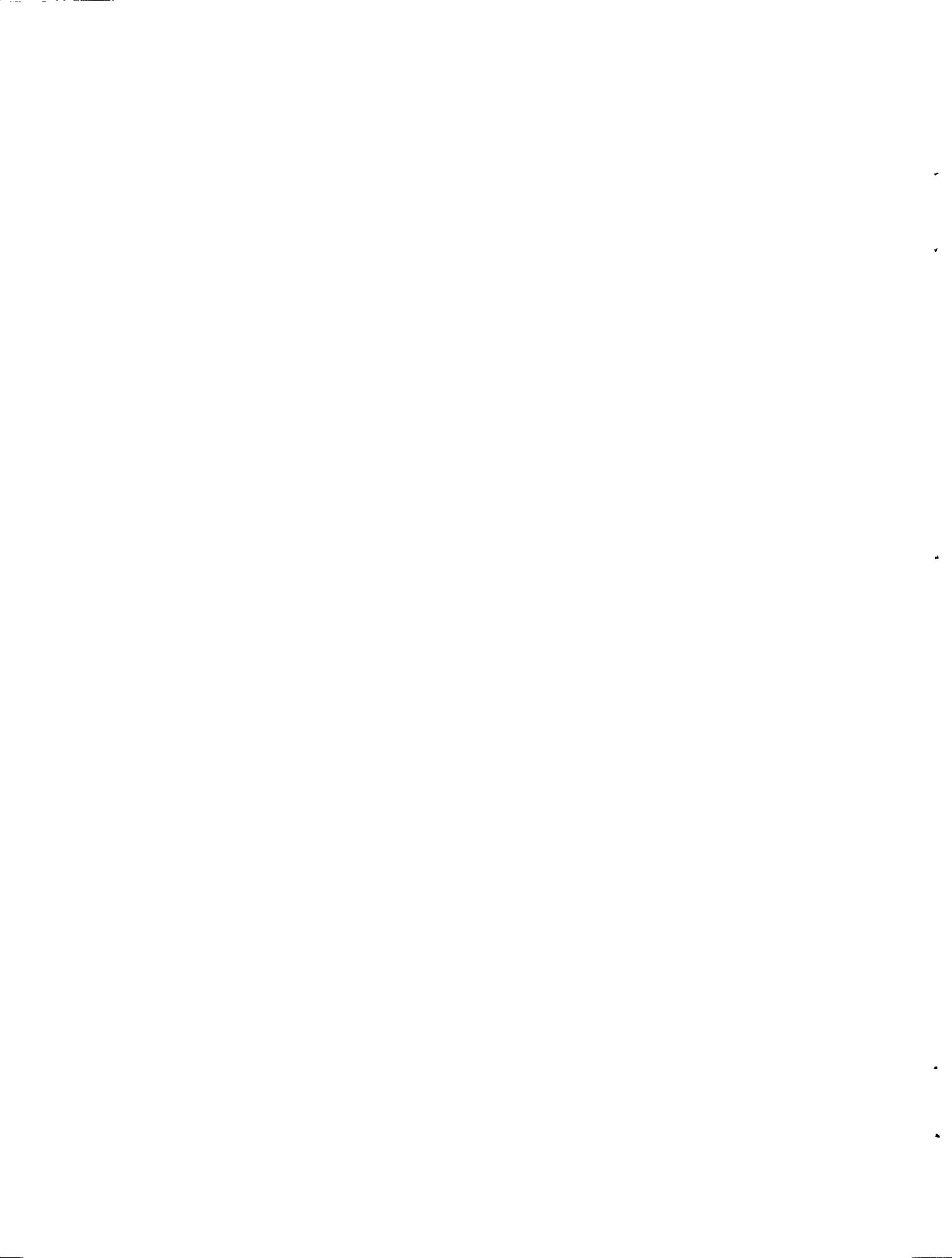


Fig. 6.5.2. Exploitation history of English sole in Area 5D, 1954-80. The dashed line is the isocline generated by Schnute's method.



