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**Results, Through 1985, Of The Rock Sole
(*Lepidopsetta Bilineata*) Tagging Experiments
In Hecate Strait (British Columbia) During
April-May 1982 With Regard To Stock Delineation**

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RESULTS, THROUGH 1985, OF THE ROCK SOLE (Lepidopsetta Bilineata)
TAGGING EXPERIMENTS IN HECATE STRAIT (BRITISH COLUMBIA) DURING
APRIL-MAY 1982 WITH REGARD TO STOCK DELINEATION

by

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ABSTRACT

Fargo, J. and S. J. Westrheim. 1987. Results, through 1985, of the rock sole (Lepidopsetta bilineata) tagging experiments in Hecate Strait (British Columbia) during April-May 1982 with regard to stock delineation. Can. MS Rep. Fish. Aquat. Sci. 1912: 51 p.

During April-May 1982, 10,617 rock sole (Lepidopsetta bilineata) were tagged and released in Hecate Strait, at six sites. Purposes of the study were age-validation (to be reported elsewhere) and stock delineation (this report). Recovery rates were relatively low for the major releases (0-2.3%), and poor condition of fish caught for tagging was deemed the principal cause. No recoveries were reported outside Hecate Strait. Some intermingling was noted of rock sole released in South Hecate Strait with those in North Hecate Strait, but none in the opposite direction. Maximum time at liberty among sub-experiments was relatively short--7-9 quarter-years. Estimates of instantaneous total mortality rate ($Z = 1.35 - 1.61$) were excessive for pleuronectids in Hecate Strait, and probably reflected the poor physical condition of the rock sole caught for tagging.

RESUME

Fargo, J. and S. J. Westrheim. 1987. Results, through 1985, of the rock sole (Lepidopsetta bilineata) tagging experiments in Hecate Strait (British Columbia) during April-May 1982 with regard to stock delineation. Can. MS Rep. Fish. Aquat. Sci. 1912: 51 p.

En avril et mai 1982, on a étiqueté et remis à l'eau dans le détroit d'Hécate, à six emplacements, 10 617 soles du Pacifique (Lepidopsetta bilineata). Les buts recherchés par cette étude étaient la confirmation de l'âge (à être indiqué ailleurs) et la délimitation des stocks (le présent rapport). Les taux de recapture ont été relativement faibles compte tenu du nombre important d'individus remis à l'eau (0-2, 3%), et le piètre état des poissons capturés pour l'étiquetage a été jugé la principale cause. Aucune recapture n'a été signalée en-dehors du détroit d'Hécate. On a observé un certain mélange de soles du Pacifique remises à l'eau au sud du détroit d'Hécate avec celles remises à l'eau au nord, mais aucun dans le sens inverse. Le maximum de temps en liberté entre les essais était relativement court, de 7 à 9 trimestres. Les estimations du taux instantané de mortalité totale ($Z=1,35-1,61$) étaient trop grandes pour les pleuronectidés dans le détroit d'Hécate et reflétaient probablement le piètre état physique des soles du Pacifique capturées pour l'étiquetage.

INTRODUCTION

Rock sole (Lepidopsetta bilineata) is an important component in the multi-species trawl fishery in Hecate Strait, British Columbia (Fig. 1) (Fargo 1985). Validation of age-determination methods and stock delineation are two aspects of rock sole studies which need attention. Accordingly, a tagging program was undertaken during April-May 1982 to address these problems.

This report deals with the results of stock delineation studies, based on tagged rock sole recovered through December 1985. Results of the age-validation studies will be reported elsewhere.

MATERIALS AND METHODS

EXPERIMENTAL DESIGN

The stock-delineation phase of the current study was based on tagging and releasing rock sole from the two known spawning congregations, presumed to be "independent" stocks. One spawning group occupies grounds near Reef Island, in Area 5C (Fig. 1). The other occupies grounds southwest of Butterworth, in Area 5D (Fig. 1).

A sub-experiment on Butterworth Ground (Area 5D) was not associated with spawning rock sole.

TAGGING

A full description of the materials and methods employed during the tagging exercise has been reported elsewhere (Harling et al. 1982). Briefly, rock sole were tagged aboard a chartered commercial trawler. Fish to be tagged were held in tanks containing circulating sea water prior to tagging. A Floy FD68B anchor tag was affixed on the eyed side of each fish in the mid-body region, about 2.5 cm below the dorsal fin. Tag number, fork length (nearest cm), and "condition" were recorded before transferring the fish to the recovery tanks. In addition, each fish was injected (intramuscular) with oxytetracycline (.25 mg/kg) for age-validation studies, the results of which will be reported elsewhere. An anaesthetic (tricaine methane sulfonate) was used intermittently. Each lot of tagged rock sole was released en masse by tipping the recovery tank at the ship's rail to spill water and fish into the sea.

TAG RECOVERY

No effort was expended to directly determine the incidence of tags in the rock sole commercial landings. Recoveries were dependent upon the vigilance and cooperation of fishermen, processing-plant employees, and our full-time, port-liaison officers stationed in Prince Rupert and Vancouver. Most tagged rock sole were recovered at the processing plants. Occasionally, tagged fish were detected in the commercial catches at sea, and reported by the captain or a crew member. Port-liaison officers collect landing records (quantity and location of catch and effort) from most trawl landings, and collect biological samples (length-frequencies, sex ratio, age structures, gonad condition, etc.) from some of these landings, as well as for tagged specimens of many species. For each recovered tagged rock sole they collected the following information: time and location of recovery, fork length (cm), sex, otolith, gonad condition, and condition--fresh or frozen whole fish, or frame (carcass after fillets were removed).

