

# Pacific Cod Tagging. II. Migration and Stock Delineation.

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II. MIGRATION AND STOCK DELINEATION.

by

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ABSTRACT

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During 1944-70, 34,218 Pacific cod (Gadus macrocephalus) were tagged by Canadian and United States biologists in the waters of British Columbia and Washington State--21,631 by Canada and 12,587 by United States. Tagging localities in Canadian waters were Hecate Strait, off southwest Vancouver Island, Juan de Fuca Strait, and Georgia Strait. Tagging localities in United States waters were Puget Sound, Georgia Strait, Juan de Fuca Strait, and off the west coast of Washington State.

Inter-regional migration was minor to negligible in virtually all experiments. Intra-regional migration also appeared to be minor, but clear delineation was inhibited by a number of factors--too few cod tagged; differential migration by size (age) and year-class abundance; and short life span of Pacific cod.

A bibliography of Canada-U.S. reports published on this subject is included.

Key words: migration, stock delineation, Pacific cod, tagging, bibliography

RÉSUMÉ

Westrheim, S. J. 1982. Pacific Cod Tagging. II. Migration. Can. MS Rep. Fish. Aquat. Sci. 1663: v + 77 p.

De 1944 à 1970, des biologistes canadiens et américains ont étiqueté 34 218 morues du Pacifique (*Gadus macrocephalus*) peuplant les eaux de la Colombie-Britannique et de l'État de Washington. 21 631 étiquettes ont été posées par les biologistes canadiens et 12 587 par les Américains. Au Canada, l'étiquetage a eu lieu dans les eaux suivantes: le détroit d'Hécate, au large de la côte sud-ouest de l'île Vancouver, le détroit Juan de Fuca et le détroit de Géorgie. Aux États-Unis, l'étiquetage a été fait dans le détroit Puget, le détroit de Géorgie, le détroit Juan de Fuca et au large de la côte ouest de l'État de Washington.

La migration inter-régionale variait de mineure à négligeable au cours de presque toutes les expériences. La migration intra-régionale semblait aussi être mineure, mais on n'a pu établir une délimitation nette en raison d'un certain nombre de facteurs dont le nombre peu élevé de morues étiquetées, la différence dans la migration selon la taille (âge) et l'abondance des classes d'âge, et la courte durée de vie de la morue du Pacifique.

Ce document comprend aussi une bibliographie des rapports publiés par le Canada et les États-Unis à ce sujet.

Mots-clés: migration, délimitation des stocks, morue du Pacifique, étiquetage, bibliographie.

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## INTRODUCTION

Pacific cod (Gadus macrocephalus) is one of the important species in the Canada-United States trawl fishery conducted off British Columbia. In response to expansion of the domestic groundfish industry and Canada's new responsibility for marine resources within the 200-mile economic zone, research has also expanded, particularly with respect to stock identification and assessment. Pacific cod is one of the groundfish species which has recently received increased attention.

This report is the second in a series to provide a comprehensive analysis of all past tagging experiments. The first report (Westrheim and Forrester 1975) contained an inventory of all Canadian Pacific cod tagging experiments, a review of all published reports relating to these experiments, and an analysis of tag-type comparison studies undertaken during some of the experiments. This report presents an analysis of past tagging experiments with respect to migration and stock identification, and a bibliography of all Canadian and U.S. reports published on this subject.

## GENERAL RESULTS

During 1944-68, 21,629 Pacific cod were tagged and released by the Fisheries Research Board of Canada--6,859 in the Strait of Georgia (International Area 4B) during 1944-61; 1,686 off Southwest Vancouver Island (Area 3C) during 1959-62; and 13,084 in Hecate Strait (Areas 5C, 5D) during 1960-68 (Fig. 1, Table 1). Details on tagging dates and types of tags used were reported by Westrheim and Forrester (1975). Recapture rates were 16% for the Strait of Georgia, 18% for the Southwest Vancouver Island experiments; and 27% for the Hecate Strait experiments.

Overall, there was little migration of tagged cod among the three tagging regions, despite substantial landings (Fig. 2). In the Strait of Georgia (Area 4B), 1,011 were recaptured for which area of capture was known, and 90.8% of these were taken in Area 4B; 8.5% in the adjacent Area 4A; 0.6% in Area 3C; and 0.2% in Area 3B (Table 1). Off Southwest Vancouver Island (Area 3C), the 283 known-area recaptures were distributed 97.9% in Area 3C; 1.8% in Area 4B; and 0.4% in Hecate Strait (Area 5C + 5D). In Hecate Strait, the 3,334 known-area recaptures were distributed 99.7% in Hecate Strait (5C + 5D); 0.2% in Queen Charlotte Sound (5A + 5B); and 0.1% off Northwest Vancouver Island (Area 3D).

Similar results were reported by Gosho (1976) for United States experiments conducted during 1955-70 in Areas 4A, 3A, 3B, and 3C (Fig. 1, Table 2). Recapture proportions within tagging regions were 97.7, 57.1, 88.1, and 85.7, respectively, for Areas 4A, 3A, 3B, and 3C. The experiments conducted in Area 4A yielded few recaptures elsewhere, except in 4B (1.9%). Numbers tagged and recaptured in the Area 3A (30/7) and 3C (92/7) experiments

were too small for interpretation, but the Area 3B experiment (109 usable recaptures) produced widespread recaptures--Areas 4A (4.6%), 3C (5.5%), 3D (0.9%), and 5A (0.9%).

## STRAIT OF GEORGIA AND VICINITY (AREA 4B)

### Introduction

Trawl fisheries in the Strait of Georgia and vicinity (Area 4B) are more seasonal than elsewhere in British Columbia waters, because of regulations and the relatively low abundance of groundfish species (Forrester and Ketchen 1963; Forrester and Smith 1974; Westrheim 1980). Time-area closures generally apply to the period April-September. Catch rates become more attractive during October-March when stocks congregate for spawning, and adverse weather prevails on the offshore grounds. Principal areas of cod production during 1945-60 were Minor Statistical Area<sup>a</sup> 14, Nanoose Bay (MSA 17-N), and the Gulf Islands (MSAs 17S+18) which together accounted for 86% of the cod landings from Area 4B (Fig. 3) (Forrester and Ketchen 1963). MSAs 12, 13, 15, and 16; 19 and 20; and 28 and 29 were each minor contributors.

Time-area closures are most prevalent in MSA 14, where a substantial portion was closed to trawling from at least late March to mid-October (Table 3). In MSA 17, Nanoose Bay (MSA 17-N) was only open during January 31 (February 1)-March 20, and Boat Harbour (17-S) was open from May 15 to the following January 14. At Nanoose Bay, Pacific cod only appear during February-March, to spawn. The January 15-May 15 closure of the Boat Harbour area was imposed to protect a small stock of English sole (*Parophrys vetulus*) during the spawning season. In MSA 18, a small area in Satellite Channel was closed to trawling from March 21 to mid-October. In MSAs 19, 20, and 29, no time-area closures were imposed. Most of MSA 28 was closed to trawling by 1954.

Catch statistics for 1954-65 exhibit the seasonal nature of the trawl fishery for Pacific cod in the major regions of Area 4B (Fig. 4). January-March and October-December are the principal periods of production. In the Southeast Strait (MSA 29 and adjacent portions of Area 4A), July-September is the only period of low production for Pacific cod (Fig. 5).

### General results

During 1954-61, 29 tagging experiments were completed in the Strait of Georgia and vicinity (Area 4B) (Fig. 3). A total of 6,814 Pacific cod were tagged and released, and 1,076 (16%) were subsequently recaptured (Table 4). Pacific cod were tagged in MSAs 14, 17, 18, 19, and 20.

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<sup>a</sup>Hereafter referred to as MSA in this report.

Prior to 1954, seven minor experiments were completed in which a total of 45 cod were tagged, and 5 (11%) were recaptured (Table 5). No notable migrations were reported. Manzer (1952) reported on the final results of the 1944 experiments, and Forrester (1954) reported on the final results of the 1952 experiments.

Migratory patterns of the tagged cod led to grouping the 1954-61 experiments into four geographic regions--MSA 14, (N. of Nanoose), Nanoose Bay (MSA 17-N), Gulf Islands (MSAs 17S+18), and Juan de Fuca (MSAs 19+20).

#### Time at liberty

Among experiments, maximum time at liberty for recaptured Pacific cod tagged in Area 4B ranged from 12 to 35 months (Table 6). Goshö (1976) reported a range of 8-50 months for 14 experiments conducted in Area 4A. For the more important experiments in Area 4B, 88-100% of the recaptured cod were taken during the first 12 months after tagging. Goshö (ibid.) reported similar results.

Plausible explanations for this phenomenon include short life-span, fisheries underway at the time and site of tagging, or tag shedding. Pacific cod grow rapidly, mature early, and die relatively young. Maturity begins at age 2; is nearly complete at age 3; and few cod live beyond age 5 (Westrheim 1977a, b). Approximate mean lengths-at-age during January-March (when most of the tagging experiments were conducted) are 45 cm at age 2.0; 62 cm at age 3.0; 70 cm at age 4.0; and 75 cm at age 5.0. Negligible quantities of cod older than age 4 have been found in the commercial landings from Area 4B. During 1954-61, size composition of cod landed from Area 4B was generally unimodal at 50-63 cm, with mean lengths ranging from 50.3 to 62.1 cm (Ketchen 1967). Hence, most of the tagged cod were mature fish nearing the end of their life span. High initial recapture rates were typical of experiments in which cod were tagged at the site of an active commercial fishery--see the results for the Deep Bay, Porlier Pass (1957), and Swanson Channel experiments (Table 6). In these cases, 47-93% of the recaptures took place during the quarter-year of tagging. For the 1958 and 1959 Porlier Pass experiments, the cod were tagged in an area permanently closed to trawling, hence the low initial rate of recapture, except for the February 1957 experiment. Tag shedding might have been a minor factor, but all experiments exhibited the same phenomenon despite the great variety of tags employed among experiments (Westrheim and Forrester 1975).

#### Size and age composition

Size composition of Pacific cod tagged in the principal experiments varied among areas (Fig. 6). At Cape Lazo and Nanoose Bay, size compositions were generally unimodal at 59 or 62 cm, suggesting that most of the fish tagged were age 3. At Porlier Pass, size composition was unimodal at 47-50 cm, with a low plateau at 56-65 cm. Thus the Pacific cod tagged at Porlier Pass were probably mostly age 2. At Swanson Channel, size composition was trimodal (44, 56, and 62 cm), and age composition was estimated to be mostly ages 2 and 3 (adjusted to January-March).

Recapture rates by length interval were remarkably uniform, over the size ranges of Pacific cod tagged at Nanoose Bay, Porlier Pass, and Swanson Channel, as indicated by the fairly congruent distributions of tagged and recovered fish. At Cape Lazo, above-average recapture rates were noted at 50-53 cm, and 65 cm. No explanation can be provided at this time.

Interestingly, the recovery rate and time at liberty were not any better, in general, for Porlier Pass experiments, involving mainly age 2 fish, than for Nanoose Bay and Swanson Channel experiments, where tagged fish were mostly age 3. Possibly there was a greater tagging mortality rate on the younger cod tagged at Porlier Pass.

## Migration

### Area 4B

Spatial distribution of recaptured cod indicated the presence of a number of sub-stocks within Area 4B. Recapture rates were high for major tagging regions, except for Nanoose Bay--93% for MSA 14; 45% for Nanoose Bay; 92% for Gulf Islands; and 81% for Juan de Fuca Strait (Table 7). Principal origins of spawning cod appearing in Nanoose Bay were Southeast Georgia Strait (MSAs 29, 80, 82, and 83), 26%; Gulf Islands (17S+18), 13%; and Juan de Fuca Strait (19, 20, and 86), 5%. Only MSA 14 did not produce any recaptures in Juan de Fuca Strait or in offshore areas (3A-3C). All regions produced recaptures in the Canada-U.S. Southeast Strait (MSAs 29, 80, 82, and 83).

### MSA 14

In MSA 14, 10 tagging experiments were completed, during 1954-57. A total of 396 Pacific cod were tagged and released, and 84 (21%) were subsequently recaptured (Table 4). Cod were tagged at Cape Lazo (271), Union Bay (9), Deep Bay (98), and French Creek (18). Two experiments yielded no recaptures--Cape Lazo in September 1954 (6 tagged); and Union Bay in October 1954 (9 tagged). Time of tagging for the remaining eight experiments was December-February.

Cape Lazo and Union Bay experiments were conducted while the trawling season was closed, whereas at Deep Bay and French Creek cod were tagged when the trawling season was open (Table 3).

Of the 61 recaptured cod for which location was known, 93% were reported from grounds within MSA 14; 5% from Nanoose Bay (MSA 17-N); and 2% from Southeast Strait (MSA 29, 80, 82, and 83) (Table 7). Most were recaptured in the tagging location--62% (21 of 34) for Cape Lazo cod and 84% (26 of 31) for Deep Bay (Table 8). Cod tagged at Cape Lazo were recaptured on all grounds in MSA 14 except French Creek, while Deep Bay cod were only recaptured at Lambert Channel, Deep Bay, and Qualicum. The single recapture within MSA 14 from French Creek was reported caught at Deep Bay.

Recaptures within MSA 14, by quarter-year, reflected the seasonal fishery (Fig. 4), and are shown below in percent for the major experiments--Cape Lazo and Deep Bay.

<u>Experiment</u>	<u>Jan-Mar</u>	<u>Apr-Jun</u>	<u>Jul-Sep</u>	<u>Oct-Dec</u>	<u>Total</u>
Cape Lazo	59	9	9	22	99
Deep Bay	91	-	-	9	100

Recaptures outside MSA 14 totalled seven (10%)--five at Nanoose Bay (17-N); one in the Gulf Islands (17S+18), and one at Orcas Island (MSA 80 of Area 4A) (Table 8, 9). They are listed below by location and time of tagging and recapture:

Recapture location		Tagging location and time			
		Cape Lazo		Deep Bay	French Creek
		Feb 1955	Feb 1957	Feb 1954	Feb 1957
17-N	Nanoose Bay	Mar 56	Mar 57	Jan 55(2)	Mar 57
17S+18	Gulf Islands	Dec 55	-	-	-
80	Orcas Island	Apr 55	-	-	-

Recaptures in MSA 14 of Pacific cod tagged elsewhere totalled 19--14 from Nanoose Bay (Table 11), 4 from Swanson Channel (Table 13), and 1 from Holmes Harbour, Puget Sound (MSA 83) (Table 10) (Gosho, 1976). Nanoose-tagged cod were recaptured in July (1), September (2), January (3), February (3), and March (5) (Table 12). Interestingly, the July and one of the September recaptures occurred during the second year after tagging.

Of the four Pacific cod tagged in Swanson Channel (MSA 18), one was tagged in February 1954 and recaptured in November 1954, and three were tagged in January 1955, and recaptured in February and March 1955 and February 1956 (Table 15). The cod tagged in January may have been destined to spawn in MSA 14.

The single recapture from Area 4A, was tagged at Holmes Harbour in May 1955-60 (exact year not known) and recaptured in April 1959 (Table 10).

Thus, minor interchanges of cod appear to take place between MSA 14 and Nanoose Bay, Gulf Islands, and Area 4A.

#### Nanoose Bay (MSA 17N)

At Nanoose Bay, four experiments were completed during February-April 1955-59a (Table 4). During March 1955, 1958, and 1959, a total of 1,975

<sup>a</sup>The April 1 segments of the 1955 (9 cod tagged) and 1959 (1 cod tagged), and the February 1957 (9 cod tagged) experiments have been omitted from further discussion. No recaptures were reported.

Pacific cod were tagged and released, and 255 (13%) were recaptured. Of the 193 cod whose recapture location was known to MSA (at least in 4A and 4B), 45% were recaptured at Nanoose Bay; 26% from the Southeast Strait (MSAs 29, 80, 82, and 83); 13% from Gulf Islands (MSAs 17S+18); 7% from MSA 14; 4% from offshore waters (Areas 3B and 3C) (Table 7).

Nanoose Bay. Apparently no local Pacific cod stock inhabits the Nanoose Bay grounds during the non-spawning season (Forrester and Ketchen, 1963). Hence, the short trawling season, during January-March, does not seriously hinder the recapture of Pacific cod at Nanoose Bay. However, three tagged cod were recaptured in April by a research vessel.