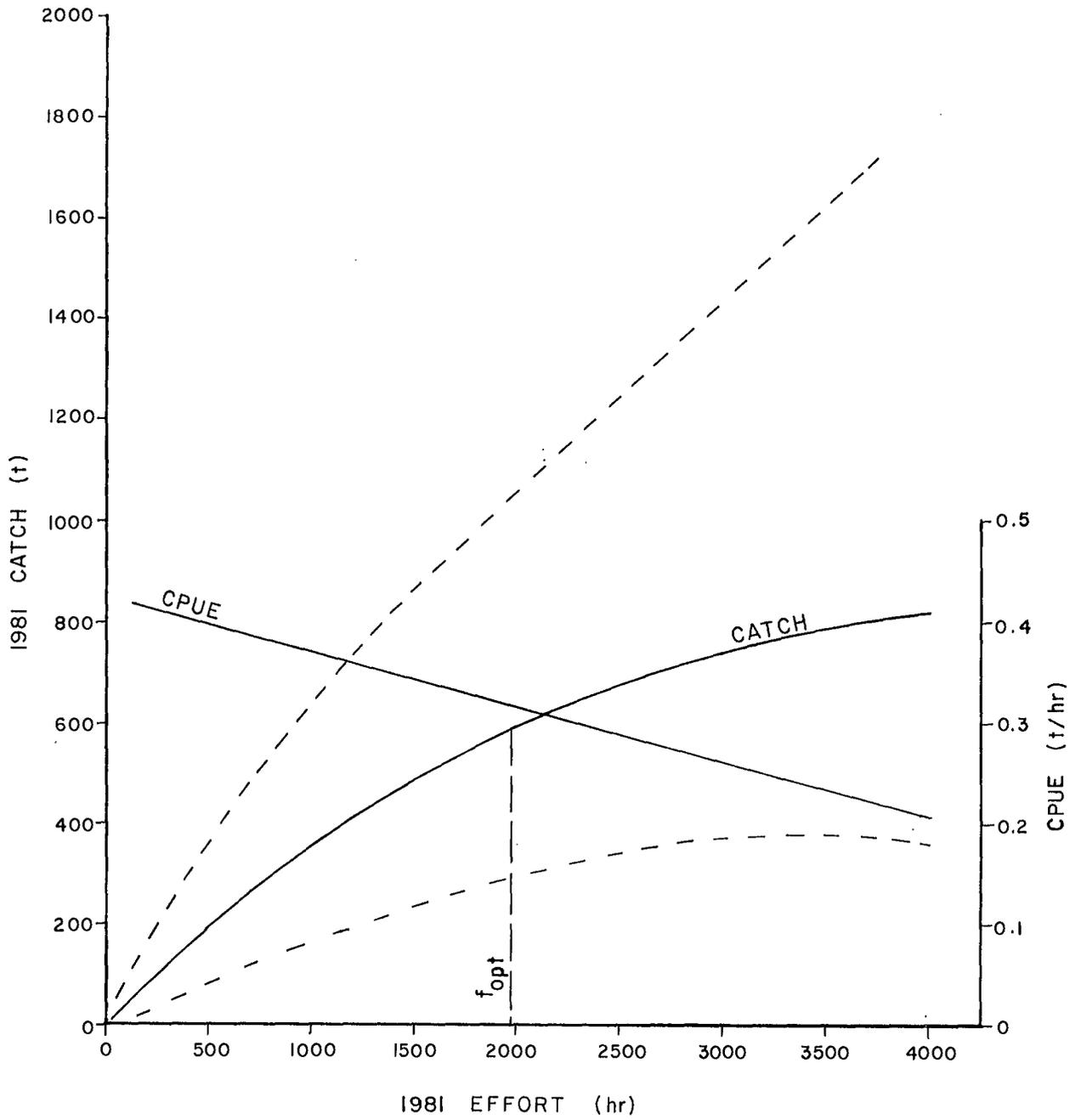
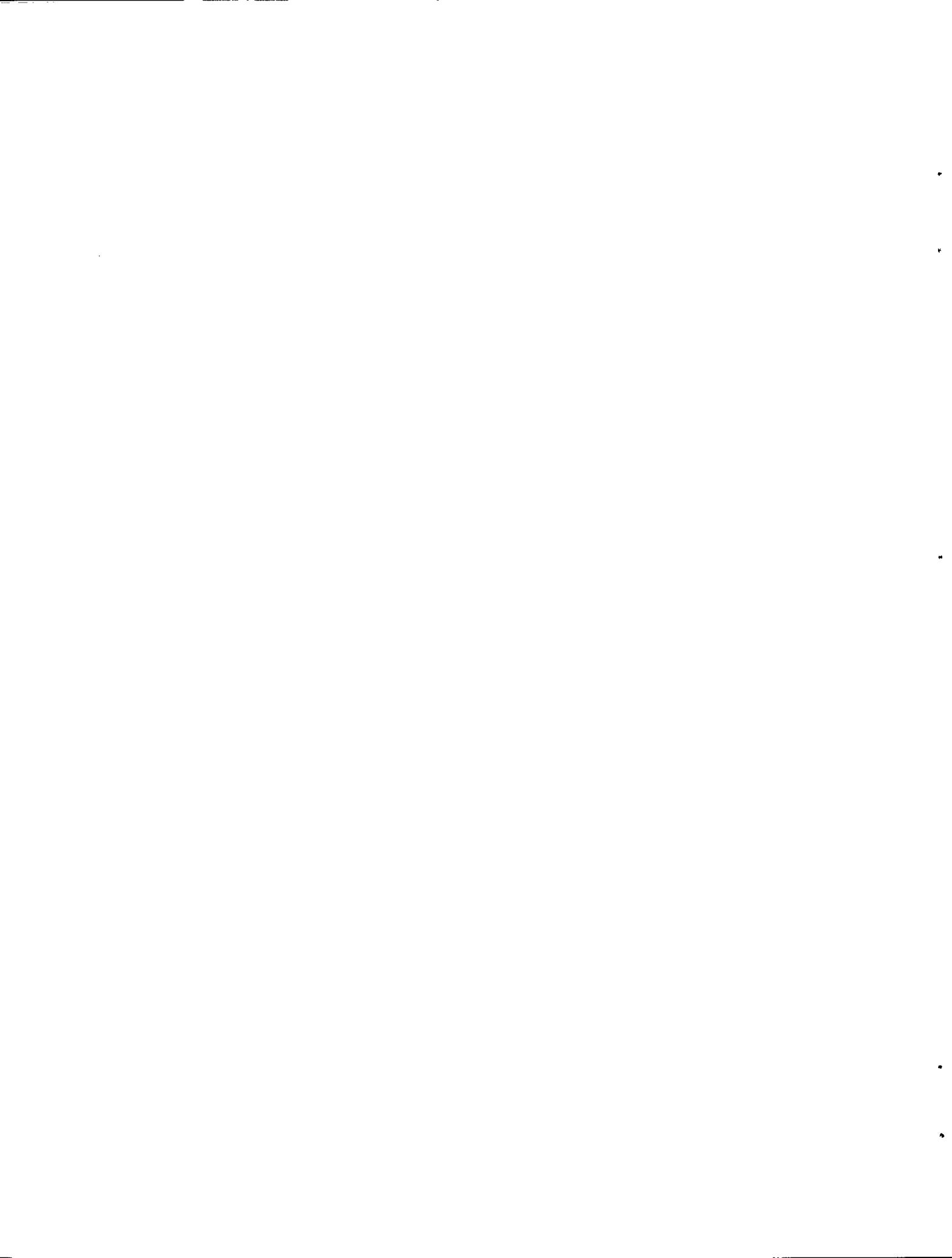


Fig. 6.5.3. Predicted 1981 catch (t) (+95% CI) and CPUE (t/h) for given effort levels for North Hecate Strait English sole.



6.6 Dover sole

6.6.1 Introduction

A directed fishery for Dover sole (Microstomus pacificus) takes place in the relatively deep water of northern Hecate Strait (Area 5D) and the west coast of the Queen Charlotte Islands (Area 5E). Production reached a peak of 210 t in 1952 in the northern fishery. From 1952 onward, production followed an irregular downward trend with landings becoming incidental to other species by the 1960s. 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 Dundas Ground combined with resumption of fishing on the Two Peaks-Butterworth Ground. In recent years also a winter fishery developed in deep waters off the west coast of the Queen Charlotte Islands.

Tag recoveries from the recent Dover sole tagging experiment (Stocker et al. 1980) seem to indicate that the northern "stock" could be considered in broader terms. For purpose of the analysis presented herein, the Dover sole resource in Areas 5C, 5D and 5E is viewed as a discrete unit.

6.6.2 Landing statistics

Landings have varied substantially over the years, being very low up to 1968. Landings have risen from 271 t in 1969 to a peak of 1,022 t in 1976. A decline followed to 484 t in 1978, and a subsequent increase to 807 t in 1980 (Table 6.6.1).

CPUE fluctuated widely in the northern Hecate Strait Dover sole fishery (Table 6.6.1). During the early 1970s CPUE declined to 0.57 t/h in 1972 with a subsequent rise to 0.76 t/h in 1974. Since 1975, CPUE fluctuated around 0.40 t/h.

6.6.3 Yield

The relationship between catch and effort for 1954-80 (Table 6.6.1) was examined using a discrete-time, stochastic version of Schaefer's production model (Schnute 1977). The analysis provides estimates of biological, fisheries, and variance parameters.

Table 6.6.2 presents the results of the parameter estimates obtained for the Dover sole stock. The resulting estimate of MSY is 661 t with a corresponding optimal fishing effort (f_{opt}) of 1,910 h for an optimal CPUE of 0.35 t/h.

6.6.4 Yield forecast

The estimates of the biological, fishery, and variance parameters were used to predict 1981 yield. The estimates, combined with most recent catch and effort information (C_{80} , E_{80}), were used to predict 1981 catch levels for the existing non-equilibrium situation (Schnute 1977). Present stock levels would yield 840 t in 1981 if fished at the optimal effort level of 1,900 h. If the effort level is similar to 1980 the projected yield would be 700 t for the northern Dover sole stock.

6.6.5 Recommendations

Based on the described analysis, and assuming no major departures from projections in the 1981 fishery, the recommended TAC for northern Dover sole is 800 t. for 1982.

If information from the 1981 fishery departs considerably from the above projections, this figure may be altered accordingly in early 1982.

Table 6.6.1. Canada-U.S. Dover sole landings (t) and effort (h) for 5C, 5D, and 5E, 1954-80.

Year	Total landings ^a (t)	CPUE ^b (t/h)	Effort ^c (h)
1954	112	0.72	156
1955	109	0.49	222
1956	123	1.16	106
1957	90	0.75	120
1958	69	1.23	56
1959	89	1.12	79
1960	106	0.89	119
1961	24	0.53	45
1962	34	0.54	63
1963	31	0.26	119
1964	84	0.53	158
1965	56	0.23	243
1966	67	0.91	74
1967	8	0.05	160
1968	34	0.58	59
1969	271	0.76	357
1970	973	0.63	1,544
1971	912	0.58	1,572
1972	922	0.57	1,618
1973	768	0.72	1,067
1974	767	0.76	1,009
1975	910	0.53	1,717
1976	1,022	0.46	2,222
1977	577	0.40	1,443
1978	484	0.54	896
1979	697	0.38	1,834
1980	807	0.52	1,552

^aData Sources: Canada - sales slips and trip logs.
 U.S. - 1954-75 Ketchen (1976)
 - 1976-79 supplied by Washington State
 Department of Fisheries

^bFrom trip logs (25 percent qualification level).

^cTotal landings/CPUE.

Table 6.6.2. Parameter estimates for northern Dover sole (5C, 5D, and 5E).

Parameter estimates from dynamic Schaefer model.

<u>Biological:</u>	<u>Fishery:</u>	<u>"Variance":</u>
$r'a$ 1.106	MSY(t) 661	σ 0.319
q 2.896 x 10 ⁻⁴	$f_{opt}(h)$ 1,910	I 0.707
$k(t)$ 2,391		

a r' = growth parameter

6.7 Rockfishes

The fishery for rockfishes in Area 5C-D has only attained any significant landings in recent years (1975-80). Sebastes brevispinis, S. pinniger and S. flavidus have been the primary contributors to the landings. More recently a fishery for S. alutus was established in lower Hecate Strait; this fishery is dealt with in Section 6.8. The assessments of stocks of the remaining Sebastes spp. can progress little beyond the descriptive stage at this point, however the increase in production from these stocks warrants even minimal treatment.

6.7.1 Silvergray rockfish (S. brevispinis)

Prior to 1976 landings of S. brevispinis were less than 30 t/yr, however landings have been increasing steadily since that time (Table 6.7.1). 1980 landings were 340 t. At the time of writing fishing effort was higher than in the past.

6.7.1.1 Condition of the resource

After 1976, when the fishery began to develop, there was a sevenfold increase in species effort and an order of magnitude increase in LPUE. Between 1977-80 LPUE varied erratically. Both qualified and nominal LPUE for the 5C-D fishery increased in 1978, then declined in 1979. In 1980 LPUE again increased although qualified effort declined by 20%.

Biological data are too limited to examine trends in age composition but they do indicate that a large proportion of older fish still remain in the population. This correlates with LPUE observations and suggests no evidence of detrimental effects of the fishery on the stock as yet. The extended age distribution of this stock does indicate the need for a cautious exploitation strategy, particularly in view of the low estimate of natural mortality.

Recent fishing activity may have located major concentrations of this species. Some confirmation may be provided by the 1981 rockfish assessment cruise to lower Hecate Strait.

6.7.1.2 Recommendation

The recommended TACs for S. brevispinis in southern (5C) and northern (5D) Hecate Strait are 400 t and 200 t, respectively.

6.7.2 Canary rockfish (S. pinniger)

Landings of S. pinniger from Hecate Strait have traditionally been incidental to those of other species. Prior to 1978, landings never exceeded 25 t/yr (Table 6.7.2). Landings have undergone a steady increase since 1978 and exceeded 200 t in 1980. Targetting activity is also increasing, as witnessed by the steady rise in qualified effort.

6.7.2.1 Condition of the resource

The increased landings of S. pinniger from Area 5C-D have been accompanied by an almost equal increase in nominal LPUE. The directed fishery for S. pinniger in southern Hecate Strait, first noted in 1978 landings, has continued to develop but not as yet to the extent where qualified LPUE could be used for assessment purposes.

Previous TAC documents have examined available biological data and, noting the sex ratio and size composition of these stocks, suggested that Hecate Strait might be a nursery area for this species. More recent biological information from commercial catches has not provided validation of this concept but rather, has shown similar characteristics to other areas. This does not preclude the concept but does indicate that extensive exploitation should be avoided until this stock is examined more thoroughly.

6.7.2.2 Recommendation

Fishery statistics continue to favour separate management of Areas 5C and 5D. Accordingly a TAC of 250 t of S. pinniger is recommended for the 5C area, where the majority of the directed fishing takes place. For Area 5D, a guideline TAC of 100 t is recommended.

6.7.3 Yellowtail rockfish (S. flavidus)

After a brief burgeoning of landings during 1978-79 S. flavidus has once again assumed the status of a minor species in Hecate Strait (Table 6.7.3). After peak landings in 1979 of ~600 t the fishery dropped to less than 170 t in 1980. While there were ~600 h of directed fishing effort (25% qualification level) in 1979, only 5 h of qualified effort were recorded in 1980. Qualified LPUE has fallen consistently since the inception of the directed fishery in Area 5D yet effort has increased substantially and the absolute removals are not considered excessive.

6.7.3.1 Condition of the resource

The brief history of the fishery for S. flavidus in Hecate Strait precludes serious assessment using these data. Biological data are similarly limited but no adverse effects of the limited fishery are evident. As noted in previous assessment documents, the controlled growth of this fishery appears possible. Decreased landings in 1980-81 were due in part to lower market demand and to the decreased fishery for walleye pollock, where S. flavidus is the primary incidentally caught species.

6.7.3.2 Recommendation

The recommended TACs for Areas 5C and 5D of S. flavidus are 200 t and 350 t, respectively for 1982.

Table 6.7.1. Catch (t), effort (h), and CPUE (t/h) of Sebastes brevispinis by Canada and United States, 1971-80.

		AREA 5C-D						AREA 5E						
		Interviewed catch (Total in brackets)			Qualified (25%)			Interviewed			Qualified (25%)			
		C	E	CPUE	C	E	CPUE	C	E	CPUE	C	E	CPUE	
1971	CAN	34.5	229	.151										
	USA	-	-	-										
1972	CAN	61.0	232	.263										
	USA	-	-	-										
1973	CAN	9.9	147	.067										
	USA	-	-	-										
1974	CAN	12.9	64	.202										
	USA	-	-	-										
1975	CAN	11.2	191	.059										
	USA	-	-	-										
1976	CAN	121.3	1,429	.085										
	USA	-	-	-										
1977	CAN	233.8	2,059	.114	135.7	446.9	.304	20.3	136.5	.149				
	USA	-	-	-	-	-	-	-	-	-				
1978	CAN	232.4	1,392	.167	171.99	249.8	.688	212.8	656.0	.324	52.82	103.7	.509	
	USA	-	-	-	-	-	-	-	-	-	-	-	-	-
1979	CAN	375(379.9)	2,881	.130	188.8	472.7	.399	51.6	283.6	.182	30.1	18.9	1.587	
	USA	-	-	-	-	-	-	-	-	-	-	-	-	-
1980	CAN	337.2	1,886	.179	235.1	381.4	.616	119.2	262.5	.454	96.3	113.8	.846	
	USA	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6.7.2. Catch (t), effort (h), and CPUE (t/h) of Sebastes pinniger by Canada and United States, 1971-80.