Southeast Strait. Recaptures of Nanoose-tagged cod in the Southeast Strait totalled 51--7 from Fraser River (MSA 29); 33 from the U.S. Gulf of Georgia (MSA 80); and 11 from Bellingham Bay, (MSA 82) (Table 11). Distributions by area among the three experiments were similar. Recaptures occurred nearly year-round, particularly for the experiments in 1958 (one month missing) and 1959 (3 months missing) (Table 9). Nanoose-tagged cod dispersed rapidly after tagging, and were distributed throughout Southeast Strait by the end of May. They remained so until spawning season in the following year. Recaptures ranged from April to January in MSA 29; March to March in MSA 80; and April to February in MSA 82. MSA 80 appeared to be the principal location selected by the Nanoose-tagged cod, based on number of tagged cod recaptured. Time of recapture reflected the seasonal nature of the trawl fishery (Figs. 4 and 5). Only four Nanoose-tagged cod were recaptured in the Southeast Strait during July-September--8.5% of the total reported from that region.

Recaptures at Nanoose Bay of Pacific cod tagged in the Southeast Strait region (MSAs 80 and 82) totalled 16--12 from the U.S. Gulf of Georgia (MSA 80), and 4 from Bellingham Bay (MSA 82) (Gosho 1976) (Table 10). All were captured during February-March, and had been tagged during January 1967, March-April 1967, and June 1970 in the U.S. Gulf of Georgia; and during April 1958 and 1968 in Bellingham Bay. These results corroborate the interchange of Pacific cod between Nanoose Bay and MSAs 80 and 82 in Area 4A as indicated by the Nanoose Bay experiments (Table 11).

Gosho (1976) estimated that in 1967, 22.5% of the Pacific cod spawning at Nanoose Bay originated from MSAs 80 and 86--mostly MSA 80. From his Table 18, the corresponding estimates for MSA 80 were 18.8% in 1967; 29.0% in 1968; and 23.2% in 1971. These represent minimum estimates insofar as all recaptured tags were probably not reported, nor were the contributions from MSA 29 and Bellingham Bay included. Quantification of the results from the Nanoose Bay experiments was not undertaken, because detailed catch statistics from Area 4A were not available.

Gulf Islands. Recapture of Nanoose-tagged cod in the Gulf Islands totalled 24--2 from MSA 17-S (N. Gulf Islands), and 22 from MSA 18 (S. Gulf Islands) (Table 11). The two recaptures in MSA 17-S originated from the March 1959 experiment, and were caught in December 1959 and January 1960 (Table 12). The 22 cod recaptured in MSA 18 originated from the three March experiments--1955 (11), 1958 (4), and 1959 (7). Overall, recapture time ranged from April to February, but varied substantially among experiments. For the 1955 experiment, all recaptures occurred during April-November 1955;

and for the 1959 experiment, April-November 1959 and February-November 1960. For the 1958 experiment, recaptures were reported only in January and February 1959. Variable migration patterns among years may explain the unusual results in 1958. From Table 11, the numbers recaptured have been converted to percentages of total usable recaptures, exclusive of those at Nanoose Bay as follows:

	March 1955	March 1958	March 1959
Gulf Islands	39.3	13.8	19.1
S. E. Strait	46.4	62.1	42.6

The relatively few Gulf Island recaptures from the 1958 experiment (13.8% vs 39.3% and 19.1) coincide with the relatively numerous S.E. Strait recaptures in the same year (62.1% vs 46.4 and 42.6). Furthermore, the 1958 commercial landings from the Gulf Islands were relatively small (~200 t), compared with those of 1955 (~600 t) and 1959 (~400 t) (Fig. 4). In the Southeast Strait, the 1958 commercial landing was relatively large (~1,100 t) with respect to that in 1959 (~800 t)--no records are available for 1955. Landings represent a reasonable measure of abundance for Pacific cod at Nanoose Bay according to Forrester and Ketchen (1963), and probably do so elsewhere as well (Westrheim 1977).

Recaptures of Gulf Islands-tagged cod at Nanoose Bay totalled nine--eight from Porlier Pass (MSA 17-S) and one from Swanson Channel (MSA 18) (Table 13). Pacific cod from Porlier Pass were tagged in February 1957 (2), March 1958 (2), and March 1959 (4), while the single cod from Swanson Channel was tagged in November 1954. These results contradict, rather than complement, those obtained from Nanoose-tagged cod recaptured in the Gulf Islands. Relatively few cod (1.5%) were recaptured at Nanoose Bay, and of these, eight of nine were tagged at Porlier Pass. Evidently, the Porlier Pass and Swanson Channel experiments did not intercept many Nanoose-bound cod.

MSA 14. Recaptures of Nanoose-tagged cod in MSA 14 totalled 14 (Table 11)--8 from Cape Lazo; 4 from Lambert Channel-Yellow Rock; and 2 from Qualicum-Parksville (Table 12). Recapture months were July (1), September (2), January (3), February (3), and March (5), which reflected the seasonal nature of the trawl fishery (Fig. 4), except that no tagged cod were reported recaptured during October-December, an important period for landings in MSA 14. Temporal and spatial distribution of the January-March recaptures suggested a southward migration towards Nanoose Bay. Cape Lazo recaptures occurred in February and March; and Qualicum-Parksville recaptures occurred in March.

Five Pacific cod tagged in MSA 14 were recaptured at Nanoose Bay (Table 8). All were tagged in February--two at Cape Lazo (1955 and 1957), two at Deep Bay (1955), and one at French Creek (1957).

Juan de Fuca Strait. Recaptures of Nanoose-tagged cod in Juan de Fuca Strait totalled eight (Table 11)--seven in MSA 19 (Victoria) and one in

MSA 86 (E. Juan de Fuca). Times of recapture were October, November, and January in MSA 19, and January in MSA 86 (Table 12). No recaptures were reported from the March 1955 experiment. January recaptures occurred in 1959 on the Canadian side and in 1960 on the U.S. side of Juan de Fuca Strait.

All 21 recaptures at Nanoose Bay of Pacific cod tagged in Juan de Fuca Strait originated from U.S. experiments in MSA 86--December 1966 (7) and January 1967 (14) (Table 10). From Table 18 of Gosho (1976), we can estimate the percentage of Pacific cod comprising the 1967 landings at Nanoose Bay as 5.3%, by combining the results of the December 1966 and January 1967 experiments.

Recaptures in Juan de Fuca Strait of Pacific cod originating at, or destined for, Nanoose Bay only occurred during October-January, and probably reflect migrations to and from the offshore grounds.

Offshore grounds. Recaptures of Nanoose-tagged cod on offshore grounds totalled seven (Table 11)--three from Area 3B (N. Washington coast), and four from Area 3C (S.W. Vancouver Island). Times of recapture were April and December in Area 3B; and April, July, August, and October in Area 3C (Table 12). Evidently, the Pacific cod spawning stock at Nanoose Bay contains an offshore component which comprises at least 5% (assuming the Juan de Fuca recaptures are part of the offshore component).

#### Gulf Islands (MSAs 17S + 18)

In the Gulf Islands, 10 tagging experiments were completed during 1954-59 (Table 4). A total of 3,843 Pacific cod were tagged and released and 689 (18%) were subsequently recaptured. There were six major experiments and four minor experiments, so designated on the basis of numbers tagged.

For the four minor experiments, 74 cod were tagged, and 11 were recaptured (Table 4). Two experiments (Boat Harbour, February 1954, N=3; Satellite Channel, November 1954, N=7) yielded no recaptures. No recaptures were reported outside the Gulf Islands from the other two minor experiments--Trincomali Channel, November 1954 (N=17); Satellite Channel, February 1954 (N=47). The eight recaptures from the Satellite Channel (MSA 18) experiment were all reported from localities in MSA 18--Active Pass (1), Satellite Channel (3), Prevost Channel (1), and unspecified (3). The three recaptures from the Trincomali Channel (MSA 17S) experiment were recaptured in Trincomali Channel (MSA 17S), Swanson Channel (MSA 18), and "Gulf Islands".

For the six major Gulf Island experiments, 3,309 cod were tagged and 632 (19%) recaptured (Table 4). Three experiments were completed in MSA 17-S at Porlier Pass (February 1957; March 1958-59), and three in MSA 18 at Swanson Channel (February and November 1954; January 1955). For the 612 tagged cod whose recapture area was known, 92.9% were recaptured in the Gulf Islands; 3.9% from Southeast Strait (MSAs 29, 80, 82, 83); 0.6% from Juan de Fuca Strait (MSA 19-20, 86); 0.7% from MSA 14; 1.5% from Nanoose Bay (MSA 17-N), and 0.3% from Area 3C (S.W. Vancouver Island) (Table 13).

Gulf Islands. Localized stocks within the Gulf Islands are suggested by the distribution of recaptures from the Porlier Pass (MSA 17-S) and Swanson Channel (MSA 18) experiments. For the three Porlier Pass

experiments of 1957-1959, 70% (199) of the 285 usable recaptures were reported from MSA 17-S, and 20% (57) from MSA 18 (Table 13). For the Swanson Channel experiments of 1954-1955, 95% (311) of the 327 usable recaptures were reported from MSA 18, and 0.6% (2) from MSA 17-S. Similarly, within MSAs 17-S and 18, most recaptures were reported from the tagging site (Table 13).

MSA 14 and Nanoose Bay (17-N). Migration of Pacific cod between the Gulf Islands and these two localities has been reported in their respective sections.

Southeast Strait. The 24 Pacific cod tagged in the Gulf Islands and recaptured in the Southeast Strait (MSAs 29, 80, 82, and 83) were distributed from the Fraser River (MSA 29) southward to Deception Pass (MSA 83) (Table 9). Geographical range of recaptures was approximately the same for the 14 cod tagged at Porlier Pass, and the 10 cod tagged at Swanson Channel. Times of recapture were April-May, July-September, and November-January for cod tagged at Porlier Pass; and for those tagged at Swanson Channel, January-May and November. Time of tagging seemed to affect time of recapture. Extensive range of recapture times was only noted for the March 1958 and 1959 experiments at Porlier Pass, and the January 1955 experiment at Swanson Channel. For the February experiments at Porlier Pass (1957) and Swanson Channel (1954), recaptures were few, and only reported during November and January-March.

Eleven Pacific cod tagged in Area 4A (Gosho 1976) were recaptured in the Gulf Islands, all during January-March--one in MSA 17-S, and ten in MSA 18 (Table 10). The cod recaptured in January 1971 in MSA 17-S was tagged June 1970 in MSA 80. For MSA 18, the Bellingham Bay (MSA 82) April 1968 experiment contributed one recapture, in February 1969. The Gulf of Georgia (MSA 80) experiments contributed four recaptures--three (February 1968 and 1969, and March 1968) from the March-April 1967 experiment, and one (February 1971) from the June 1970 experiment. The east Juan de Fuca (MSA 86) experiments contributed five recaptures--two from the January 1967 experiment (February 1967 and 1970), and three from the December 1966 experiment (February-March 1967).

Juan de Fuca. Four Gulf Islands-tagged Pacific cod were recaptured in Juan de Fuca Strait--three from the Porlier Pass experiment in March 1959, and one from the Swanson Channel experiment in January 1955 (Table 13). Recapture times for the Porlier Pass cod were February and October 1960, and for the Swanson Channel cod, January 1962 (Table 15).

Six Pacific cod tagged in Juan de Fuca Strait were recaptured in the Gulf Islands--five from MSA 86 (Table 10), and one from MSA 19 (Table 17). Cod from MSA 86 were tagged in December 1966 and January 1967, and were recaptured in February (1967, 1970-71) and March (1967). The cod from MSA 19 was tagged in April 1960 and recaptured in October 1960.

Offshore Grounds. Two Pacific cod tagged in the Gulf Islands were recaptured in Area 3C (Table 13). They were tagged at Porlier Pass in March 1959, and were recaptured on Big Bank in July 1959 and October 1960, respectively.

One Pacific cod tagged on offshore grounds was recaptured in the Gulf Islands. It was tagged May 1961 on Amphitrite Bank (Area 3C) and recaptured somewhere in MSA 18 in April 1962 (Table 23).

Juan de Fuca Strait (MSAs 19+20)

Three tagging experiments were completed in Juan de Fuca Strait--two at Victoria (MSA 19), in April and October 1960, respectively and one at Port San Juan (MSA 20) in May 1961 (Table 4). A total of 578 cod were tagged and released and 48 (8%) were subsequently recaptured. The October 1960 experiment at Victoria yielded only one recapture which occurred in the month and area of tagging.

Migration was limited for recaptured tagged cod from the April 1960 and May 1961 experiments in Juan de Fuca Strait. All but three of the 45 recaptures (from known area) were reported from within the Victoria-Clo-oose (MSA 19-21)<sup>a</sup> region (Table 16). Two of the exceptions were recaptured in the Gulf Islands (MSA 18)--in October 1960 and January 1962; and one was recaptured off Point Roberts (MSA 80) in May 1961. For the remaining 42 recaptures, a distinct migration pattern was evident--westward in the spring, and eastward in the autumn and winter. Cod tagged off Victoria in April 1960 were first reported at Port San Juan during April-May (none were recaptured off Victoria until September); and at Clo-oose in May-June. No further recaptures were reported until September-November 1960, when 29 were recaptured off Victoria. Next recapture was in June 1961 at Clo-oose, followed by single recaptures at Victoria in September and November 1961. The final recapture was reported in 1962, at Victoria in September. The two recaptures from the May 1961 experiment at Port San Juan reflect the same pattern--one at Port San Juan in May 1961, and one at Clo-oose in July 1961.

Monthly landings of Pacific cod from MSAs 19-21, during 1960-62 also appear to reflect a westward migration in spring, and an eastward migration in autumn and winter (Fig. 7). Westward migration is marked by the peak landings in MSA 20 during April or May; and in MSA 21, during April, May, or June. Eastward migration was marked by increasing October landings eastward from MSA 21, and peak landings in January from MSA 19.

A total of 19 Pacific cod tagged elsewhere were recaptured in Juan de Fuca Strait (MSA 19 and 20)--4 from Area 4A, 10 from Area 4B, and 5 from Area 3C (Table 17). Area 4A-tagged cod originated from December-January tagging in E. Juan de Fuca (MSA 86), and May tagging at Holmes Harbour. Additional information on cod migration through Juan de Fuca Strait has recently been published (Bargmann 1980). A total of 643 Pacific cod were tagged at Agate Pass (MSA 83) during February-March 1977. Through December 1979, 121 tags (18.6%) were returned. Most cod (76%) were recaptured in MSA 83. However, four were recaptured in MSA 19--three during September-October 1977, and one in September 1978. Four were recaptured in MSA 86--all in March 1978.

Area 4B-tagged cod originated from March experiments at Nanoose Bay and Porlier Pass. For Nanoose-tagged cod, recapture months were October (1), November (3), and January (3); and for the Porlier Pass-tagged cod recapture months were October (1), January (1), and February (1). Area 3C-tagged cod originated from May-June tagging on Swiftsure and Amphitrite banks. Recapture

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<sup>a</sup>MSA 21 is actually part of Area 3C, but has been included in this analysis for obvious reasons.

months were July (1), October (2), and November (2). Most of these tagged cod were recaptured during October-February, and were presumably in transit from the offshore grounds to their respective spawning grounds in Areas 4A and 4B. The single July recapture off Port San Juan suggests that feeding cod occasionally enter Juan de Fuca Strait.

## DISCUSSION

Migrations of Pacific cod tagged in selected areas of the Strait of Georgia and vicinity (Area 4B) suggested the presence of highly localized stocks in MSA 14, Gulf Islands, and perhaps Juan de Fuca Strait; and a highly migratory stock which appeared at Nanoose Bay only during the spawning season. Nanoose Bay cod "summer" in MSA 14, Gulf Islands (MSAs 17S & 18), Puget Sound and vicinity (Area 4A), and on the offshore banks off Northwest Washington State (Area 3B) and Southwest Vancouver Island (Area 3C). No quantification of this extensive dispersion was possible due to inadequate numbers tagged and/or unavailable catch statistics.

The need for corroborative evidence for migration analyses was re-emphasized by two phenomena noted in the 1954-60 experiments. First, repetitive tagging revealed among-year variation in migratory patterns of cod tagged at Nanoose Bay and in the Gulf Islands. Second, contradictory results, among experiments, were noted in the migration of tagged cod between Nanoose Bay and the Gulf Islands.

### S.W. VANCOUVER ISLAND (AREA 3C)

#### General results

Six tagging experiments were conducted with Pacific cod off Southwest Vancouver Island (Area 3C) (Fig. 1; Table 18), all within the period May 1959-September 1962. Five experiments were conducted on Amphitrite Bank, and one on Big Bank (Fig. 8). A total of 1,686 cod were tagged and released, and 304 (18%) were subsequently recaptured. Among experiments, numbers tagged ranged from 57 to 574, and recapture rates ranged from 0 to 36%. Generally poor recovery rates were ascribed primarily to: (1) secondary priorities to other activities (4 experiments); (2) few cod tagged, due to low cod abundance during 1959-62 (Fig. 8); and (3) low survival rate of small cod tagged in May 1959 and September 1962.