		AREA 5C-D						AREA 5E					
		Interviewed catch (Total in brackets)			Qualified (25%)			Interviewed			Qualified (25%)		
		C	E	CPUE	C	E	CPUE	C	E	CPUE	C	E	CPUE
1971	CAN	24.7	310	.080									
	USA	-	-	-									
1972	CAN	1.9	77	.025									
	USA	-	-	-									
1973	CAN	8.1	50	.162									
	USA	-	-	-									
1974	CAN	-	1	-									
	USA	-	-	-									
1975	CAN	3.2	102	.031									
	USA	-	-	-									
1976	CAN	7.5	273	.027									
	USA	-	-	-									
1977	CAN	15.4	412	.037	5.8	10.0	.580	.6	29.0	.021	.2	1.0	.200
	USA	-	-	-	-	-	-	-	-	-	-	-	-
1978	CAN	101.4	701	.145	67.3	80.4	.837	8.3	36.0	.231	5.1	1.0	5.140
	USA	-	-	-	-	-	-	-	-	-	-	-	-
1979	CAN	124.9(124.9)	758	.164	74.9	101.7	.736	.44	38.4	.010	.1	.9	.111
	USA	-	-	-	-	-	-	-	-	-	-	-	-
1980	CAN	205.2	1,074.9	.191	61.5	127.4	.482	.5	13.5	.037	-	-	-
	USA	-	-	-	-	-	-	-	-	-	-	-	-

Table 6.7.3. Catch (t), effort (h), and CPUE (t/h) of Sebastes flavidus by Canada and United States, 1971-80.

		AREA 5C-D						AREA 5E						
		Interviewed catch (Total in brackets)			Qualified (25%)			Interviewed			Qualified (25%)			
		C	E	CPUE	C	E	CPUE	C	E	CPUE	C	E	CPUE	
1971	CAN	50.5	201	.251										
	USA	-	-	-										
1972	CAN	25.5	108	.236										
	USA	-	-	-										
1973	CAN	.5	42	.012										
	USA	-	-	-										
1974	CAN	47.1	242	.195										
	USA	-	-	-										
1975	CAN	53.3	303	.176										
	USA	-	-	-										
1976	CAN	178.9	1,002	.179										
	USA	-	-	-										
1977	CAN	295.2	2,713	.109	89.37	220.7	.405	3.72	51.0	.073	1.38	10.0	.138	
	USA	-	-	-	-	-	-	-	-	-	-	-	-	
1978	CAN	356.5	2,493	.143	113.27	337	.336	1.57	50.6	.031	-	-	-	
	USA	-	-	-	-	-	-	-	-	-	-	-	-	
1979	CAN	584.4(590.2)	3,776	.154	280.30	604.7	.464	.34	26.0	.026	-	-	-	
	USA	-	-	-	-	-	-	-	-	-	-	-	-	
1980	CAN	165.7	1,414.2	.109	2.14	4.17	.513	-	-	-	-	-	-	
	USA	-	-	-	-	-	-	-	-	-	-	-	-	

6.8 Pacific ocean perch (S. alutus)

The fishery for S. alutus in southern Hecate Strait (Moresby Gully) was initiated in 1980, on a stock discovered by the Fisheries Research Board in 1973 (Westrheim et al. 1973, Westrheim 1974). Landings in 1980 were ~2,100 t. Previous biomass estimates based on surveys (Westrheim et al. 1974, Harling et al. 1979) suggested a sustainable yield of approximately 1,500 t, based on assumptions of parabolic surplus production, and this figure was used as a preliminary recommended TAC for 1981. Uncertainties about survey coverage and assumptions about the distribution of the resource prompted another biomass survey in 1981. Results of this survey were unavailable at the time of writing.

6.8.1 Condition of the resource

The S. alutus stock in Moresby Gully is probably the last unexploited stock of this species in Canadian waters. The stock has a very large component of large, old fish and because the contribution of these older individuals to stock maintenance and dynamics is not understood, the exploitation of this stock should be approached with caution. The decreased productivity associated with other exploited stocks of S. alutus has been previously noted and the Moresby Gully stock may provide the best opportunity for understanding the relationships between biomass, age composition and productivity.

6.8.2 Recommendation

The results of the 1981 biomass survey of this area will provide a substantial input into yield determination. Since these results are not available at the time of writing the recommended TAC of S. alutus in the 5C area during 1982 is 1,500 t. The recommended TAC in Area 5D is 100 t.

Exploitation of the Moresby Gully stock of S. alutus must be monitored closely and changes in biological and fishery data related to stock productivity of this and other stocks.

7. WEST COAST OF QUEEN CHARLOTTE ISLANDS (AREA 5E) STOCK ASSESSMENTS

Principal species (based on a 5-yr average) in the Canadian landings from the west coast of Queen Charlotte Islands are Pacific ocean perch (1,217 t), Other rockfish (1,005 t), and sablefish (320 t).

In the following sections stock assessments are presented for Pacific ocean perch, and rockfish. Assessment for sablefish is presented for the entire coast in Section 2.1 of this report.

Table 7.1. British Columbia groundfish landings (t) by main species in the Queen Charlotte Islands (Area 5E), 1976-80.

Species	1976	Canadian landings ^a (t)			1980 ^d	5-yr average
		1977	1978	1979		
Pacific ocean perch	78.8	1,550.6	2,426.5	1,066.8	961.5	1,216.8
Other rockfish	0.7	1,635.6	1,709.5	816.8	863.1	1,005.1
Sablefish	249.9	159.2	344.6	805.6	40.9	320.0

^a Included are landings by trawl, trap, longline, handline, and troll.

^d 1980 handline, and troll landings not available.

7.1 Pacific ocean perch (Sebastes alutus)

Previous documents have dealt with the historical foreign fishery in this area, which was largely restricted to north of 54°00'N. South of 54°00'N the rockfish fishery has experienced uninterrupted declines in catch rate. Statistics of the fishery for all Sebastes spp. are:

	Year			
	1977	1978	1979	1980 ^a
Landings (t)	2824	4097	1375	1761
Effort (h)	613	1337	495	948
LPUE (t/h)	4.61	3.06	2.78	1.85

^aPreliminary figures

Declines in productivity and catch rates have occurred for almost all major fishing grounds. Time/area closures were instituted in 1979 in an attempt to optimize productivity of the two major rockfish species, S. alutus and S. reedi.

7.1.1 Condition of the resource

Regression of fishery statistics over the period of the domestic fishery suggests a biomass of ~15,200 t with a 90% confidence interval of 11,800-24,500 t. Approximately 65% of this biomass was S. alutus. The 1979 biomass survey of the 5E area indicated a rockfish biomass of approximately 18,300 t ± 38%; although the percentage of S. alutus was lower in the survey estimate (40-45%). The survey did not attain detailed coverage of the lower west coast of the Queen Charlotte Islands, however, and the estimate of S. alutus composition may be low.

Fishery removals from Area 5E have been highly localized and previous management measures have reflected this localization (specific time area/closures). The persistence of declining fishing success for these areas, as reflected in CPUE, is a matter of grave concern. In large measure, the maintenance of production from Area 5E has resulted from shifts in centres of production, in response to declining CPUE. CPUE decreases in some localities have been even more dramatic.

Biomass calculations suggest yields in the 300-600 t range for S. alutus south of 54°00'N. Landings may have reduced primitive biomass by almost 40%; if this is true then subsequent yield should be set no greater than what will maintain stock levels at present size. Future research into factors arising from the age structure of the stock may dictate different management objectives.

Data from the fishery have indicated that S. alutus may be more available in the early months of the year. The successful optimization of joint but unequal yields of S. alutus and S. reedi in Area 5E has made use of this change in availability, by restricting S. alutus harvest when it is available in greater measure than S. reedi (January-March).

The foreign fishery for S. alutus north of 54°00'N has been detailed in previous reports. The 1979 biomass survey of the Langara Spit area resulted in a biomass estimate of 5,225 t of marketable rockfish, of which ~ 2,800 t was S. alutus. The 1981 permit fishery in this area did not result in major landings of S. alutus, rather the landings were composed primarily of S. aleutianus. There is therefore no evidence indicating any substantive change in the S. alutus stock in this area. Biological data do not show evidence of strong incoming year-classes.

7.1.2 Recommendation

No changes in the TACs for S. alutus in Area 5E during 1982 are recommended. North of 54°00'N the recommended TAC is 200 t and south of this parallel the recommended TAC is 600 t. In addition the January-March (inclusive) closure south of 54°00'N is again recommended for 1982.

7.2 Yellowmouth rockfish (Sebastes reedi)

Area 5E has been one of the few coastal areas supporting a fishery for S. reedi; the production history is contained in Table 7.2.1. Production has declined since the inception of the fishery in Area 5E until 1980, although some production drops were due to closures. CPUE also declined from 1977-79 but did rise in 1980. Qualified CPUE declined by 38% in 1980, and has declined since the fishery began.

Biological data for S. reedi in Area 5E are also limited but they do not show an extensive age composition similar to the other Sebastes spp. The 1979 samples from this area show a broad mode of abundance between 17-27 yr and no fish older than 35 yr. By contrast, samples of S. reedi from Area 3C, where S. reedi is not generally fished show the more typical age spectrum for this genus (9-60 yr).

7.2.1 Condition of the resource

The age composition of S. reedi in Area 5E is inconsistent with the assumed exploitation history of this area. The lack of older fish in this stock when compared with other areas suggests substantial exploitation pressure or unavailability of older fish. The former is less probable due to the general co-occurrence of this species and S. alutus, which has evidently suffered relatively light fishing pressure. Age composition of S. reedi is similar to that in Queen Charlotte Sound, where exploitation has been substantial. Total instantaneous mortality (Z) estimates for the west coast Charlottes and Queen Charlotte Sound are 0.34-0.38 and 0.14-0.21, respectively.

The age composition of this stock must be closely monitored for changes resulting from exploitation.

7.2.2 Recommendation

A TAC of 600 t of S. reedi is recommended for Area 5E south of 54°00'N during 1982. North of 54°00'N a TAC of 100 t is recommended.

7.2.3 Other rockfish

The other Sebastes spp. of major importance in the 5E area are S. aleutianus and S. brevispinis. The former has been the major contributor to the fishery north of 54°00'N during 1980. Little fishery or biological data are available on these species. Age composition data for both species show very extensive structure to the stocks; up to 100 yr for S. aleutianus. 1980 fishery data suggest slightly greater biomass of S. aleutianus north of 54°00'N, than did the 1979 survey (Table 7.2.2).

7.2.4 Recommendation

North of 54°00'N the following TACs for rockfishes other than S. alutus are recommended for 1982:

<u>S. aleutianus</u>	250 t
<u>S. brevispinis</u>	100 t

South of 54°00'N, the recommended TAGs are:

<u>S. aleutianus</u>	250 t
<u>S. brevispinis</u>	350 t
<u>S. pinniger</u>	400 t
<u>S. proriger</u>	250 t
<u>S. ruberrimus</u>	300 t

Table 7.2.1. Canadian catch (t) and CPUE (t/h) of Sebastes reedi, 1971-80.

Year	AREA 5C-D						AREA 5E					
	Interviewed catch (Total in brackets)			Qualified (25%)			Interviewed			Qualified (25%)		
	C	E	CPUE	C	E	CPUE	C	E	CPUE	C	E	CPUE
1971	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-
1977	3.8	3.0	1.26	3.75	2.5	1.50	1256.7	583.0	2.156	1243.30	458.20	2.713
1978	-	-	-	-	-	-	973.4	579.0	1.681	727.61	274.57	2.650
1979							394.2	414.0	.952	321.60	195.80	1.642
							(405.4)					
1980							470.4	317.9	1.480	470.42	317.98	1.479

Table 7.2.2. Canadian catch (t), effort (h) and CPUE (t/h) of Sebastes aleutianus, 1971-80.

Year	AREA 5E					
	Interviewed catch (Total in brackets)			Qualified (25%)		
	C	E	CPUE	C	E	CPUE
1971	-	-	-	-	-	-
1972	-	-	-	-	-	-
1973	-	-	-	-	-	-
1974	-	-	-	-	-	-
1975	-	-	-	-	-	-
1976	-	-	-	-	-	-
1977	76.3	135.0	.565	74.69	66.00	1.132
1978	134.0	390.0	.344	100.89	111.20	.907
1979	206.1 (206.1)	487.0	.423	168.00	185.60	.905
1980	31.9	92.8	.345	28.31	13.30	2.129

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APPENDIX 1

ESTIMATED INSTANTANEOUS TOTAL MORTALITY (Z) RATES FOR ROCKFISHES (Sebastes spp.)

As a result of recent changes in age determination techniques for rockfishes, our estimation of mortality rates for these species has also changed. Figure A1 illustrates the difference in age estimates and mortality rates between surface and section ageing for Sebastes alutus in Area 5E. Similar changes have been noted for all other rockfishes examined.

Table A1 presents estimates of total mortality, as derived using most recent ageing techniques. In most instances where stocks have no history of exploitation or only limited exploitation, the estimate of Z is taken as an approximation of M. Previous estimates of M, where available, are included under the species headings. No independent estimates of M are available, with the exception of that from application of Fournier's catch-at-age model for S. alutus in Queen Charlotte Sound (Section 5.2).

The implications of lowered natural mortality rates are major, since many methods of yield calculation carry the implicit or explicit consideration of M in their calculations, most often as a fixed component of a variable Z. Reduction of this component obviously raises the mortality component attributable to fishing.

Table A1. Summary of total instantaneous mortality rates (Z) by species, by statistical area and for sexes combined for both research and commercial rockfish catches, 1977-1979.