### Time at liberty

Among experiments, maximum time at liberty ranged from 6 to 11 quarter years (Table 19). For the May-June experiments on Amphitrite Bank, 52-87% of the recaptures occurred during the first two quarter years (including quarter year of tagging). For the September experiment on Big Bank, only 6% of the recaptures were taken during the quarter year (actually month) of tagging, and no other appreciable proportion until Quarter II of 1963.

### Size and age composition

Size composition of tagged cod varied substantially among experiments (Table 20). On Amphitrite Bank, modal sizes were 41 and 62 cm (ages 2 and 3) in May 1959; 47, 59, 62, and 68 cm (ages 2, 3, and 4) in May-June 1961; and 47, 59, 68, and 74 cm (ages 2, 3, 4, and 5) in May-June 1962. On Big Bank, modal sizes in September 1962 were 35, 50, and 59 cm (ages 1, 2, and 3). Recapture rates were not uniform among size intervals. For small (young) cod, recapture rates were low except for the May 1961 experiment on Amphitrite Bank--0-13% at modal intervals of 35, 41, and 47 cm; except for 32% for 47 cm in May 1961. For large (older) cod, recapture rates were 21-41% at 59 or 62 cm for three experiments (May 1959, 1961, May-June 1962), but 0-8% at 59 or 62 cm for the other three experiments (June 1959, 1961; September 1962). The May 1961 experiment on Amphitrite Bank was particularly successful--27-72% recapture rates among the size intervals 44-74 cm (N=22-93). However, the only other experiment directed only at Pacific cod, i.e. June 1961 on Amphitrite Bank, yielded returns of only 0-19% per interval (N=12-97) over the same range of size intervals.

### Migration

Among areas. Only 7 of the Pacific cod tagged in Area 3C were reported from grounds outside Area 3C (Table 21)--five in Area 4B; and one each in 3B and 5C+5D. All appeared to reflect spawning migrations. The Hecate Strait (Area 5C+5D) recapture occurred in April 1963, and the Umatilla (Area 3B) recapture occurred in March 1964 (Table 22). Both cod were tagged on Big Bank in September 1962. The five recaptures in Area 4B occurred in a timely manner--October (1959 and 1961) at Port San Juan (MSA 20); November (1961) off Victoria (MSA 19); and April (1962) in the Gulf Islands (MSA 18). All were tagged on Amphitrite Bank during May-June (1959 or 1961).

A total of 25 tagged cod were recaptured in Area 3C which were tagged elsewhere--Areas 4A, 4B, 3A, and 3B (Table 23). Both feeding and spawning migrations appear to be reflected in these migrations.

Origins of the feeding cod recaptured in Area 3C during April-October were Nanoose Bay and Porlier Pass in Georgia Strait (Area 4B), and off Cape Flattery (Area 3B) (Table 23). The Area 4B cod were tagged in March 1959 and recaptured on Big Bank in July 1959 and October 1960. The Area 3B cod were tagged in May 1967 and recaptured on Swiftsure Bank in June and July 1967.

Origins of the spawning cod recaptured in Area 3C were Juan de Fuca Strait (Area 4A), and the west coast of Washington State (Areas 3A and 3B) (Table 23). Cod tagged during January 1967, April 1968, and December 1966 in East Juan de Fuca Strait were recaptured on Swiftsure or Amphitrite Bank during February, March and April. Cod tagged off Destruction Island (Area 3B) and Grays Harbor-Willapa (Area 3A) during May 1967 were recaptured on Amphitrite Bank during February 1968 and 1969.

Among grounds (within Area 3C). Information on recapture location by ground was available for 261 tagged cod--251 tagged on Amphitrite Bank and 10 tagged on Big Bank (Table 24).

For cod tagged during May-June on Amphitrite Bank, principal time of recapture was April-September, when 228 (91%) of the recaptures were accounted for. Amphitrite Bank accounted for 86-100% of the recaptures during each quarter. Lennard Island (MSA 24) accounted for recaptures during January-March (5%) and April-June (2%). Big Bank accounted for recaptures during April-June (1%) and July-September (8%); and Swiftsure Bank accounted for recaptures during April-June (2%) and July-September (6%). No recaptures were reported from the Clo-oose or Cape Flattery Spit grounds.

For cod tagged on Big Bank, recaptures were reported from Big Bank (April-June and July-September), Amphitrite Bank (January-March and April-June), and Clo-oose (January-March and April-June). No recaptures were reported for Lennard Island, Swiftsure Bank, or Cape Flattery Spit. Both Amphitrite Bank and Clo-oose Ground are acknowledged spawning grounds for Pacific cod.

### Discussion

The 1959-62 cod tagging experiments in Area 3C provided no definitive conclusions about the migratory habits of Pacific cod, because of the limited magnitude and scope of the experiments. Based on the results achieved, Pacific cod may move about extensively within Area 3C, but relatively few emigrate, and there are few immigrants. There appears to be a minor exchange of Pacific cod in Area 3C with those in Areas 4B, 4A, 3B, and 3A. Area 3C apparently serves as a feeding area for some, and a spawning area for others.

## HECATE STRAIT (AREAS 5C AND 5D)

### Introduction

Hecate Strait-Dixon Entrance (Areas 5C and 5D) is the most productive region for Pacific cod off British Columbia (Fig. 2). Principal

historical trawling grounds are Two Peaks-Butterworth (hereafter referred to as Two Peaks), White Rocks, Horseshoe, and Ole Spot, which together account for about 90% of the annual landings of cod from Hecate Strait (Fig. 9). Two Peaks, Ole Spot, and Horseshoe grounds are important primarily during spring and summer, while White Rocks is important primarily during winter, as an assembly point for spawning cod (Fig. 10).

### General results

In Hecate Strait, 15 Pacific cod tagging experiments were completed during 1960-68 (Table 25). A total of 13,084 cod were tagged and 3,584 (29%) recaptures were subsequently reported. Tagging experiments were categorized major (7) or minor (8) on the basis of numbers tagged and recaptured, and/or purpose of experiment.

Major experiments were completed during January-February 1960-61 and 1968 on White Rocks and/or adjacent Bonilla grounds; and during May on Two Peaks (1965), Butterworth (1964), and White Rocks (1965) (Table 25). The winter experiments involved 3,864 cod tagged, and 1,059 (27%) recaptured. The spring experiments involved 6,950 cod tagged, and 2,322 recaptured (33%).

Minor experiments were completed during February, and May-September, from Wiah Point<sup>a</sup> (Dixon Entrance) south to Ramsay Island (Table 25). A total of 2,270 cod were tagged, and 203 (9%) were recaptured. Six of the eight experiments were secondary to trawl explorations.

### Time at liberty

Maximum time at liberty for tagged Pacific cod ranged from 8 to 11 quarter-years for major experiments, and 5-13 quarter-years for minor experiments (Table 27). However, for all experiments, 76-100% of the recaptured cod were reported during the first four quarter-years (including tagging quarter-year), and for all but two experiments, 62-89% in the first two quarter-years.

### Size and age composition

For the seven major experiments, size composition varied among experiments, but recapture rate did not vary appreciably among size intervals for individual experiments (Fig. 11 and 12). Filial size compositions, in per cent, of recaptured cod (based on size at tagging), were nearly congruent with the parent size composition in each experiment. Similar results were obtained with the minor experiments, but are not shown here.

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<sup>a</sup>Wiah Point is located on the north shore of Graham Island approximately 45 naut mi west of Two Peaks Ground. It is not shown in Fig. 9, and no regular trawl fishery exists in this area.

Age composition was roughly deduced for the tagged cod in each of the major experiments, based on unpublished age-length data. Results are summarized below:

Experiment	Modal size <sup>a</sup> (cm)	Principal age (y)	Secondary age (y)
1960 White Rocks (Feb)	44; 56	2	3
1961 White Rocks (Jan-Feb)	56;65;44	3	4;2
1964 Butterworth (May)	47	2	-
1965 Two Peaks (May)	47;59;71	2	3;4
White Rocks (May)	56	3	-
1968 White Rocks (Feb)	53	2-3	-
Bonilla (Feb)	59	3	-

<sup>a</sup>In order of descending magnitude.

Thus, the 1957 and 1958 year classes were tagged on White Rocks Ground during February 1960 and January-February 1961. The 1962 year class was tagged on Two Peaks-Butterworth and White Rocks grounds during May 1964-65. The 1964 and 1965 year classes were tagged on White Rocks-Bonilla Ground during February 1968. Abundance of the 1957-58 year classes was low, while that of the 1962 year class was high; and for the 1964-65 year classes, average (Fig. 2).

### Migration

Emigration of Pacific cod from Hecate Strait was potentially possible in three directions--north, west, and south. During 1960-70, no appreciable trawl fisheries existed northward or westward of Hecate Strait which might have recaptured tagged cod. Southward, emigration was negligible. Of the 3,588 usable recaptures (recapture location known), only nine (0.3%) were recaptured outside Hecate Strait (Table 1)--seven in Queen Charlotte Sound (Areas 5A and 5B) and two from off northwest Vancouver Island (Area 3D) (Table 27). No emigrants were reported from minor experiments. Pacific cod recaptured in Queen Charlotte Sound were tagged on Butterworth (May 1964) and White Rocks (May 1965) grounds, while the cod recaptured off Vancouver Island were tagged on White Rocks Ground (January-February 1961).

Immigration of Pacific cod to Hecate Strait is also poorly defined because cod were only tagged considerably southward (Areas 3C, 4A, and 4B)--none in Queen Charlotte Sound. Only three tagged cod were recaptured in Hecate Strait--all from U.S. experiments in Area 4A (Gosho 1976). One cod was "allegedly"<sup>a</sup> recaptured by a U.S. trawler on Bonilla Gound in February 1959.

<sup>a</sup>Gosho noted this recapture was not confirmed.

Tagging locality was Holmes Harbour (Puget Sound) in May 1958. Two cod were recaptured in "North Hecate Strait", also by U.S. trawlers, in November 1958 and February 1959, respectively. They had been tagged during February 1958 in Sequim Bay (E. Juan de Fuca Strait).

Within Hecate Strait, individual Pacific cod wandered widely. Indeed, of the 56 tag-recapture cells in Table 28, only 16 (29%) were unfilled, and five of these were accounted for by Ramsay Island Ground, where no regular fishery exists. Cod tagged at Wiah Point (Dixon Entrance) were recaptured on all grounds except Shell and Ramsay Island. Similarly, cod tagged off Ramsay Island were recaptured on Horseshoe, Ole Spot, and Two Peaks grounds. Cod tagged on White Rocks Ground, the most important spawning ground, were recaptured on every ground listed in Table 29.

#### Minor experiments

Minor experiments yielded few recaptures, but even these indicated the extensive wandering of individual cod (Table 29). However, the high proportion of recaptures at the tagging location is evident. Of interest are the February-March recaptures of cod tagged off Wiah Point (Dixon Entrance) in June 1966 which were reported from Dixon Entrance, Two Peaks, White Rocks, Ole Spot, Horseshoe, and Reef Island. Of these, only White Rocks and Reef Island are acknowledged spawning areas. Similarly, the Horseshoe experiment in February 1968 yielded recaptures in March-April 1968 on Two Peaks, White Rocks, Ole Spot, and Horseshoe.

#### Major experiments

Migration of Pacific cod was minor for five of the seven major experiments. Recapture rate at tagging locality was 77-88% for the 1960-61 winter experiments, and 81-93% for the 1964-65 spring experiments, in contrast to 44% and 28%, respectively, for the two 1968 winter experiments (Table 27).

Winter experiments. Principal secondary recapture location for Pacific cod tagged during winter 1960-61 on White Rocks Ground was Two Peaks-Butterworth Ground--10% and 21%, respectively (Table 27). These cod were members of the relatively weak 1957-58 year classes. Landings during 1960-63 were particularly small from Ole Spot and Horseshoe Ground (Fig. 10). In contrast, secondary recapture localities for cod tagged in February 1968 on White Rocks Ground, were Ole Spot-Horseshoe (35% and 48%) and Two Peaks-Butterworth (19% and 17%). These cod were members of the 1965-66 year classes; of average abundance, as evidenced by the 1968-70 landings on all the major grounds in Hecate Strait.

The relatively low recapture rate on Two Peaks-Butterworth Ground from the 1960 experiment (10%), compared to those of the 1961 and 1968 experiments (17-21%) may be due in part to a differential migration by size (age) away from the White Rocks-Bonilla Ground. Mean lengths (based on length at tagging) of cod recaptured at Two Peaks were larger than for cod recaptured at White Rocks for both the 1960-61 and 1968 experiments (Table 30). For the 1960-61 experiments mean lengths of cod recaptured on Two Peaks Ground ranged

from 52.6 to 63.0 cm, compared to 48.4-52.4 cm for cod recaptured on White Rocks Ground. Since only the 1960 experiment involved primarily age 2 cod, a smaller proportion would be expected to be recaptured on Two Peaks Ground. Similar differential migration was noted for the 1968 experiments on White Rocks and Bonilla grounds. Mean lengths of cod recaptured on White Rocks Ground ranged from 57.2 to 59.6 cm, compared to 62.0-67.0 cm for recaptures on Two Peaks Ground, and 58.0-61.8 cm for recaptures on Ole Spot and Horseshoe Ground.

Spring experiments. Few cod tagged during May 1964-65 migrated to other grounds. Only 1% and 14%, respectively, of the recaptured cod from the Two Peaks 1965 and Butterworth 1964 experiments were reported from White Rocks Ground, and only 10% of the recaptured cod from the White Rocks 1965 experiment were reported from Two Peaks Ground (Table 27). Interestingly, the three experiments yielded similar proportions (2-4%) of recaptures from Ole Spot and Horseshoe Ground. Since the 1964-67 landings were relatively large from both grounds (Fig. 10), the relatively few recaptures suggest little interchange during spring-summer between Two Peaks or White Rocks and the Ole Spot-Horseshoe region--at least during 1964-67.

No differential migration with respect to size or age was evident (Table 30).

### Discussion

Few Pacific cod tagged in Hecate Strait were recaptured elsewhere, but individual tagged cod wandered widely within Hecate Strait. Intra-regional migration patterns appear to vary with respect to size (age) at tagging and year-class abundance. Apparently, Pacific cod in Hecate Strait constitute a single geographical stock, but with two or more sub-stocks.

### SUMMARY

Pacific cod appear to be well delineated into geographical units off British Columbia (Canada) and Washington State (USA), based on the results of numerous tagging experiments during 1944-70. A modest, but unquantifiable, inter-regional migration was evident between Georgia Strait, Puget Sound, and the offshore grounds adjacent to Vancouver Island and Washington State. The relatively short life span, and concomitant high mortality rate, limits the results obtainable from tagging adult cod. Hence, studies of migration were limited, for practical purposes, to the first 12 mo at liberty.

Even within regions, tagged cod tended to remain in the tagging locality. Notable exceptions were cod tagged during the spawning season. Based on the results of the relatively substantial experiments in Hecate

Strait, intra-regional delineation of Pacific cod stocks based on tagging is a complex problem whose solution will require carefully designed, multi-year experiments.

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Table 1. Distribution (%) by international area of recaptured Pacific cod tagged by the Fisheries Research Board of Canada during 1954-68.

Tagging area	Nos. tagged	Usable recaptures <sup>a</sup>	Recapture area							Unknown area
			4A	4B	3B	3C	3D	5A+5B	5C+5D	
4B <sup>b</sup> (1954-62)	6,814	1,011	8.5	<u>90.8</u>	0.2	0.6	0	0	0	65
3C (1959-62)	1,686	283	0	1.8	0.1	<u>97.9</u>	0	0	0.4	21
5C+5D (1960-68)	13,084	3,334	0	0	0	0	0.1	0.2	<u>99.7</u>	250
Total	21,584	4,628								336
%		21								2

<sup>a</sup>Recapture area known.

<sup>b</sup>The 1944 and 1952 experiments have been omitted due to small numbers tagged (22 and 23) and recovered (2 and 3), and type of tag--Petersen disc in 1944 and opercular strap in 1952.

Table 2. Distribution (%), by international area, of recaptured Pacific cod tagged by the Washington State Department of Fisheries during 1955-70 (Gosho 1976).

Year	Tagging area	Nos. tagged	Usable recaptures	Recapture area								Unknown area
				4A	4B	3A	3B	3C	3D	5A	5D	
(1955-58; 66-70)	4A	10,749	2,570	<u>97.7</u>	1.9	0	0.2	0.4	0	0.03	0.2	586
(1955-57; 66-67)	3A	30	7	0	0	<u>57.1</u>	14.3	28.6	0	0	0	0
	3B	1,716	109	4.6	0	0	<u>88.1</u>	5.5	0.9	0.9	0	35
	3C	92	7	0	14.3	0	0	<u>85.7</u>	0	0	0	0
<b>Total</b>		<b>12,587</b>	<b>2,693</b>									<b>603</b>
<b>%</b>			<b>21</b>									<b>5</b>

Table 3. Area-time trawl closures in Area 4B during 1954-65.