Species	Area	Sample type, date	Z	N	
<u>S. aleutianus</u>	5E	Commercial 1978	0.05	194	
		1979	0.02	99	
		Research 1979	0.04	194	
<u>S. alutus</u>	5B	Commercial 1979	0.10	797	
	Previous estimate 0.12 (M)	5C	Commercial 1979	0.06	200
		5D	Commercial 1979	0.01	99
	5E	Commercial 1978	0.05	504	
		1979	0.05	949	
		Research 1979	0.02	280	
<u>S. brevispinis</u>	3C	Commercial 1978	0.04	100	
	Previous estimate 0.20 (M)	5A	Commercial 1978	0.04	57
			1979	0.04	199
		Research 1979	0.05	98	
	5B	Commercial 1977	0.05	191	
		1978	0.04	198	
		1979	0.07	97	
	5C	Research 1979	0.03	99	
		Commercial 1978	0.05	193	
	5D	Commercial 1979	0.06	100	
Commercial 1977		0.05	457		
	1978	0.03	98		

(cont'd.)

Table A1. (cont'd.)

Species	Area	Sample type, year	Z	N
<u>S. crameri</u>	5E	Research 1979	0.07	198
<u>S. entomelas</u>	5B	Research 1979	0.05	100
<u>S. flavidus</u>	3D	Research 1978	0.10	282
Previous estimate	5B	Commercial 1979	0.07	199
0.2 (M)		Research 1979	0.07	300
	5D	Commercial 1979	0.06	100
<u>S. pinniger</u>	3D	Commercial 1977	0.02	120
Previous estimate		1979	0.03	201
0.2 (M)		Research 1979	0.02	103
	5A	Commercial 1978	0.04	99
	5B	Commercial 1977	0.05	101
		1978	0.08	290
		1979	0.05	100

(cont'd.)

Table A1 (cont'd.)

Species	Area	Sample type, year	Z	N
<u>S. pinniger</u>	5C	Commercial 1978	0.05	380
		1979	0	89
	5E	Commercial 1978	0.02	100
<u>S. proriger</u>	5A	Commercial 1978	0.10	85
<u>S. reedi</u>	5A	Commercial 1977	0.11	286
		1979	0	100
Previous estimate 0.15 (M)		Research 1978	0.08	295
		1979	0.18	100
	5B	Commercial 1979	0.12	100
	5E	Commercial 1977	0.19	411
		1978	0.16	461
		1979	0.21	392
		Research 1979	0.12	199
<u>S. zacentrus</u>	5E	Research 1978	0.07	198

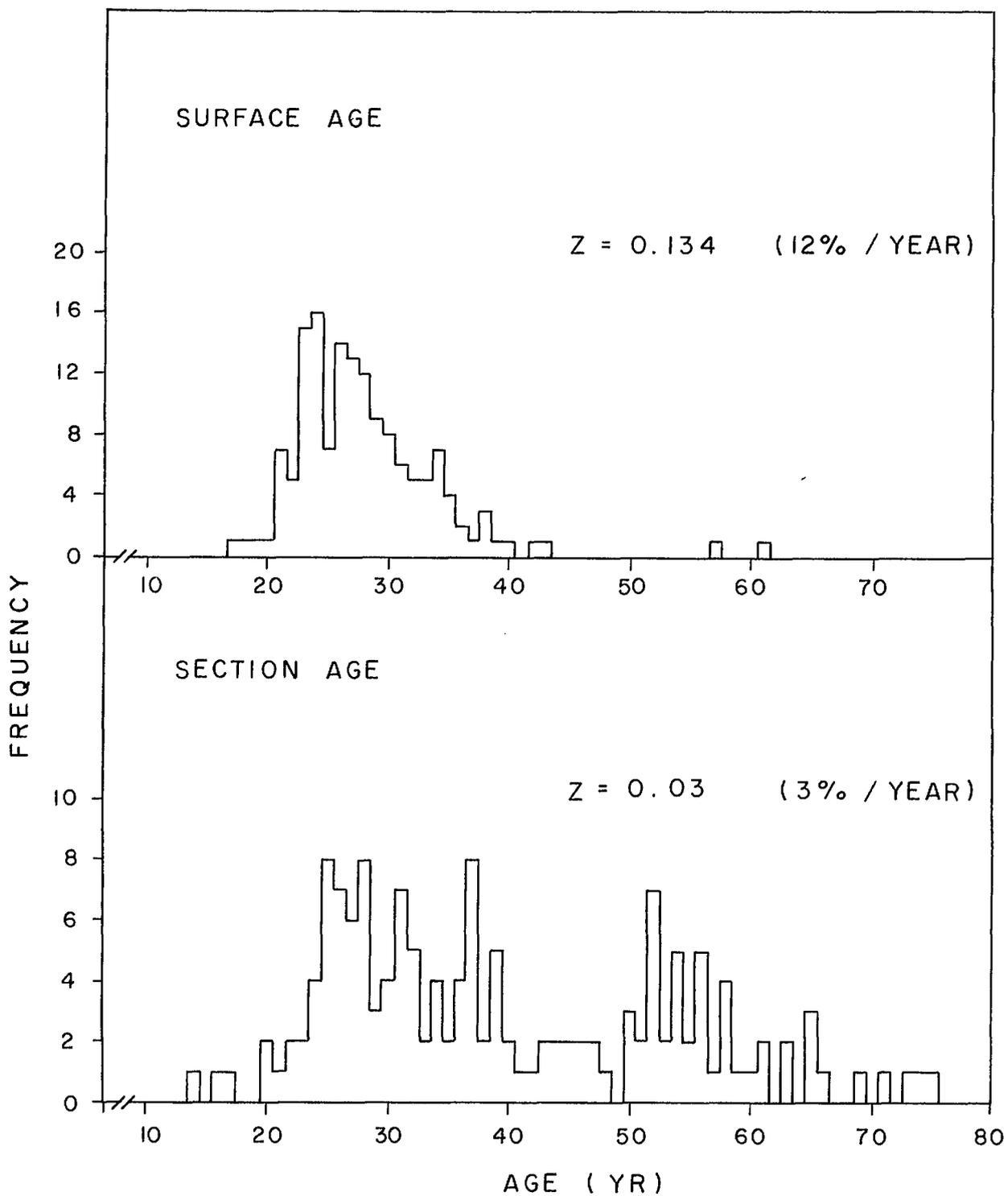
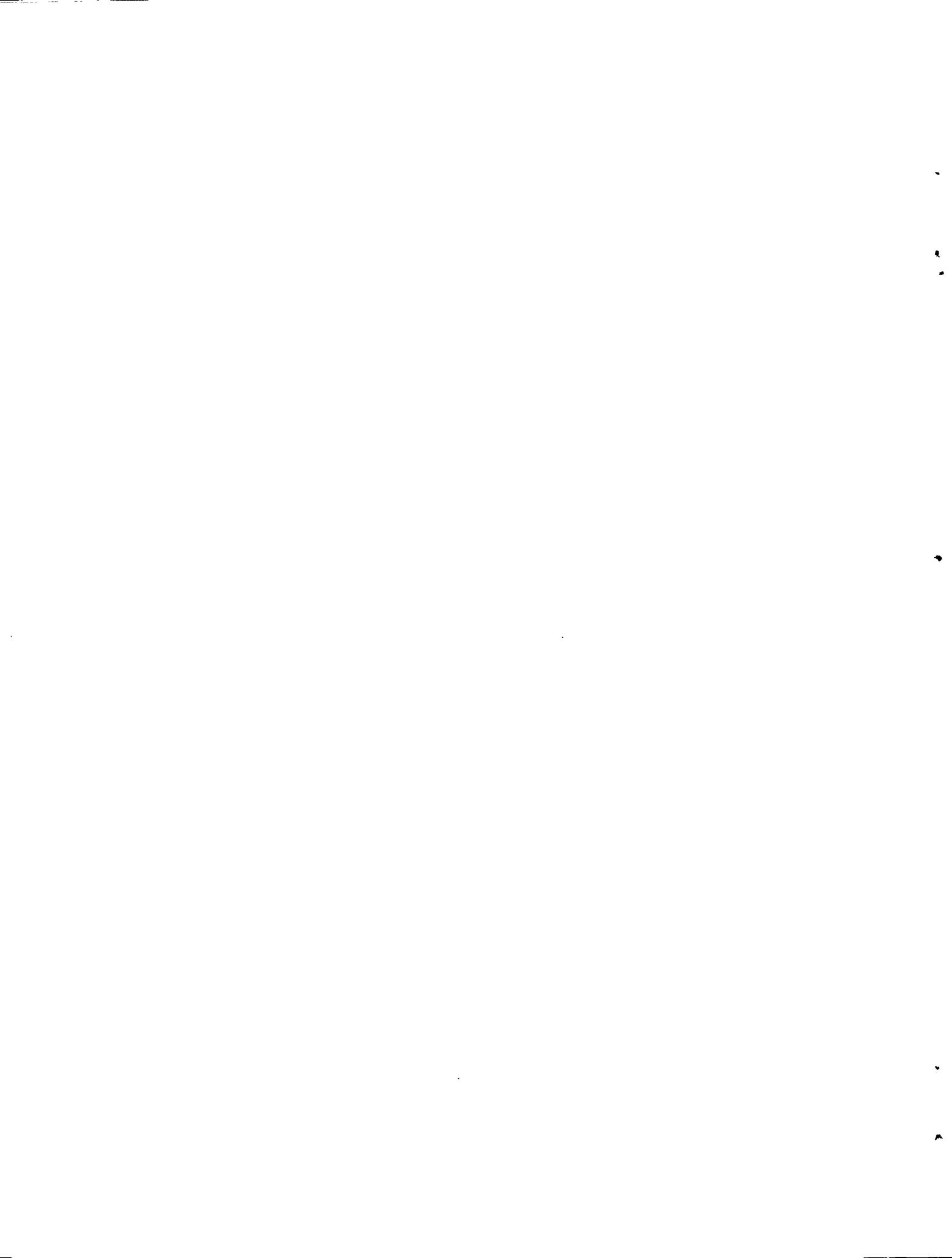