Location	Annual fishing days	Fishing season	
		Open	Close
MSA 14			
Cape Lazo	123	mid-Oct	mid-Feb
Union Bay	8 <sup>a</sup>	mid-Oct	mid-Dec
Baynes Sound-Ballenas	156	mid-Oct	Mar 20
MSA 17			
Nanoose Bay	48	(Jan 31) Feb 1	Mar 20
Boat Harbor	255	May 15	Jan 14 <sup>b</sup>
MSA 18			
Satellite Channel	ca. 145	mid-Oct	Mar 20 <sup>c</sup>

<sup>a</sup>Fridays only.

<sup>b</sup>Extension to Jan. 31 in 1954.

<sup>c</sup>Except 1953-54: Dec. 1-Jan. 31; Feb. 10-Mar. 20.

Table 4. Summary of Pacific cod tagging experiments conducted in the Strait of Georgia and vicinity (Area 4B), 1954-61.

Tagging location	Month	Year	No. tagged	No. recaptured	% recaptured	
<b>14      <u>North of Nanoose</u></b>						
Cape Lazo	Feb	1954	38	3	8	
		1955	168	26	15	
		1957	59	13	22	
	Sep	1954	<u>6</u>	<u>0</u>	<u>0</u>	
	T		271	42	16	
Union Bay	Oct	1954	9	0	0	
Deep Bay	Jan	1955	34	14	41	
	Feb	1954	16	2	13	
	Dec	1954	<u>48</u>	<u>23</u>	<u>48</u>	
	T		98	39	40	
French Creek	Feb	1957	<u>18</u>	<u>3</u>	<u>17</u>	
Sub-total			396	84	21	
<b>17N      <u>Nanoose Bay</u></b>						
	Feb	1957	9	0	0	
	Mar	1955	610	94	15	
		1958	713	48	7	
		1959	<u>652</u>	<u>113</u>	<u>17</u>	
	T		1984	255	13	
	Apr	1955	9	0	0	
		1959	<u>1</u>	<u>0</u>	<u>0</u>	
Sub-total			1994	255	13	
<b>17S+18      <u>Gulf Islands</u></b>						
17S	Boat Harbor	Feb	1954	3	0	
17S	Porlier Pass	Feb	1957	388	85	22
		Mar	1958	642	44	7
		1959	<u>1234</u>	<u>178</u>	<u>14</u>	
	T		2264	307	14	
17S	Trincomali Chan.	Nov	1954	17	3	18

Table 4 (cont'd).

Tagging location	Month	Year	No. tagged	No. recaptured	% recaptured	
<b>17S+18 <u>Gulf Islands</u></b>						
18	Satellite Chan.	Feb	1954	47	8	17
		Nov	1954	7	0	0
		T		<u>54</u>	<u>8</u>	<u>15</u>
18	Swanson Channel	Jan	1955	838	295	35
		Feb	1954	207	30	14
		Nov	1954	<u>463</u>	<u>46</u>	<u>10</u>
		T		1508	371	25
Sub-total			3846	689	18	
<b>19+20 <u>Juan de Fuca</u></b>						
19	Victoria	Apr	1960	230	45	20
		Oct	1960	<u>331</u>	<u>1</u>	<u>0.3</u>
		T		<u>561</u>	<u>46</u>	<u>8</u>
20	Port San Juan	May	1961	17	2	12
Sub-total			578	48	8	
<b>Grand Total</b>			6814	1076	16	

Table 5. Results of Pacific cod tagging experiments conducted prior to 1954 in the Strait of Georgia and vicinity (Area 4B).

Tagging				Recapture		
Location		Time	No.	No.	Area	
14	N. of Nanoose	Nov 1944	6	0	-	
17N	Nanoose	Jan 1952	10	3	Area 4B (2); Unknown (1)	
17S+18	Gulf Islands	Nov 1944	7	1	Unknown	
		Nov 1952	13	0	-	
29	Fraser River	Nov 1944	9	1	Boundary Bay (Area 4B)	
Total			45	5		

Table 6. Distribution (%) of tagged Pacific cod, by recapture time (quarter-year) and tagging locality, from principal experiments conducted in Area 4B, 1954-60.

Tagging		Usable recaptures <sup>a</sup>	Recapture time												
			Year I				Year II				Year III				Year IV
Location	Time		1	2	3	4	1	2	3	4	1	2	3	4	1
14	Cape Lazo	Feb 1955	26	19	15	12	27	27	-	-	-	-	-	-	-
		1957	13	38	-	-	23	38	-	-	-	-	-	-	-
	Deep Bay	Dec 1954	23	x	x	x	9	83	-	-	4	4	-	-	-
		Jan 1955	14	93	-	-	-	7	-	-	-	-	-	-	-
17N	Nanoose Bay	Mar 1955	94	-	18	3	16	47	7	1	1	6	-	-	-
		1958	48	6	19	6	17	46	-	2	2	2	-	-	-
		1959	113	-	13	5	14	53	8	1	2	4	-	-	-
17S	Porlier Pass	Feb 1957	85	55	6	1	19	13	-	-	1	5	-	-	-
		Mar 1958	44	2	20	11	30	10	7	5	2	2	-	-	-
		Mar 1959	178	7	10	5	32	25	9	-	7	5	-	1	-
18	Swanson Chan.	Nov 1954	46	x	x	x	28	63	2	2	-	4	-	-	-
		Jan 1955	295	73	x	1	10	5	Tr	1	1	-	-	-	1
		Feb 1954	30	47	7	-	13	27	7	-	-	-	-	-	-
19	Victoria	Apr 1960	45	x	13	9	58	-	7	2	7	2	-	2	-

<sup>a</sup>Recapture time known.

Table 7. Distribution (%) of Pacific cod tagged in Georgia Strait and vicinity (Area 4B), by location of tagging and recapture<sup>a</sup>, 1954-62.

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

<sup>a</sup>Recapture location known.

Table 8. Distribution (number) of Pacific cod tagged in MSA 14 and subsequently recaptured, by location of tagging and recapture.

		Location		
		Recapture	Tagging	
	Cape Lazo		Deep Bay	French Creek
14	Oyster River	1	-	-
	Cape Lazo	21 (62%)	-	-
	Lambert Channel	3	1	-
	Deep Bay	2	26 (84%)	1
	Yellow Rock	1	-	-
	French Creek	-	-	- (0%)
	Qualicum	2	2	-
17-N	Nanoose Bay	2	2	1
17S+18	Gulf Islands	1	-	-
80 <sup>a</sup>	Orcas Island	1	-	-
Usable recaptures		34	31	2

<sup>a</sup>S.E. Strait, Area 4A.

Table 9. Distribution of individual Pacific cod tagged in Area 4B and recaptured in southeast Area 4B, and Area 4A, by location and time of tagging and recapture, 1954-60.

Recapture area	Tagging						
	Cape Lazo (14)	Nanoose Bay (17-N)			Porlier Pass (17-S)		
	Feb 1955	Mar 1955	Mar 1958	Mar 1959	Feb 1957	Mar 1958	Mar 1959
29 Fraser River	-	Apr 55 Aug 55 Nov 55	Sep 58 Dec 58 Jan 59	Apr 59	-	-	-
80 Pt. Roberts- Boundary Bay	-	Apr 55	Oct 58 Dec 58	Apr 59(2) May 59 Jul 59 Oct 59 Nov 59(2) Dec 59 Mar 60	Nov 57	Apr 58	Jul 59 Nov 59
80 Birch Bay	-	-	-	-	-	Apr 59	Jan 60
80 Cherry Point (Alden Bank)	-	Apr 55 May 55(2)	Aug 58 Oct 58(2)	May 59 Jun 59(3) Dec 59	-	-	-
80 Orcas Island (Lummis Island)	Apr 55	Apr 55(3) Aug 55	Mar 58 Apr 58(2) Jun 58	-	-	-	Jul 59

Table 9. (cont'd)

Recapture area	Tagging						
	Cape Lazo (14)	Nanoose Bay (17-N)			Porlier Pass (17-S)		
	Feb 1955	Mar 1955	Mar 1958	Mar 1959	Feb 1957	Mar 1958	Mar 1959
82 Bellingham Bay	-	Jan 56(2)	May 58(3) Feb 59	Apr 59 Oct 59(4)	-	Dec 58 Sep 59	Aug 59 Sep 59(2) Nov 59
83 Deception Pass	-	-	-	-	-	May 59	-
86 Port Angeles	-	-	-	Jan 60	-	-	-
<b>Total</b>	<b>1</b>	<b>13</b>	<b>18</b>	<b>21</b>	<b>1</b>	<b>5</b>	<b>8</b>

Table 9 (cont').

Recovery area	Tagging				Total
	Swanson Channel (18)		Victoria (19)		
	Jan 1955	Feb 1954	Nov 1954	Apr 1960	
29 Fraser River	Nov 56	Feb 54	Jan 55	-	9
80 Pt. Roberts- Boundary Bay	Feb 55	-	Mar 55	May 61	20
80 Birch Bay	May 55(2)	-	-	-	4
80 Cherry Point (Alden Bank)	-	-	-	-	11
80 Orcas Island (Lummis Island)	Apr 55	-	-	-	13
82 Bellingham Bay	Jan 56	-	-	-	18
83 Deception Pass	May 55	-	-	-	2
86 Port Angeles	-	-	-	-	1
<b>Total</b>	<b>7</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>78</b>

Table 10. Distribution of individual Pacific cod tagged in Area 4A and recaptured in Area 4B, by location and time of tagging and recapture, 1958-71 (from Gosho 1976).

Recapture location	Tagging					
	Holmes Harbour (83)	Bellingham Bay (82)		Gulf of Georgia (80)		
	May 1966-50	Apr 1958	Apr 1968	Jan 1967	Mar-Apr 1967	Jun 1970
14 Cape Lazo	Sep 59	-	-	-	-	-
17-N N Nanoose Bay	-	Feb 59	F/M <sup>a</sup> 69 (3)	Mar 67 (3)	F/M 68 (4) F/M 69	F/M 71 (4)
17-S S N. Gulf Islands	-	-	-	-	-	Jan 71
18 S. Gulf Islands	-	-	Feb 69	-	Feb 68 Feb 69 Mar 68	Feb 71
19 Victoria	-	-	-	-	-	-
20 Port San Juan	Unk	-	-	-	-	Unk
<b>Total</b>	<b>2</b>	<b>1</b>	<b>4</b>	<b>3</b>	<b>8</b>	<b>7</b>

Non-producing experiments:

Area	Time	T	R	%R
86 E. Juan de Fuca (4)	Feb 68	1,141	39	3
	Nov 68	110	21	19
	Dec 68	134	46	34

<sup>a</sup>F/M=February-March. Nanoose Bay area is only open to trawling February 1-March 20.

Table 10 (Cont'd)

Recapture location	Tagging		Total	
	E. Juan de Fuca (86)			
	Jan 1967	Dec 1966		
14 Cape Lazo	-	-	1	
17-N Nanoose Bay	F/M 67 (12) F/M 68 (2)	F/M 67 (7)	37	
17-S N. Gulf Islands	-	-	1	
18 S. Gulf Islands	Feb 67 Feb 70	Feb 71 (2) Mar 67	10	
19 Victoria	Feb 70	Feb 67	2	
20 Port San Juan	-	Unk	3	
<b>Total</b>	<b>17</b>	<b>12</b>	<b>8</b>	<b>54</b>

Table 11. Distribution (numbers) of Pacific cod tagged at Nanoose Bay, by time of tagging and location of recapture.

Recapture location		Tagging time			Total	%
Sub-area		Mar 1955	Mar 1958	Mar 1959		
14	Cape Lazo-Parksville	3	4	7	14	7
17-N	Nanoose Bay	28	16	43	87	46
17-S	N. Gulf Islands	-	-	2	2	13
18	S. Gulf Islands	11	4	7	22	
19	Victoria	-	1	6	7	4
86	E. Juan de Fuca	-	-	1	1	
29	Fraser River	3	3	1	7	
80	Gulf of Georgia (U.S.)	8	11	14	33	27
82	Bellingham Bay	2	4	5	11	
3B	N. Washington Coast	-	2	1	3	4
3C	S.W. Vancouver Island	1	-	3	4	
Total		56	45	90	191	101

Table 12. Distribution of individual Pacific cod tagged at Nanoose Bay and recaptured elsewhere other than the Southeast Strait, by time of tagging, and location and time of recapture, 1955-60.

Recapture area	Tagging time						Total
	Mar 1955		Mar 1958		Mar 1959		
14 Cape Lazo	--	Jul 56	--	Jan 59 (2) Sep 59	Sep 59	Jan 60 Feb 60 (2)	8
Lambert Channel- Yellow Rock	--	Mar 56	--	Feb 59	--	Mar 60 (2)	4
Qualicum- Parksville	--	Mar 57	--	--	--	Mar 60	2
17-S N. Gulf Islands	--	--	--	--	Dec 59	Jan 60	2
18 S. Gulf Islands	Apr 55 (2) Jul 55 Oct 55 Nov 55 (7)	--	--	Jan 59 Feb 59 (3)	Apr 59 May 59 (2) Nov 59	Feb 60 May 60 Nov 60	22
17S+18 Gulf Islands	Nov 55	Feb 56	--	--	--	May 60	3
19 Victoria	--	--	--	Nov 59	Oct 59 Nov 59 (2)	Jan 60 (3)	7
12 <sup>a</sup> Cape Flattery	--	--	Dec 58	--	--	--	1
14 <sup>a</sup> Umatilla	--	--	--	--	Apr 59	--	1

Table 12. (cont'd)

Recapture area	Tagging time				Total
	Mar 1955	Mar 1958	Mar 1959		
15 <sup>a</sup> Destruction Island	-- --	Dec 58 --	-- --		1
23 <sup>b</sup> Big Bank	-- --	-- --	Jul 59 Oct 60		2
- Area 3C	Apr 56 --	-- --	Aug 59 --		2
Total	17	11	27		55

<sup>a</sup>Area 3B--N. Washington coast.

<sup>b</sup>Area 3C--S.W. Vancouver Island.

Table 13. Distribution (numbers) of Pacific cod at Porlier Pass and Swanson Channel by time of tagging and location of recapture.

MSA	Recapture location	Tagging location and time						Total	%
		Porlier Pass (17-S)			Swanson Channel (18)				
		Feb 1957	Mar 1958	Mar 1959	Feb 1954	Nov 1954	Jan 1955		
14	Cape Lazo-Parksville	-	-	-	1	-	3	4	0.7
17N	Nanoose Bay	2	2	4	-	1	-	9	1.5
17S	S. Gulf Islands	60	23	116	-	1	1	201	32.8
18	S. Gulf Islands	16	9	32	25	38	248	368	60.1
19	Victoria	-	-	2	-	-	-	2	0.3
20	Port San Juan	-	-	1	-	-	1	2	0.3
29	Fraser River	-	-	-	1	1	-	2	0.3
80	Gulf of Georgia (U.S.)	1	2	6	-	-	4	13	2.1
82	Bellingham Bay	-	3	4	-	-	2	9	1.5
23	Big Bank (Area 3C)	-	-	2	-	-	-	2	0.3
<b>Total</b>		<b>79</b>	<b>39</b>	<b>167</b>	<b>27</b>	<b>41</b>	<b>259</b>	<b>612</b>	<b>99.9</b>

Table 14. Distribution (numbers) of Pacific cod tagged at Porlier Pass and Swanson Channel, and recaptured within the Gulf Islands, by location and time of tagging, and location of recapture, 1954-59. (Excluding recaptures of known MSA but unknown locality.)

Recapture	Tagging						Total
	Porlier Pass			Swanson Channel			
	Feb 1957	Mar 1958	Mar 1959	Feb 1954	Nov 1954	Jan 1955	
<b>17-S N. Gulf Islands</b>							
Boat Harbour	4	5	8	-	-	-	17
Pylades Channel	-	2	4	-	-	-	6
Stuart Channel	1	1	3	-	-	-	5
Porlier Pass	48	11	17	-	-	-	76
Trincomali Channel	7	4	80	-	1	1	93
Total	60	23	112	-	1	1	197
<b>18 S. Gulf Islands</b>							
Active Pass	6	-	4	5	3	31	49
Swanson Channel <sup>a</sup>	7	7	16	16	31	189	266
Satellite Channel	1	1	3	2	-	3	10
Prevost Channel	-	-	-	1	1	5	7
Tumbo Channel	-	1	3	-	-	1	5
Total	14	9	26	24	35	229	337
<b>Total</b>	<b>74</b>	<b>32</b>	<b>138</b>	<b>24</b>	<b>36</b>	<b>230</b>	<b>534</b>

<sup>a</sup>Includes Captain's Passage.

Table 15. Distribution of individual Pacific cod tagged at Porlier Pass and Swanson Channel and recaptured elsewhere in Area 4B, by time of tagging, and location and time of recapture, 1954-62.

Recovery location	Tagging						Total
	Porlier Pass			Swanson Channel			
	Feb 57	Mar 58	Mar 59	Feb 54	Nov 54	Jan 55	
14 Cape Lazo-Parksville	--	--	--	Nov 54	- -	Feb 55 Mar 55 Feb 56	4
17-N Nanoose Bay	Mar 58 Mar 59	Feb 59 Mar 59	Mar 60 (3) Mar 61	- -	Feb 56	- -	9
29 Fraser River	- -	- -	- -	Feb 54	Jan 55	Nov 56	3
19 Victoria	- -	- -	Feb 60 Oct 60	- -	- -	- -	2
20 Port San Juan	- -	- -	Jan 62	- -	- -	- -	1
<b>Total</b>	<b>2</b>	<b>2</b>	<b>7</b>	<b>2</b>	<b>2</b>	<b>4</b>	<b>20</b>

Table 16. Distribution (numbers) of Pacific cod tagged in the Canadian portion of Juan de Fuca Strait by time and location of tagging and recapture, 1960-62.

Tagging		Recapture		No.
Time	Location	Time	Location	
1960 Apr	19 Victoria	1960 Apr-May	20 Port San Juan	2
		May-Jun	21 <sup>a</sup> Clo-oose	4
		Sep	19 Victoria	4
		Oct	18 Gulf Is.	1
			19 Victoria	21
		November	19 Victoria	4
		1961 May	80 <sup>b</sup> Point Roberts	1
		Jun	21 <sup>a</sup> Clo-oose	1
		Sep	19 Victoria	1
		Nov	19 Victoria	2
		1962 Jan	18 Swanson Channel	1
		Sep	19 Victoria	1
1961 May	20 Port San Juan	1961 May	20 Port San Juan	1
		Jul	21 <sup>a</sup> Clo-oose	1
<b>Total</b>				<b>45</b>

<sup>a</sup> Area 3C.

<sup>b</sup> Area 4A.

Table 17. Distribution of individual Pacific cod recaptured in the Canadian portion of Juan de Fuca Strait which were tagged elsewhere, by time and location of tagging and recapture, 1959-70.

Tagging Location	Time	Recapture Location		Total
		MSA 19	MSA 20	
4A 86 E. Juan de Fuca <sup>a</sup>	Jan 1967	Feb 70	—	2
	Dec 1966	Feb 67	—	
	83 Holmes Harbour <sup>a</sup>	May 1955-60	Oct 59	—
80 Gulf of Georgia <sup>a</sup>	Jun 1970	Oct 70	—	1
4B 17-S Porlier Pass	Mar 1959	Feb 60	Jan 62	3
		Oct 60		
17-N Nanoose Bay	Mar 1958	Nov 59	—	7
	Mar 1959	Oct 59	—	
		Nov 59(2)		
		Jan 60(3)		
3C 23 Firing Range	May 1959	—	Oct 59	4
	Jun 1961	Nov 61(2)	Oct 61	
21 Swiftsure <sup>a</sup>	May 1967	—	Jul 67	1
Total		15	4	19

<sup>a</sup>United States experiment.

Table 18. Summary of Canadian Pacific cod tagging experiments conducted off Southwest Vancouver Island (Area 3C), May 1959-September 1962.

Tagging Area	Month	Year	Tagged	Recaptured	
			N	N	%
Amphitrite Bank <sup>a</sup>	May	1959 <sup>b</sup>	145	22	15
	Jun	1959 <sup>b</sup>	57	0	0
	May	1961	574	209	36
	Jun	1961	503	41	8
	May-Jun	1962 <sup>c</sup>	157	15	10
Big Bank	Sep	1962 <sup>d</sup>	250	17	7
Total			1,686	304	18

<sup>a</sup>Reported as Firing Range in Westrheim and Forrester (1975).

<sup>b</sup>Secondary to shrimp exploration.

<sup>c</sup>Secondary to juvenile flatfish survey.

<sup>d</sup>Secondary to petrale sole tagging.

Table 19. Distribution (%) of Pacific cod tag recaptures by quarter-year after tagging, and experiment, Southwest Vancouver Island, (Area 3C) 1959-62.

Experiment			Usable Recaptures <sup>a</sup>	Percent												
				Year 1			Year 2				Year 3				Year 4	
				II	III	IV	I	II	III	IV	I	II	III	IV	I	II
Amphitrite Bank	May	1959	22	45	27	5	-	14	9	-	-	-	-	-	-	-
	May	1961	209	73	14	2	6	2	2	1	1	-	-	-	-	-
	Jun	1961	41	20	32	10	20	10	5	-	5	-	-	-	-	-
	May-Jun	1962	15	33	47	-	-	13	7	-	-	-	-	-	-	-
Big Bank	Sep	1962	17	X	6	-	6	41	-	18	18	-	-	-	12	-

<sup>a</sup>Recapture time known.

Table 20. Size composition (numbers) of Pacific cod tagged (T) in Area 3C, and subsequent percent recaptures (%R)<sup>a</sup> by experiment, Southwest Vancouver Island, 1959-62.

Fork Length <sup>a</sup> (cm)	Amphitrite Bank										Big Bank	
	May 1959		Jun 1959		May 1961		Jun 1961		May-Jun 1962		Sep 1962	
	T	%R	T	%R	T	%R	T	%R	T	%R	T	%R
26	1	0	-	-	-	-	-	-	-	-	-	-
9	4	0	-	-	-	-	-	-	-	-	5	0
32	3	0	-	-	-	-	-	-	-	-	46	4
5	4	0	-	-	2	0	6	0	-	-	81	7
8	17	0	-	-	2	0	5	0	-	-	52	6
41	21	0	-	-	4	0	3	0	6	0	18	0
4	11	18	-	-	21	33	11	0	5	0	4	0
7	4	0	-	-	28	32	12	8	8	13	5	0
50	2	0	-	-	22	27	16	6	7	0	11	9
3	5	20	4	0	28	46	20	10	7	14	8	0
6	9	22	4	0	49	41	21	19	10	0	4	50
9	7	57	10	0	68	41	50	14	28	21	7	0
62	17	29	12	0	93	41	75	12	24	13	2	0
5	16	31	11	0	91	73	95	6	19	5	3	33
8	11	27	10	0	75	33	97	8	21	0	2	0
71	11	0	5	0	47	32	60	3	8	0	1	0
4	2	0	1	0	39	31	24	4	12	0	1	0
7	-	-	-	-	4	50	7	0	2	0	-	-
80	-	-	-	-	-	-	1	0	-	-	-	-
Total	145	15	57	0	573	36	503	8	157	8	250	6
UNK	-	-	-	-	1	1	-	-	-	3	-	2

<sup>a</sup>Length at time of tagging.

Table 21. Pacific cod tag recaptures (numbers), by area, from experiments conducted in Area 3C, 1959-62.

Recovery area		Amphitrite Bank				Big Bank	Total	1959-65 Mean Annual Landing (t)
		May 1959	May 1961	June 1961	May- June 1962	Sep 1962		
Hecate Strait	5C+5D	-	-	-	-	1	1	4,000
Queen Charlotte Sound	5A+5B	-	-	-	-	-	0	809
W. Vancouver Island	3D	-	-	-	-	-	0	112
	3C	18	195	36	13	14	276	1,013
Washington-Oregon	3B	-	-	-	-	1	1	636
	3A-2D	-	-	-	-	-	0	53
Georgia Strait and vicinity <sup>a</sup>	4B	1	1	3	-	-	5	640
Puget Sound and vicinity <sup>a</sup>	4A	-	-	-	-	-	0	652
Sub-total		19	196	39	13	16	283	
Unknown		3	13	2	2	1	21	
Total		22	209	41	15	17	304	

<sup>a</sup>Includes Juan de Fuca Strait.

Table 22. Records of individual Pacific cod recaptured outside Area 3C, and tagged within Area 3C, by area and time of recapture.

Recapture location <sup>a</sup>	Time	Tagging	
		Location	Time
5C+5D Hecate Strait	Apr 1963	Big Bank	Sep 1962
4B(20) Port San Juan	Oct 1959 1961	Amphitrite Bank	May 1959 Jun 1961
(19) Victoria	Nov 1961 (2)	Amphitrite Bank	Jun 1961
(18) Gulf Islands	Apr 1962	Amphitrite Bank	May 1961
3B Umatilla	Mar 1964	Big Bank	Sep 1962

<sup>a</sup>MSA in parentheses.

Table 23. Record of individual Pacific cod recaptured in Area 3C, but tagged elsewhere, by time and location of tagging and recapture.

Tagging		Recapture (location and time) <sup>a</sup>				
Area	Time	Swiftsure Bank	Big Bank	Amphitrite Bank	Unknown	
4B	Nanoose Bay (MSA 17N)	Mar 55	-	-	-	Apr 55
		Mar 59	-	Jul 59 Oct 60	-	Aug 59
	Porlier Pass (MSA 17S)	Mar 59	-	Jul 59(2)	-	-
4A <sup>b</sup>	E. Juan de Fuca (MSA 86)	Jan 67	Feb 67(2) Mar 67	-	Apr 67(2)	-
		Apr 68	Feb 69	-	-	-
		Dec 66	Feb 67(4)	-	Feb 68	-
3B <sup>b</sup>	Cape Flattery	May 67	Jun 67 Jul 67(2)	-	-	-
		Nov 66	Mar 67	-	-	-
		Dec 66	-	-	Mar 67	-
	Destruction Is.	May 67	-	-	Feb 69	-
3A <sup>b</sup>	Grays Harbor-Willapa	May 68	-	-	Feb 68 Feb 69	-

<sup>a</sup>Detailed records of U.S.-tagged cod supplied by Jim Beam (WDF).

<sup>b</sup>U.S. tagging experiments.

Table 24. Distribution (%) of Pacific cod recaptured within Area 3C, and tagged on Amphitrite Bank and Big Bank, by ground and quarter-year.

Time	Usable Recaptures <sup>a</sup>	Lennard Island	Big Bank	Recapture location			C. Flattery Spit
				Amphitrite Bank	Swiftsure Bank	Clo-oose	
<u>Amphitrite Bank (May-June 1959, 1961-62)</u>							
Jan-Mar	22	5	-	95	-	-	-
Apr-Jun	178	2	1	96	2	-	-
Jul-Sep	50	-	8	86	6	-	-
Oct-Dec	1	-	-	100	-	-	-
Total	251						
<u>Big Bank (September 1962)</u>							
Jan-Mar	4	-	-	50	-	50	-
Apr-Jun	5	-	20	40	-	40	-
Jul-Sep	1	-	100	-	-	-	-
Oct-Dec	0	-	-	-	-	-	-
Total	10						

<sup>a</sup>Recapture ground known.

Table 25. Inventory of major and minor Canadian tagging experiments in Hecate Strait (Area 5C + 5D), 1960-68.

Tagging period and location	No. tagged	No. recovered	% recovered	
<u>Major experiments</u>				
<u>Winter (Jan-Feb)</u>				
White Rocks	1960	1,228	285	23
	1961	1,044	247	24
	1968 <sup>a</sup>	499	181	36
Bonilla	1968	1,093	346	32
<u>Spring (May)</u>				
Butterworth <sup>b</sup>	1964	3,615	1,047	29
Two Peaks	1965	648	308	48
White Rocks	1965	<u>2,687</u>	<u>967</u>	<u>36</u>
Sub-total		10,814	3,381	31
<u>Minor experiments</u>				
<u>Winter (Feb)</u>				
Horseshoe	1968	209	48	23
<u>Spring (May-June)</u>				
Wiah Point <sup>c</sup>	1966	238	96	40
Two Peaks <sup>b</sup>	1964	65 <sup>b</sup>	26 <sup>b</sup>	40
Bonilla <sup>a</sup>	1966	81	4	5
<u>Summer (Jul-Sep)</u>				
Bonilla <sup>c</sup>	1965	640	11	2
Reef Island <sup>c</sup>	1965 (2)	386	0	0
Ramsay Island <sup>c</sup>	1965	<u>651</u>	<u>18</u>	<u>3</u>
Sub-total		2,270	203	9
Grand total		13,084	3,584	27

<sup>a</sup>Listed as Bonilla in Westrheim and Forrester (1975).

<sup>b</sup>Listed as Archibald in Westrheim and Forrester (1975).

<sup>c</sup>Secondary to trawl explorations.

Table 26. Pacific cod tag recaptures (%), by quarter year of recapture, for major and minor experiments in Hecate Strait, 1960-68.

Tagging		Usable recaptures <sup>a</sup>	Percent												
Location	Year		Qtr.	Year 1				Year 2				Year 3			
				I	II	III	IV	I	II	III	IV	I	II	III	IV
<u>Major experiments</u>															
Two Peaks	1965	II	308	X	28	54	2	3	9	3	0	0	T <sup>b</sup>	-	-
Butterworth	1964	II	1,047	X	27	19	5	20	7	14	1	2	5	1	-
White Rocks	1960	I	283	49	23	6	12	7	1	1	1	1	-	-	-
	1961	I	247	66	15	4	3	10	T	0	0	T	T	-	-
	1965	II	965	X	25	37	14	12	7	1	2	1	0	1	T
	1968	I	177	37	28	7	4	10	10	5	0	1	-	-	-
Bonilla	1968	I	344	46	25	8	2	8	9	1	T	-	-	-	-
<u>Minor experiments</u>															
Wiah Point	1966	II	96	X	38	35	1	6	3	5	0	9	2	-	-
Two Peaks	1964	II	26	X	27	58	0	15	-	-	-	-	-	-	-
Bonilla	1965	III	11 <sup>c</sup>	X	X	9	9	9	27	9	0	9	9	0	9
	1966	II	3	X	0	33	0	0	33	33	-	-	-	-	-
Horseshoe	1968	I	48	60	29	4	0	4	2	-	-	-	-	-	-
Ramsay Is.	1965	III	18 <sup>d</sup>	X	X	6	0	0	83	6	0	0	0	0	0

<sup>a</sup>Recapture time known.

<sup>b</sup>T = trace.

<sup>c</sup>9% in Qtr. II, Year 4.

<sup>d</sup>6% in Qtr. III, Year 4.

Table 27. Distribution (%) of Pacific cod in major experiments, in Hecate Strait, by location and time of tagging, and by location of recapture, 1960-68.

Recapture location	Tagging location <sup>a</sup> and time						
	Winter (Jan-Feb)				Spring (May)		
	WR 1960	WR 1961	WR 1968	BO 1968	TP 1965	BU 1964	WR 1965
MacIntyre Bay	-	1	-	1	0.4	0.2 <sup>b</sup>	0.4
Two Peaks <sup>c</sup>	10	21	19	17	93	81	10
White Rocks <sup>d</sup>	88	77	44	28	1	14	81
Shell	-	-	1	1	-	-	-
Ole Spot	-	-	20	39	2	2	4
Horseshoe	1	-	15	9	4	2	4
Reef Island	-	-	2	4	-	-	0.1
Ramsay Island	0.4	-	-	-	-	-	-
Queen Charlotte Sound (5A+5B)	0.4	-	-	-	-	0.2	0.5
N.W. Vancouver Island (3D)	-	1	-	-	-	-	-
Total	99	100	101	99	100	99	99
Usable Recaptures <sup>e</sup>	257	220	124	246	252	852	856

<sup>a</sup>Location code: BO = Bonilla; BU = Butterworth; TP = Two Peaks; WR = White Rocks.

<sup>b</sup>Includes one recapture by longline off Cape Muzon (N. Dixon Entrance).

<sup>c</sup>Includes Butterworth.

<sup>d</sup>Includes Bonilla.

<sup>e</sup>Recapture location known.

Table 28. Distribution of Pacific cod tagged and recaptured within Hecate Strait and Dixon Entrance, by location. (+ = one or more recaptures; - = no recaptures).

Tagging location	Recapture location							
	Dixon Ent. <sup>a</sup>	Two Peaks <sup>b</sup>	White Rocks <sup>c</sup>	Shell	Ole Spot	Horseshoe	Reef Is.	Ramsay Is.
Wiah Point	+	+	+	-	+	+	+	-
Two Peaks	+	+	+	-	+	+	-	-
Butterworth	+	+	+	-	+	+	-	-
White Rocks	+	+	+	+	+	+	+	+
Bonilla	+	+	+	+	+	+	+	-
Horseshoe	-	+	+	+	+	+	-	-
Ramsay Is.	-	+	-	-	+	+	-	+

<sup>a</sup>Includes Wiah Point.

<sup>b</sup>Includes Butterworth.

<sup>c</sup>Includes Bonilla.