Fig. A 1. Comparison of estimated age frequency for *S. alutus* from Area 5E when aged from surface readings of otoliths (top) and sections of otoliths (bottom).



APPENDIX 2

RECONSTRUCTION AND SIMULATION MODELS FOR PACIFIC OCEAN PERCH IN GOOSE ISLAND GULLY

1. Reconstruction Model [Fournier and Archibald (in press)]

One of the important features of Fournier's model is its incorporation of both measurement and process errors. For example, it is assumed that:

$$\hat{C}_i = C_i e^{\epsilon_i}$$

where C_i = estimated total catch in year i
 C_i = actual total catch in year i
 ϵ_i = independent normally-distributed random variable with mean zero and variance σ^2 .

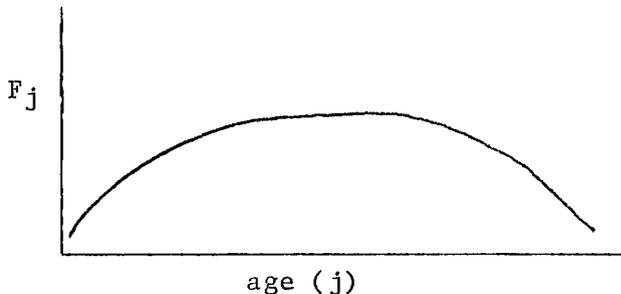
While the true value of σ^2 will be unknown, the choice used will reflect our confidence in the catch estimation. M was assumed to be constant over all ages and years.

Instantaneous fishing mortality (F) is more complicated to parameterize and was approached in the following way:

$$\log F_{ij} = a_i + b_j$$

where F_{ij} = F of age j in year i
 a_i = general level of F due to the activity (effort) of fishermen in year i
 b_j = relative level of fishing vulnerability of age class j

The b_j term represents recruitment to the fishery and is flexible in that any curve that is applicable to the particular situation may be used. In our case, b_j was parameterized in the shape of a flattened parabola:



The drop in F at older ages would indicate fish moving out of the fishing ground, perhaps to deeper water. In our case the drop in F at the older ages was reduced because the F for the last few ages was held constant.

The incorporation of additional information and assumptions

Ageing errors - The problem of accurate age determination is a major source of error in the ocean perch data. The entire data series available to us (1963-1977) was aged by surface reading of otoliths, a method which is believed to underestimate the true age, especially for older fish (Beamish 1979). Surface age estimates of more than 17 years could not be relied upon and essentially provided no information beyond the fact that there were older fish. Underestimates of four years or more were common. As a result, age-groups ≥ 17 yr were lumped together in the catch-at-age data.

Ageing errors for otoliths <17 yr were smaller (generally <2 yr) and an attempt was made to adjust the input data for these errors, using 1979 ageing information to quantify the corrections. Since corrections for this group resulted in very small improvements in model fits, all reconstructions were done with no adjustments made for fish <17 yr old.

Fishing effort - Effort information was incorporated into the model by way of the following assumption:

$\log F_{ij} = a_i + b_j$
where $a_i = \log q_i + \log E_i + D_i$
and where q_i = catchability in year i (may be held constant or allowed to vary with time)
 E_i = total fishing effort expended on perch in Goose Island Gully in year i
 D_i = a random normal variable with mean zero and variance σ^2

The model can be directed to favour solutions where the average F in each year is related to the observed effort by penalizing it for deviating from the observed effort. This is done by subtracting a penalty function from the log likelihood function the model is trying to maximize, and this penalty function is given a weight to account for the investigator's subjective judgement about the accuracy of the effort information. This weighting factor (W) is related to the variance of D_i as follows:

$$\frac{1}{2\sigma^2} = W$$

A large weight (small σ^2) would force the model to pursue solutions that conform closely to the effort information, implying a great deal of confidence in that information. A small weight (large σ^2) would allow the model to pursue solutions that only loosely conform to the effort information. In our case, a weight of 25 ($\sigma = 0.14$) was used in the reconstructions, implying only a moderate amount of faith in the data.

Stock-recruit relationship - For Pacific ocean perch, we assumed a Ricker-type relation between parental stock size (number of females ≥ 11 yr old x age-specific fecundity) and recruitment to the fishery 6 years later (6 years was the youngest age in the catch). The model then contains the additional consideration that solutions which have a Ricker-type relation between stock and subsequent recruitment are to be favoured. Penalty weights may also be assigned here according to the user's intuition about the fidelity of the stock-recruit relationship.