Table 29. Distribution of individual Pacific cod recaptured from minor tagging experiments in Hecate Strait, by location and time of tagging and recapture, 1960-68.

Recapture locality <sup>a</sup>						
DE	TP-BU	SH	WR-BO	OS	HS	ReI
<u>Wiah Point (June 1966)</u>						
Jun 66 (35)	Jun 66	-	Jan 67	Mar 67	Mar 68	Mar 68
Sep 66 (12)	Aug 66 (4)		Feb 67			
June 67 (17)	Sep 66 (17)		Jan 68 (2)			
Mar 68	Feb 68 (2)					
Apr 68	Mar 68					
Aug 70						
<u>Two Peaks (May 1964)</u>						
-	Jun 64 (7)	-	-	-	-	-
	Jul 64					
	Mar 65					
<u>Bonilla (September 1965)</u>						
-	Jul 66	-	Sep 65	Mar 67	Apr 67	-
			Nov 65			
			Nov 67			
<u>Bonilla (June 1966)</u>						
-	Sep 67	-	-	-	Sep 66	-
					Apr 67	
<u>Horseshoe (February 1968)</u>						
-	Mar 68	Apr 69	Mar 68	Mar 68 (6)	Mar 68 (20)	-
	Apr 68		Apr 68	Apr 68	Apr 68 (2)	
				Mar 69	May 68 (4)	
					Jun 68	
					Jul 68	
					Aug 68	
					Mar 69	
<u>Ramsay Island (August 1965)</u>						
-	May 66	-	-	Jun 66	Apr 66 (9)	Aug 65
					May 66	
					Sep 66	

<sup>a</sup>Locality: DE = Dixon Entrance; HS = Horseshoe; OS = Ole Spot; ReI = Reef Is.; TP-BU = Two Peaks-Butterworth; WR-BO = White Rocks-Bonilla.

Table 30. Mean length (cm), based on length at tagging, of recaptured Pacific cod from major experiments in Hecate Strait, by experiment and quarter-year of recapture.

Tagging		Recapture quarter	Recapture area							
			Two Peaks <sup>a</sup>		White <sup>b</sup> Rocks		Ole Spot		Horseshoe	
Location	Year		X	N	X	N	X	N	X	N
<u>Winter experiments (Jan-Feb)</u>										
White Rocks	1960	1	63.0	3	52.4	133	-	0	-	0
		2-5	52.6	17	48.4	89	-	0	-	0
	1961	1	61.7	11	55.9	137	-	0	-	0
		2-5	61.3	37	55.4	31	-	0	-	0
	1968	1	62.0	3	57.2	26	60.7	9	58.5	5
		2-5	63.2	18	58.2	22	59.8	11	58.0	9
Bonilla	1968	1	67.0	6	59.6	53	61.8	57	60.9	8
		2-5	64.4	31	57.9	17	59.4	39	60.0	14
<u>Spring experiments (May)</u>										
Two Peaks	1965	2	54.6	76	-	0	60.8	5	-	0
		3-6	55.1	160	81.5	2	-	0	63.3	9
Butterworth	1964	2	50.3	285	-	0	-	0	-	0
		3-6	50.4	319	49.4	100	49.6	14	48.9	8
White Rocks	1965	2	51.5	4	58.4	237	62.0	1	71.0	1
		3-6	56.3	75	56.1	428	58.3	26	56.2	29

<sup>a</sup>Includes Butterworth Ground.

<sup>b</sup>Includes Bonilla Ground.

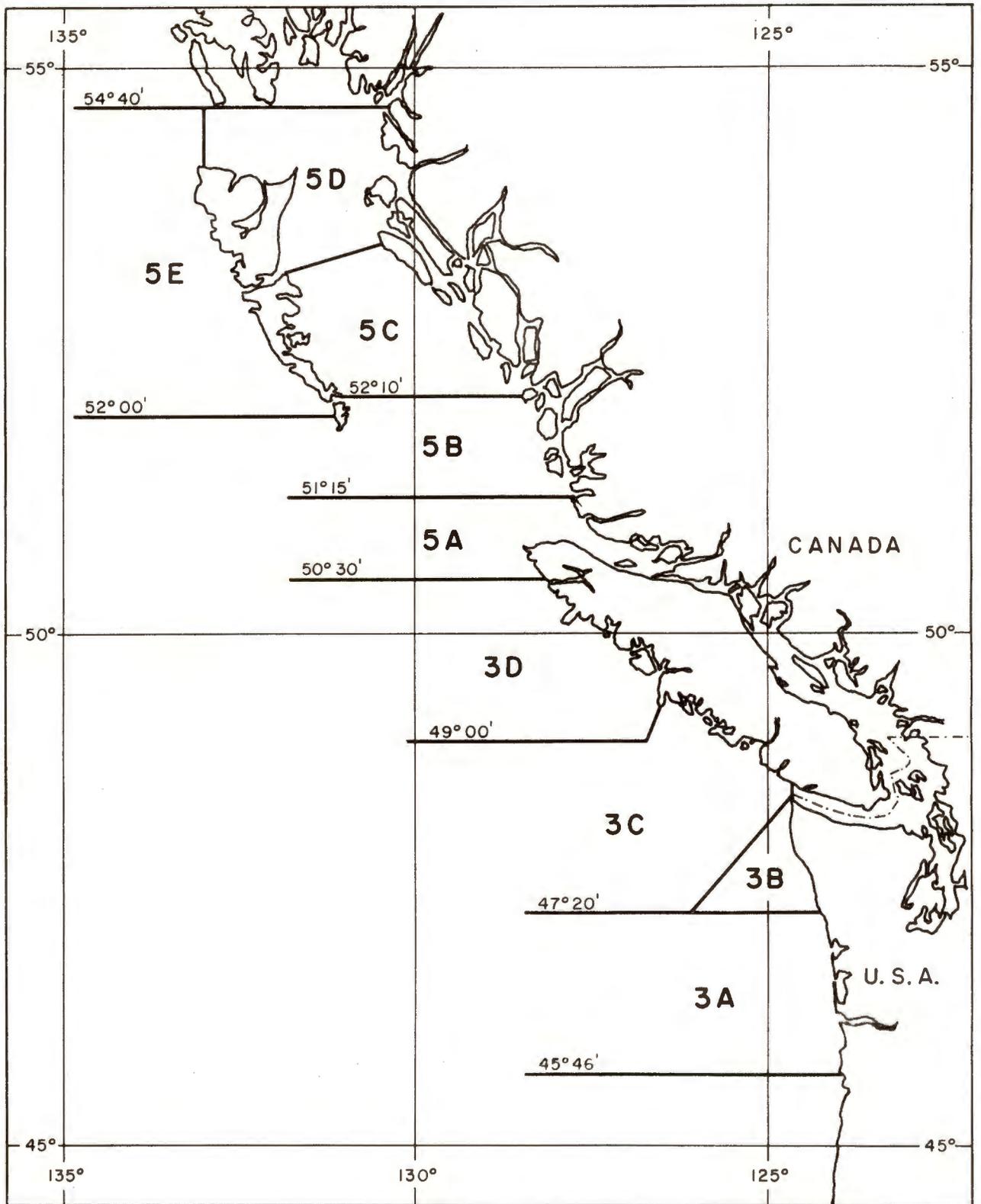


Fig. 1. International statistical areas for Canada-U.S. groundfish landings.



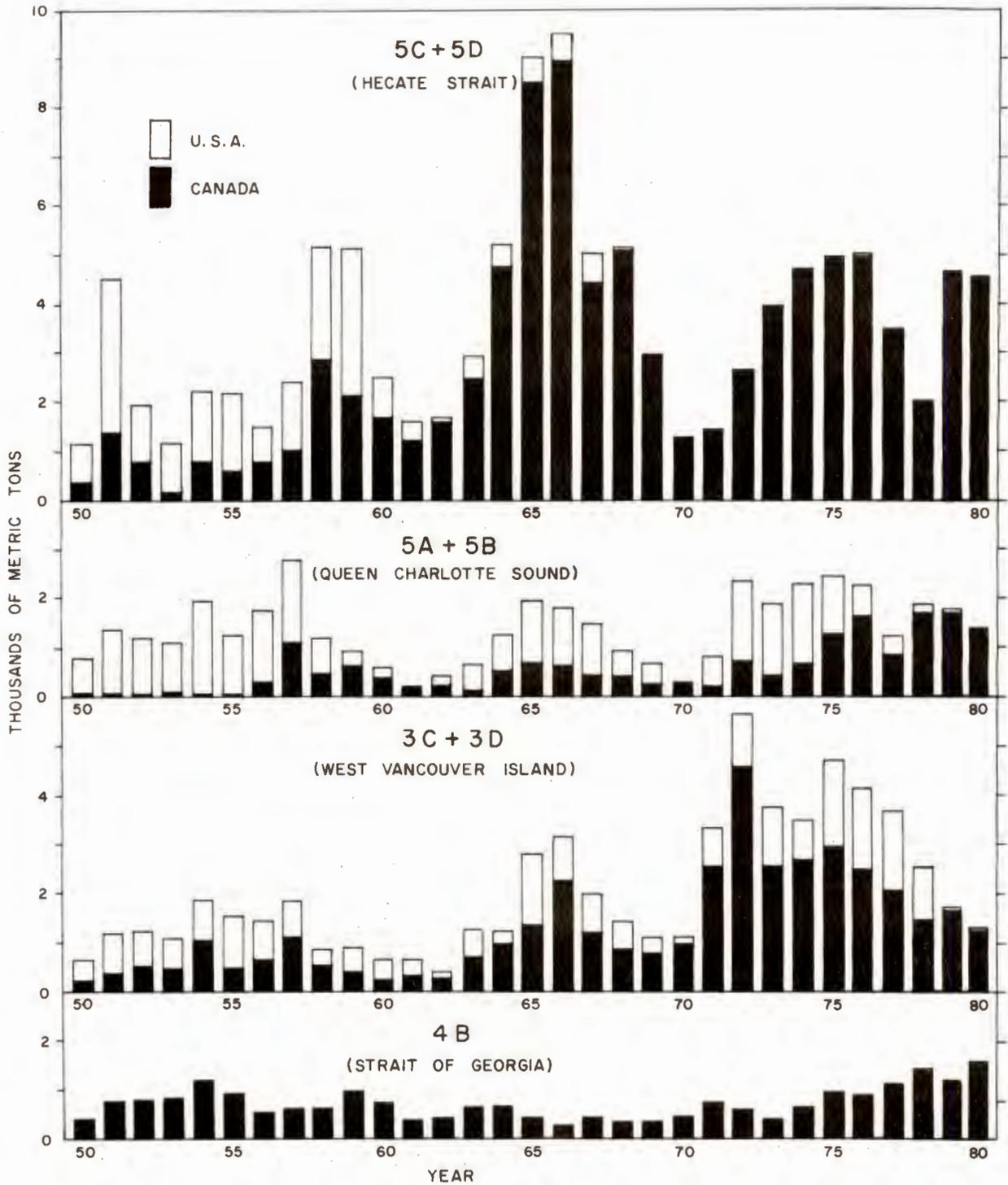


Fig. 2. Canada-U.S. landings (t) of Pacific cod from regions off British Columbia, 1950-80.



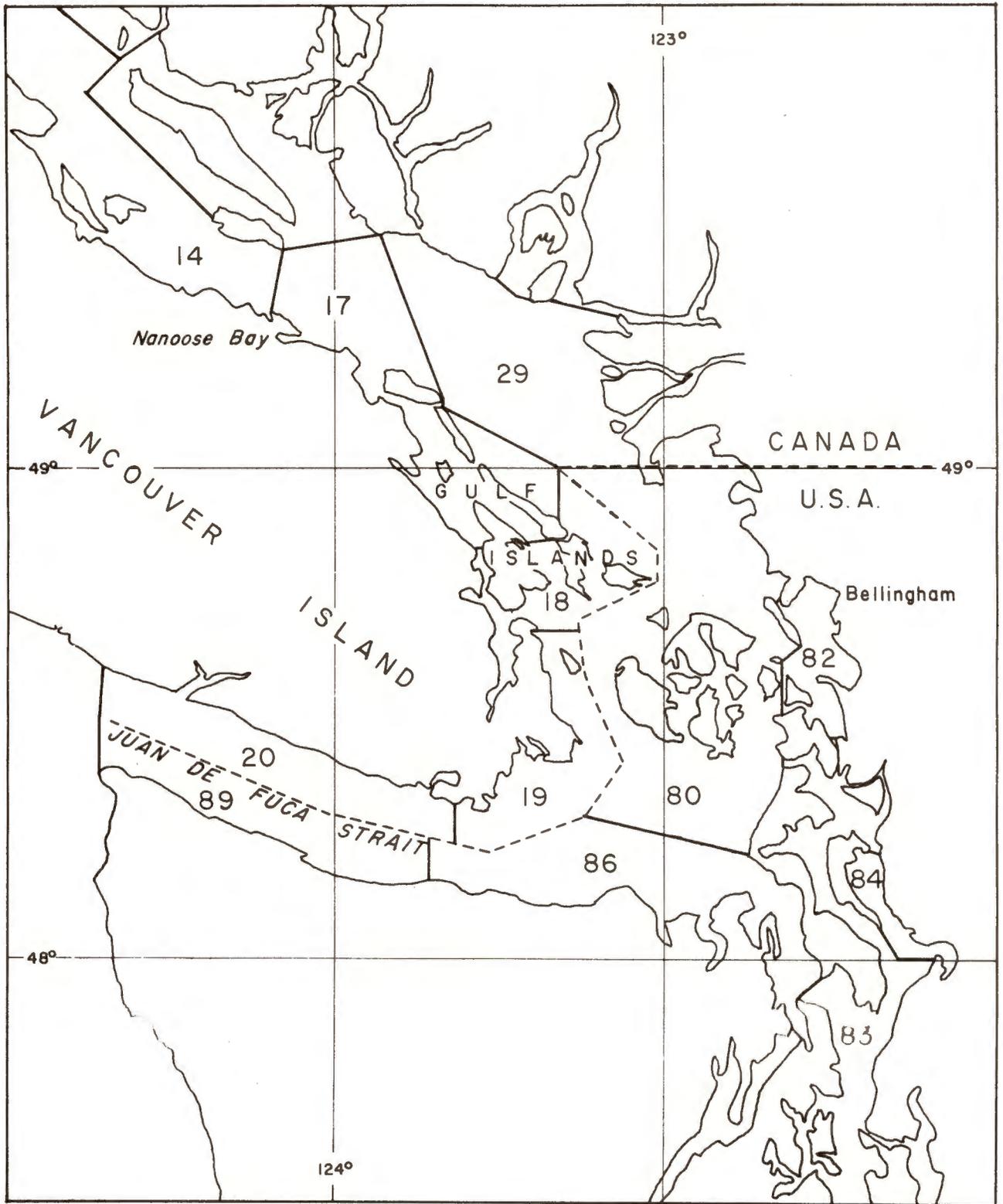


Fig. 3. Minor statistical area (MSA) in Area 4A (U.S.) and 4B (Canada).



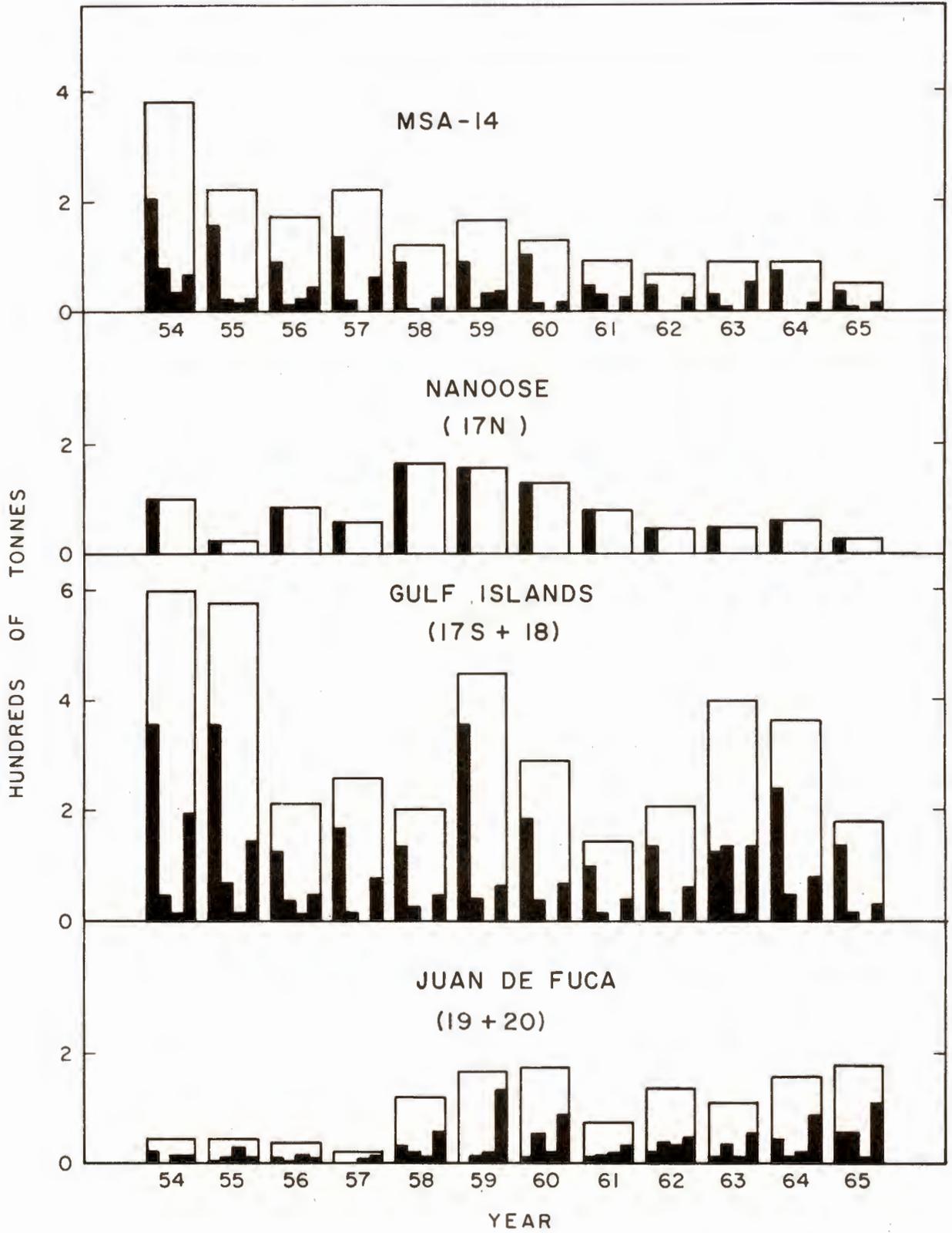


Fig. 4. Pacific cod landings (t) from principal regions of Area 4B, by quarter-year, 1954-65.



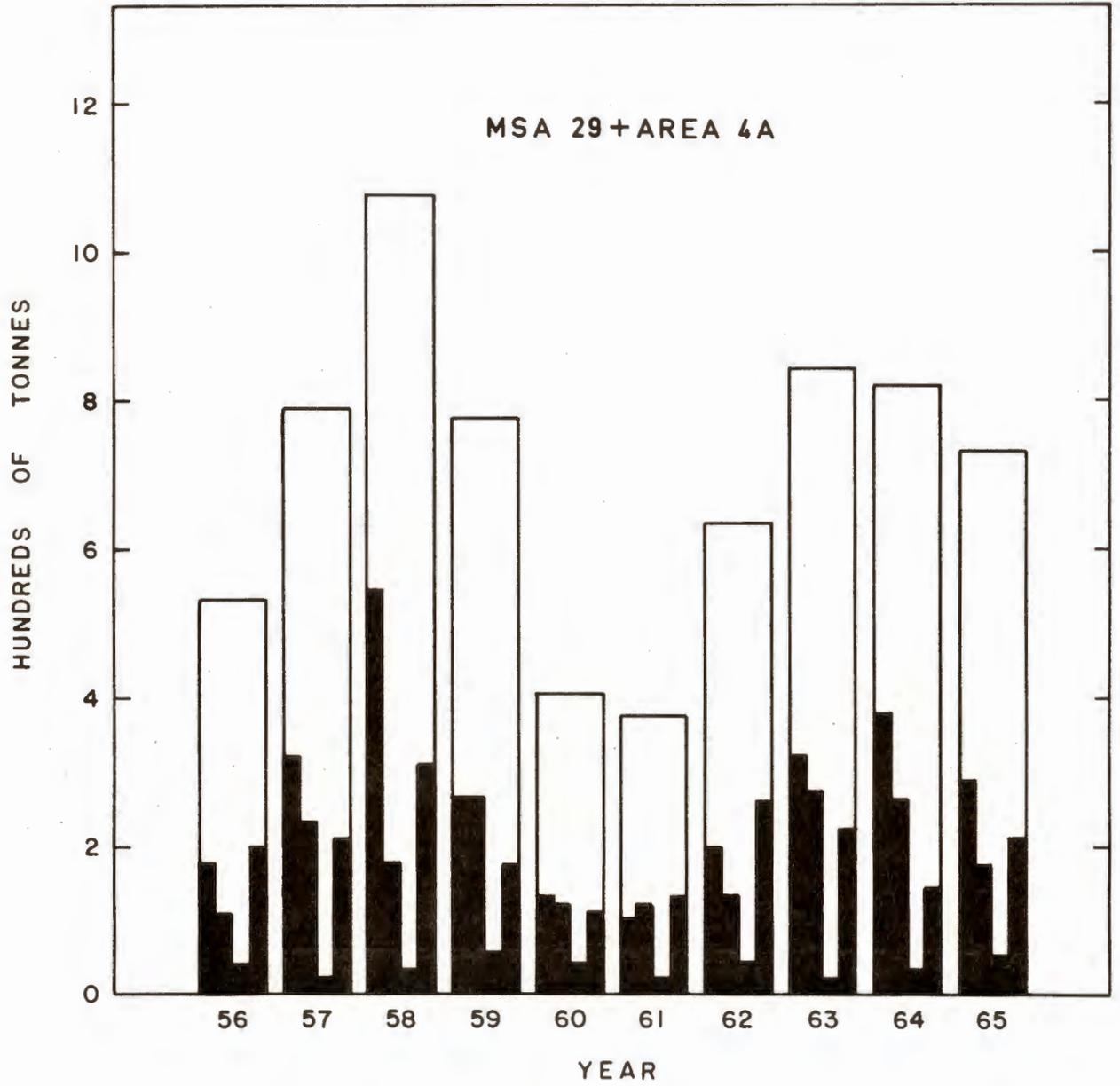


Fig. 5. Pacific cod landings (t) from MSA 29 (Canada) + Area 4A (U.S.), by quarter-year, 1956-65.



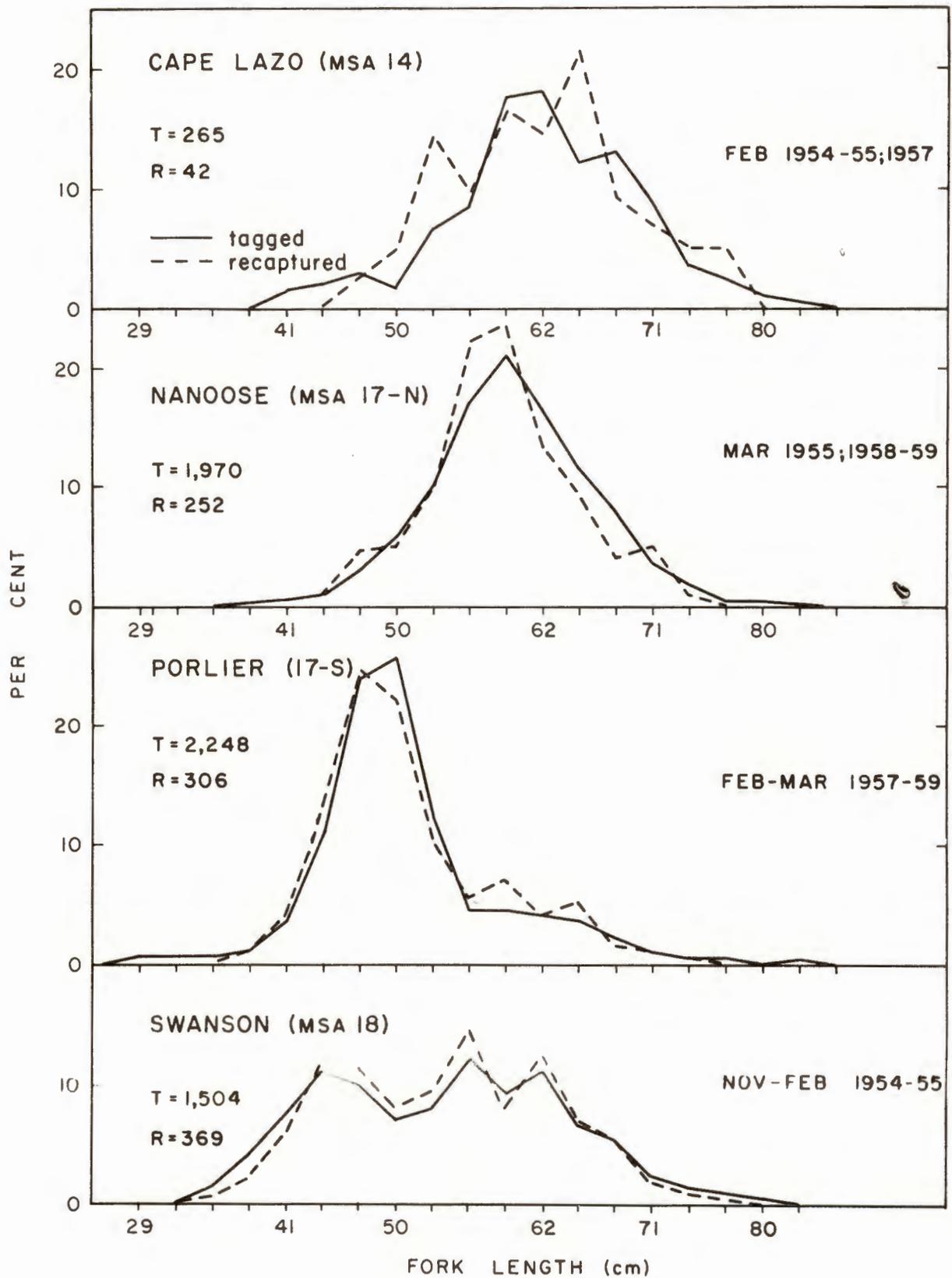


Fig. 6. Size composition (%) of tagged and recaptured Pacific cod (at time of tagging) from experiments in Area 4B, by region.



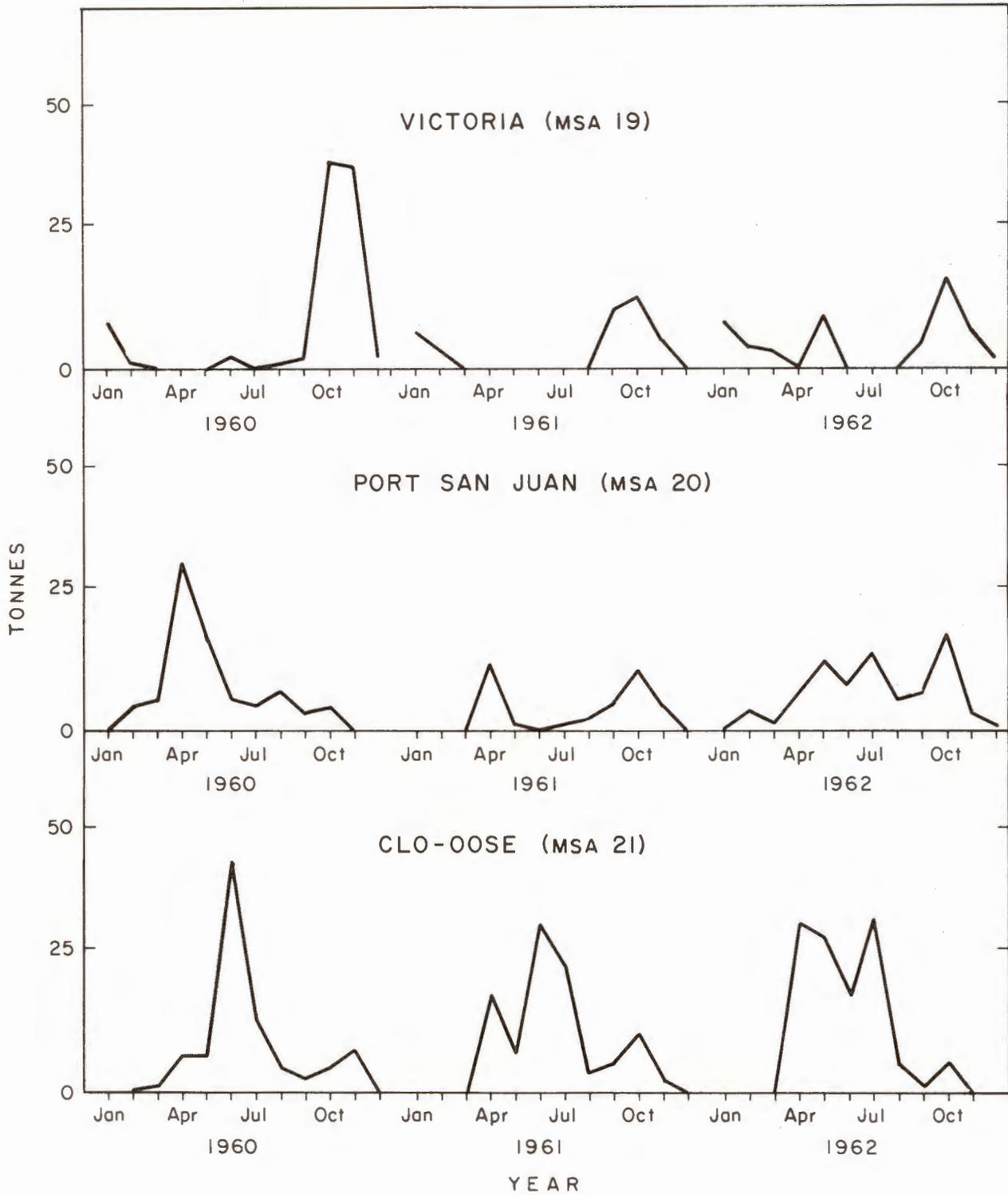


Fig. 7. Pacific cod landings (t) from MSAs 19, 20, and 21, by month, 1960-62.



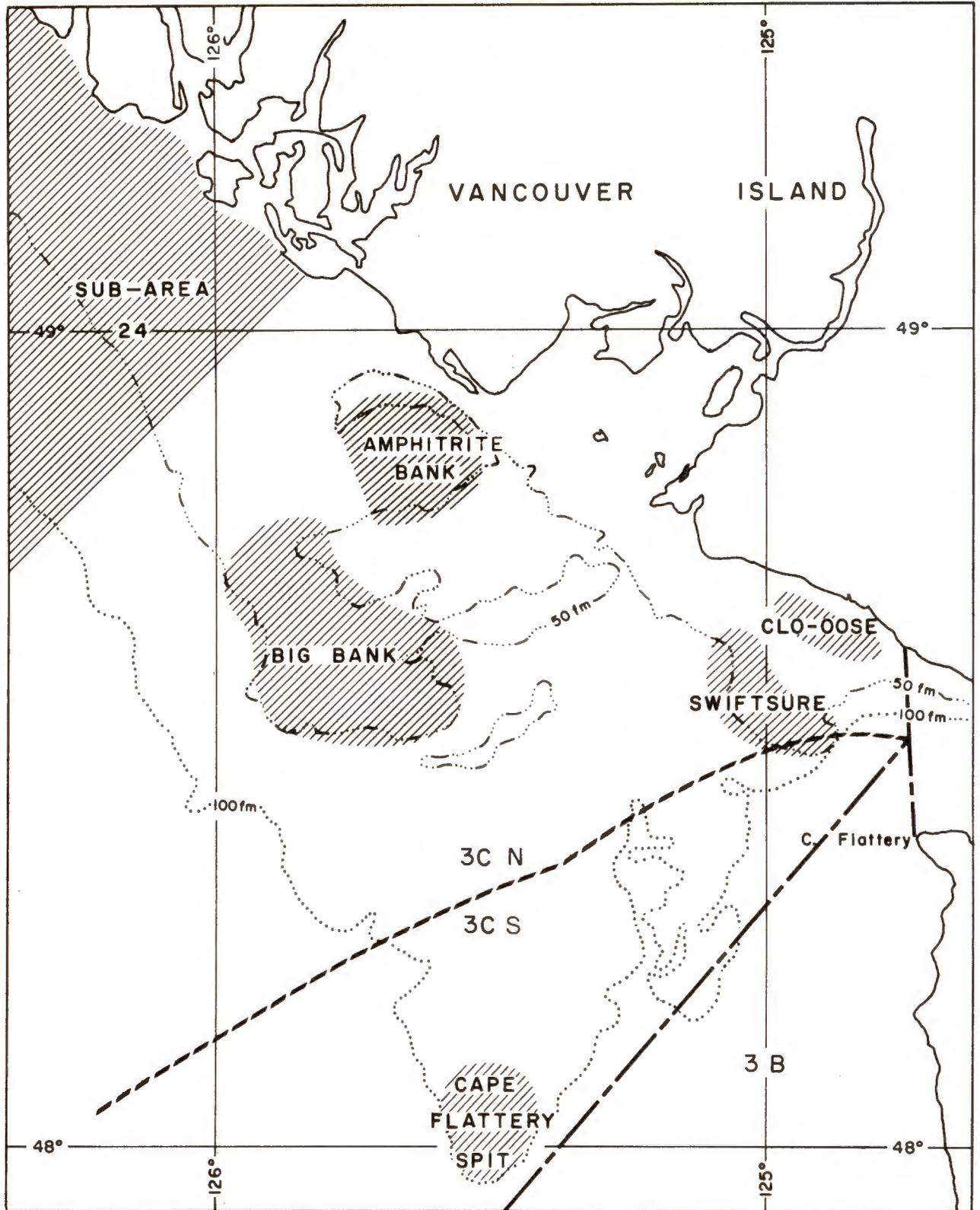


Fig. 8. Trawling grounds in Area 3C.