Relative error sizes - The stock-reconstruction model deals with a large amount of information, most of it with an unknown degree of error associated with it. It must know what relative accuracy is involved with the data and underlying processes if it is to know which parameters to vary in an attempt to arrive at a reasonable solution. Since the errors involved are largely unknown the approach taken was to adjust the various relative errors (variances) until a suitable fit was deemed to be obtained. This procedure is quite arbitrary, but is an inescapable fact that age structure and effort data do not contain enough information to determine the relative accuracies of the

ageing data, the total catch data, the regularity of fishing mortality, or the relationships between effort and average fishing mortality and between stock size and subsequent recruitment.

In these reconstructions, the instantaneous natural mortality was fixed at 0.05. Once the model has been allowed to find a solution, M can be freed from its fixed value and estimated by the model. This was done and the final model estimate was ≈ 0.04 which provides some support for our choice of a low value for M. Decreasing M to 0.04 did not significantly improve the overall fit to the data and the results are not presented; the main difference as compared to the 0.05 run was a slight decrease in the reconstructed numbers at age and a slight increase in fishing mortality. Additional support for the value in the 0.05-0.04 range was derived from those runs using fixed values of M which were much higher (e.g. 0.20); after release from these constraints all such runs derived estimates of $M = 0.05$.

As mentioned earlier, older age classes (>17 yr) were lumped together in the input catch-at-age data. Without doing this, the severe ageing errors for older fish presented in the data produced unreasonable results. For example, without lumping the older ages the fit was best with a value of 0.3 for M, an impossibly high value give that 60-yr old fish are common in unexploited S. alutus stocks.

Although the inclusion of a generalized stock-recruit relation does not improve overall model fit, it may provide us with a more reasonable solution, at least one that assumes there is a relationship, however vague, between parent stock size and subsequent recruitment. Other than the great variability in recruitment due to unknown environmental factors, the greatest source of error in this is the age-specific fecundity data, which in our case was obtained from Gunderson (1976) (Table A2). These data indicate that fecundity is constant for females >24 yr old, but fecundity is not well investigated for older fish. If in fact fecundity continues to increase with age beyond age 24, then this would significantly affect the parameters of the stock-recruit curve estimated from the reconstruction. A sensitivity analysis concerning this aspect of age-specific fecundity is underway, and preliminary results indicate that the increase in fecundity beyond age 24 would have to be substantial in order to significantly alter the estimated stock-recruit relationship.

2. Forward simulations

Forward simulations were made with a simple model incorporating considerations of age-specific mortality and fecundity, as well as stochastic variation in the stock-recruitment relationship. The model was driven by numbers and results were converted to weight in order to obtain stock biomass and yield estimates. Some comments on features of the model follow.

Assignment of mortalities - Natural mortality was again assumed to be independent of age and year and was set at 0.05. Fishing mortality was allowed to vary between simulation runs so different harvesting strategies could be examined, but was held constant for the duration of each run. Each fishing mortality used was the same in a relative sense to the 1977 F at age as calculated by the reconstruction. That is, to produce any desired F level for simulation, the F for each age class in 1977 was multiplied by a constant, 0.5, 1.0, 1.5, etc. This method assumes the recruitment pattern to the

fishery does not change over the time period simulated (in our case, 30 years into the future). The values of reconstructed F at age for 1977 are shown in Table 5.2.3.

Calculation of numbers of fish - Change in number of fish in the population over time was assumed to follow the usual exponential decline:

$$N_{i+1,j+1} = N_{ij} e^{-Z_{ij}}$$

where i = year subscript
 j = age subscript

$$Z_{ij} = F_{ij} + M$$

= total instantaneous mortality of age j fish in year i.

The proportion of total deaths that contribute to the yield is calculated using the well-known catch equation (after Ricker 1975):

$$C_{ij} = \frac{N_{ij} F_{ij}}{Z_{ij}} \left(1 - e^{-Z_{ij}} \right)$$

where C_{ij} = catch of age j fish in year i.

The simulation model deals separately with age-classes 6-28 inclusive and lumps older fish into a >29 yr-old category. This is simply a bookkeeping device and does not affect the results since M and F are assumed to be constant for these older fish. The bookkeeping is done as follows:

$$N_{i+1,>29} = N_{i,>29} e^{-Z_{i,>29}} + N_{i,28} e^{-Z_{i,28}}$$

where N_{i+1,>29} = the number of fish of age >29 yr in year i+1.

Converting numbers to weight - once numbers of fish have been calculated for both the population and the catch, it is simply a matter of multiplying by the average weight-at-age in order to convert the results to weight. Since there is no direct weight-at-age data available for Pacific ocean perch off the B.C. coast, length-at-age and length-weight information were used to produce an estimate of the weight-at-age relationship. The average weights-at-age used in the simulation are presented below:

Age (years)	Weight (kg)								
6-13 (respectively)	.485	.529	.572	.614	.654	.694	.732	.770	
14-21 (respectively)	.806	.841	.876	.909	.942	.973	1.00	1.03	
22->29 (respectively)	1.06	1.09	1.12	1.15	1.17	1.20	1.22	1.30	

Recruitment - Factors affecting the recruitment of ocean perch are virtually unknown and certainly nothing is known of the relative importance of parental stock size and environmental factors. At present, the only prediction available for recruitment is parental stock size and the relationship between these two variables as estimated by the reconstruction analysis. Population fecundity (parental stock size) was calculated from the number at age and age-specific fecundity information. The assumption of a specific sex ratio is unimportant as the fecundity numbers are only important in a relative sense. The assumptions being made in the calculation of population fecundity are that neither the age-specific fecundity nor the sex ratio changes with time and that the sex ratio (whatever it is) is the same for all ages. The latter may not be true in unexploited stocks, and may underestimate parent stock effects.

The foregoing would be sufficient to account for future recruitment if parental stock size were the only factor influencing ocean perch recruitment. Environmental factors undoubtedly play a major role and this is clearly seen in the very large year-classes that occur once every decade or so (presumably as a result of favourable environmental conditions), with the intervening year-classes being comparatively weak. The variation about predicted recruitment due to environmental influences would therefore appear to be log-normal and this can be partly taken into account by introducing stochastic variation:

Original predictive equation -

$$R = \alpha P e^{-\beta P}$$

where R = predicted number of recruits (6-yr-olds) 6 yr later,
 P = parental stock fecundity,
 α, β = parameters of Ricker curve.

Stochastic equation -

$$R = \alpha P e^{-\beta P} e^i$$

where i is a normally distributed random variable with mean of zero and variance of σ^2 .

Results of the simulations are presented in Section 5.2.

This simulation model is very simplistic in the sense that it does not take into account the changes in the stock structure which will occur during the reconstruction process, and which will have a beneficial effect on stock reproduction. A more detailed model which accounts for these and other changes is being formulated.

Table A2. Absolute fecundity (thousands of eggs per female) of Pacific ocean perch in Queen Charlotte Sound, from Gunderson (1976), and corresponding relative fecundity values used in the analysis.

Age of female (years)	Absolute fecundity	Relative fecundity
<u><10</u>	0	0
11	45.7	1.00
12	55.7	1.25
13	67.3	1.50
14	78.6	1.75
15	90.1	2.00
16	100.4	2.20
17	111.5	2.45
18	122.1	2.70
19	133.5	2.90
20	142.2	3.10
21	151.3	3.30
22	158.9	3.50
23	166.9	3.65
<u>>24</u>	175.2	3.80