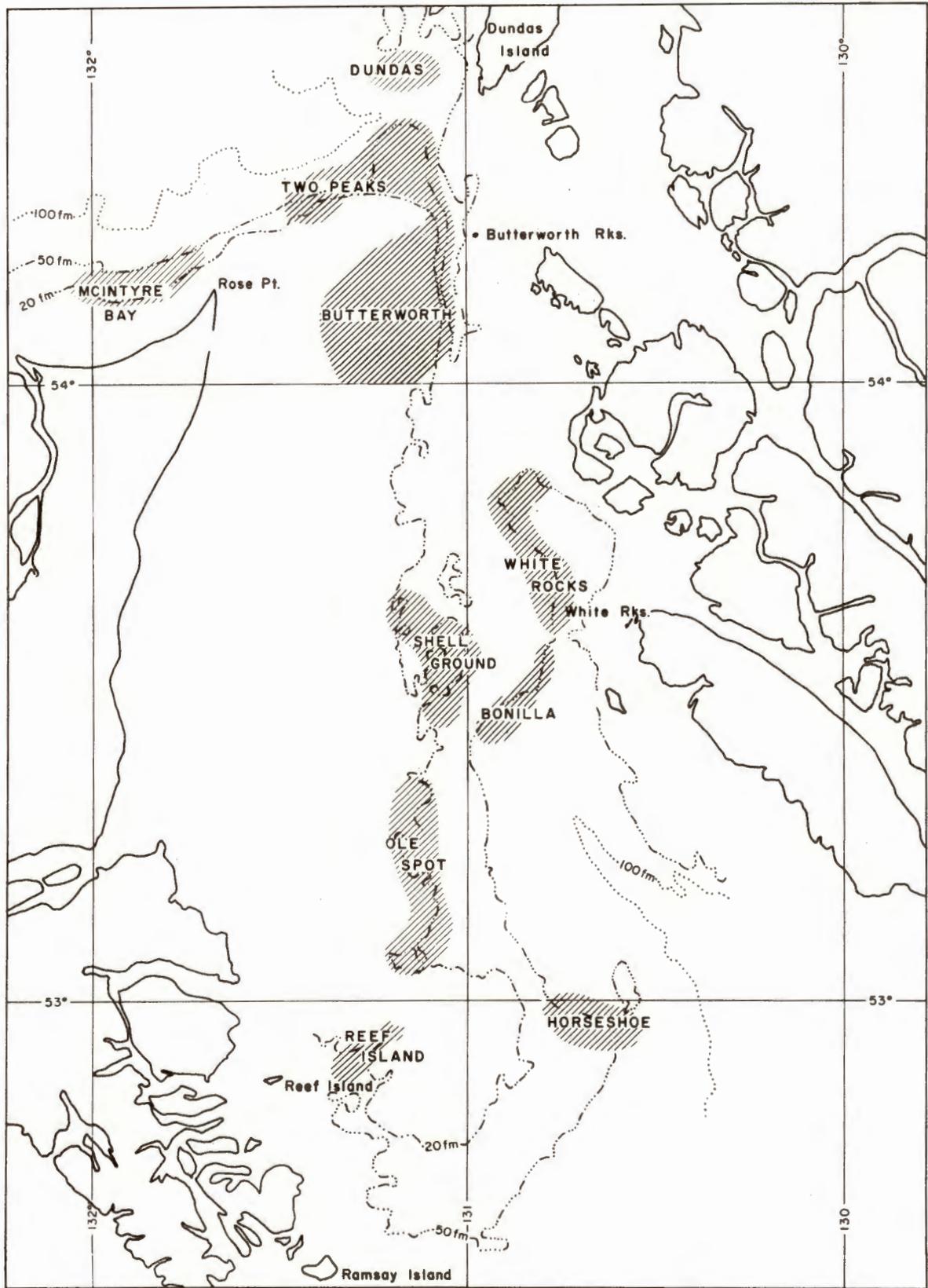


Fig. 9. Trawling grounds in Hecate Strait (Area 5C and 5D).  
(Fig. 6.1.1 in 1982 TAC Report.)



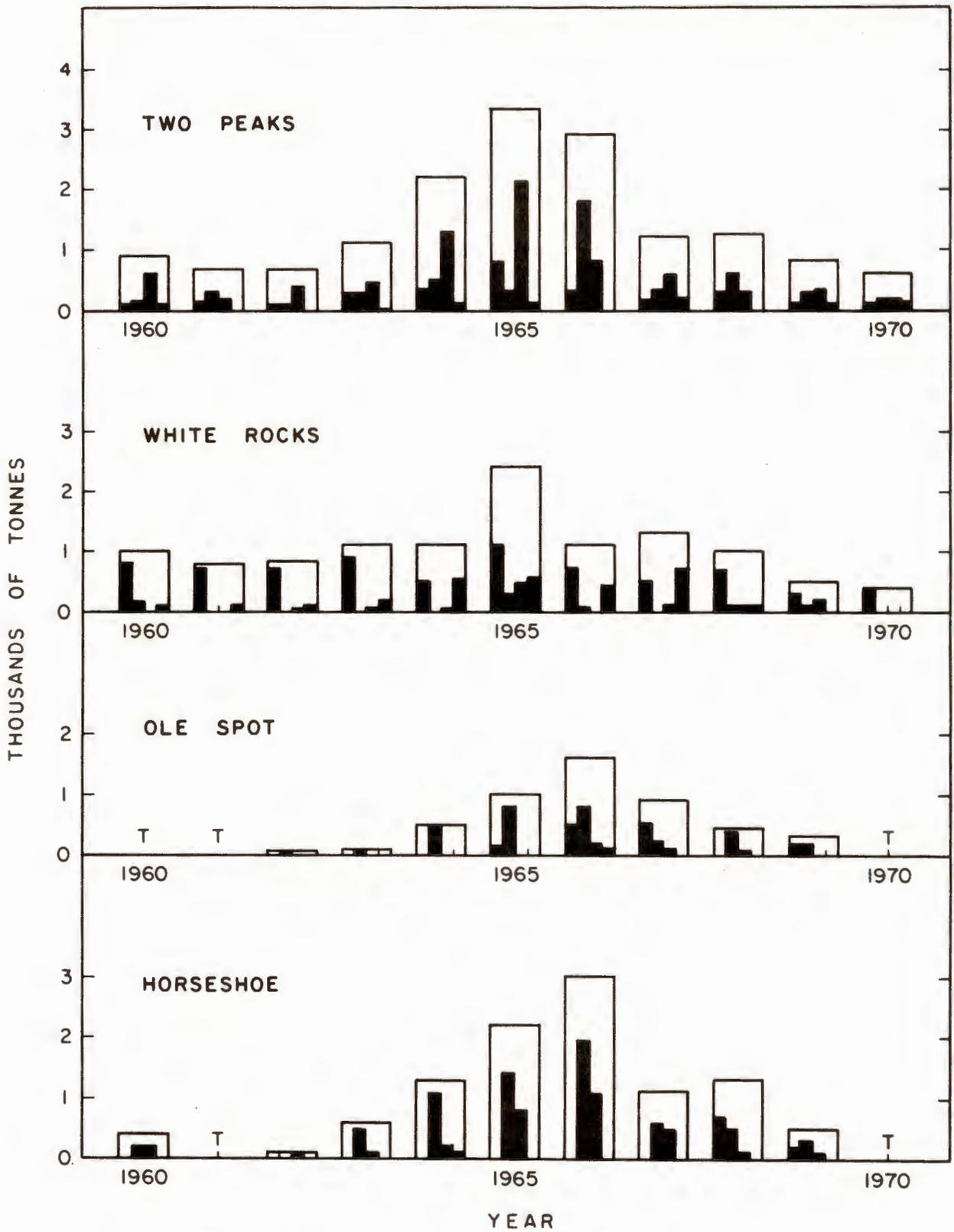


Fig. 10. Canada-U.S. landings (t) of Pacific cod from the principal grounds in Hecate Strait, by quarter year, 1960-70.



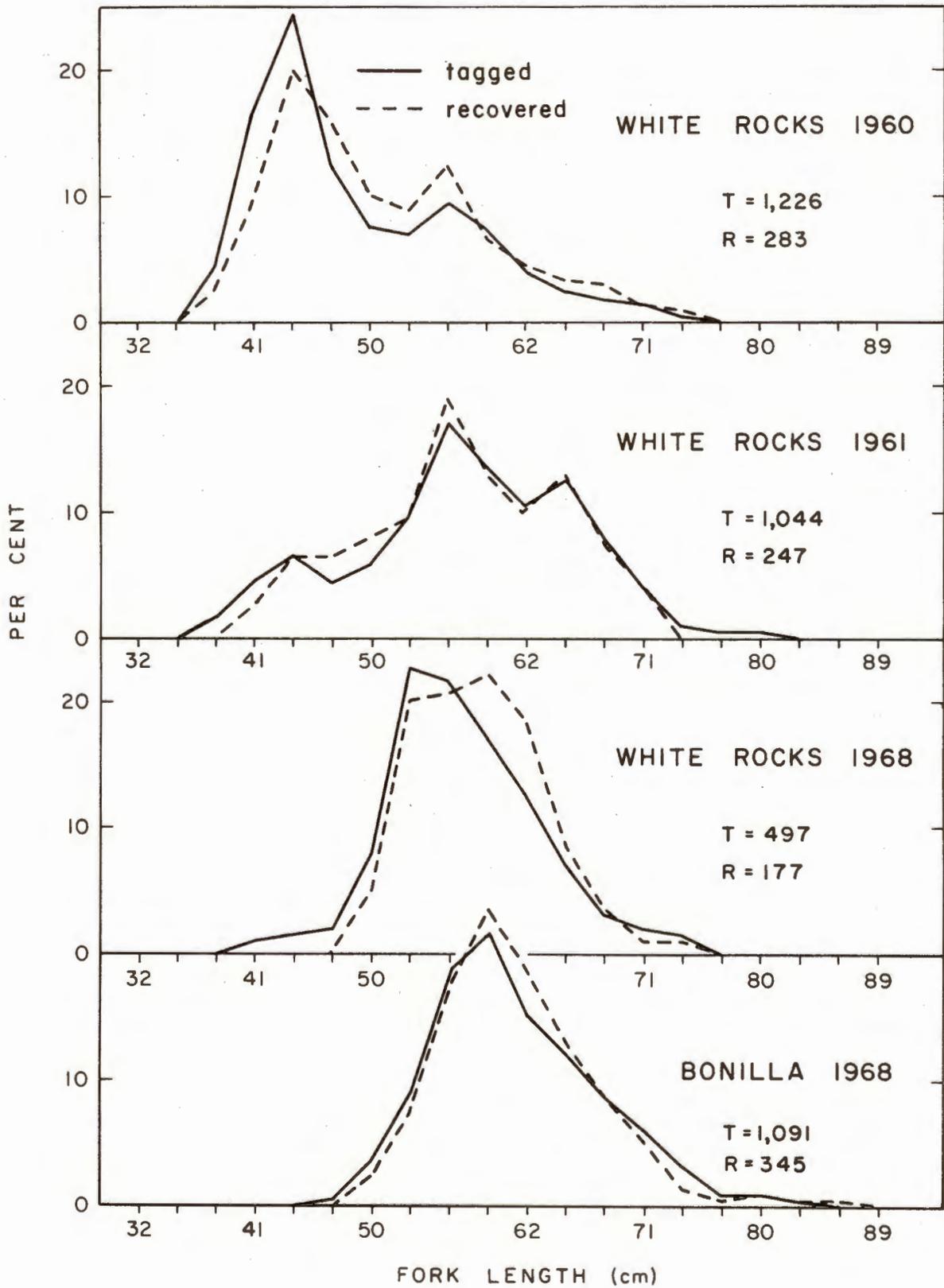


Fig. 11. Size composition (%) of tagged and recaptured Pacific cod (at time of tagging) for major winter (January-February) experiments in Hecate Strait, 1960-61 and 1968.



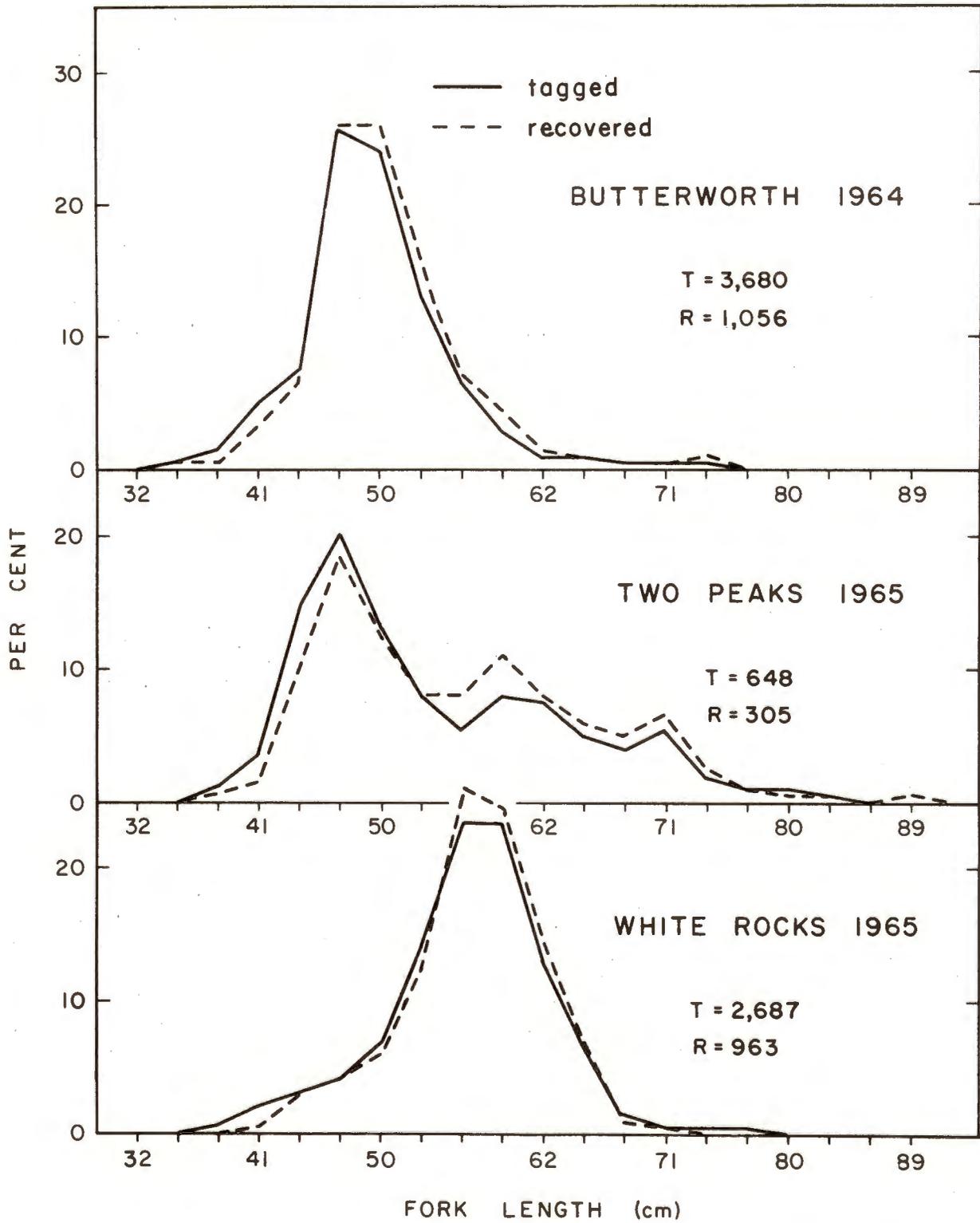


Fig. 12. Size composition (%) of tagged and recaptured Pacific cod (at time of tagging) for major spring (May) experiments in Hecate Strait, 1964-65.