The following criteria were used to assign recovery location from information provided by the vessel captain:

1. If at least 90% of the rock sole catch was made in a single major area, minor area, or locality (ground), the recovered tag was assigned to that location.
2. If the rock sole catch was made in two or more minor areas or localities within a single major area, the recovered tag was assigned to the major area.
3. If the rock sole catch originated in two or more major areas, recovery location was listed as unknown.

FACTORS AFFECTING RECOVERY RATE

Seven factors were investigated which might have affected recovery rate: location of release; length at release; sex ratio at release; condition at release; numbers released per haul; use of anaesthetic and water temperature at release.

Injection of OTC was also postulated as a factor affecting recovery rate, but the disproportionate (injected vs non-injected) sample sizes (<5% of fish were not injected) precluded analysis of this factor. A laboratory experiment conducted prior to the tagging indicated that the dosage of OTC used during the tagging experiment was non-lethal.

Tag shedding was not considered as a factor affecting recovery rate because Floy anchor tags have been used with good recovery results in Dover sole (Fargo et al. 1985) and English sole tagging experiments.

Originally, a multivariate analysis of the six factors affecting recovery rate was attempted in order to take the effects of variables on one another into account. However, several of the variables used for the

multivariate analysis were found to be confounded and Chi-square tests were employed instead. Chi-square tests of independence (Dixon and Massey 1969, p. 240) employed to determine significance of differences in recovery rates among factors were 2 x n contingency tests, with n-1 degrees of freedom.

For analytical purposes, length-frequencies were compiled in 2-cm intervals whose mid-points were even-numbered lengths -- 24.5 = 23.5-25.4, etc.

TIME AT LIBERTY

Recoveries were arrayed by quarter-years (January-March, etc.) for assessing time at liberty.

DISPERSION

Dispersion was assessed qualitatively and quantitatively. Quantitative recovery rates were numbers recovered per 100 t of rock sole landed.

MORTALITY RATES

Instantaneous total mortality rate (Z) was estimated from the arrays of "quantified" recoveries with respect to time. That is, $\ln(\text{nos./100 t})$ was regressed on time at liberty (Ricker 1975).

RESULTS

GENERAL

During April 29-May 10, 1982, 10,617 rock sole were tagged and released in Hecate Strait (Harling et al. 1982) (Table 1). An additional 30 were tagged, but died before release. Three sub-experiments were involved in South (Area 5C) and North (5D) Hecate Strait. Through December 1985, 134 (1.3%) tagged rock sole were recovered.

In South Hecate Strait (Area 5C), 5078 tagged rock sole were released, and 76 (1.5%) were recovered. Three release grounds were involved--Cumshewa (486/0/0%) (No. released/No. recovered/%recovered), Reef Island Flats (2363/54/2.3%), and Reef Island Gully (2229/22/1.0%) (Fig. 2).

In North Hecate Strait (Area 5D) 5539 tagged rock sole were released, and 58 (1.0%) were recovered. Three release grounds were involved--Seal Rocks-S (1446/7/0.5%); Seal Rocks-N (3725/8/0.2%), and Butterworth (368/43/11.7%) (Fig. 2).

Size composition of rock sole tagged and released in the current study (sub-experiments combined) was uni-modal (36.5 cm), with a mean of 36.6 cm, and a range of 24.5-56.5 cm (Fig. 3; Table 3). Size composition of the subsequent recoveries was bi-modal (38.5 and 32.5 cm), with a mean of 36.2 cm, and a range of 26.5-46.5 cm. Size composition of commercial landings, during 1983-85, was uni-modal (38.5 cm), with a mean of 39.1 cm, and a range of 24.5-52.5 cm. Principal length intervals ($\geq 10\%$) in the landings were 34.5-44.5 cm (84.8%). Comparable values were 32.5-40.5 cm (72.0%) for releases, and 30.5-40.5 cm (78.4%) for recoveries.

FACTORS AFFECTING RECOVERY RATE

Location of release

The recovery rate for rock sole released in Area 5C (1.5%) was significantly greater ($x^2=35.4$; $P<.01$) than for those released in Area 5D (1.0%) (Table 1). This phenomenon is not readily explained, because landings in Area 5C during all of 1982 and January-June 1983 were severely restricted by a trawl closure (Fig. 4). Landings and trawling effort were reduced substantially during 1980-83 as a result of the closure. Subsequent to June 1983, trawling effort remained low in Area 5C (and even Area 5D) due to the low abundance of Pacific cod (Gadus macrocephalus). Rock sole landings by International Area and locality in Hecate Strait over the time of this experiment are listed in Appendix tables 1 and 2.

Within Area 5C, the recovery rate for rock sole released at Cumshewa was 0%, while the recovery rate for Reef Island Flats (2.3%) was significantly larger ($x^2=12.050$; $P<.01$) than for those released at Reef Island Gully (1.0%).

Within Area 5D, the recovery rate for rock sole released on Butterworth Ground (11.7%) is obviously significantly larger than the rate for releases at Seal Rocks-S (0.5%) or Seal Rocks-N (0.2%). The latter two are not significantly different from one another ($x^2=3.077$; $P>.05$).

The recovery rates for the Reef Island sub-experiments (1.0 and 2.3%) are significantly larger than those for the Seal Rocks sub-experiments (0.5 and 0.2%).

Length at release

Among major experiments, size compositions of rock sole were uni-modal--38.5 cm for Area 5C, and 34.5 cm for Area 5D (excluding the Butterworth sub-experiment) (Table 4). Corresponding recovery rates were 1.5 and 0.3%, suggesting an inverse relationship between recovery rate and length at tagging. Among size intervals, recovery rates were polymodal for both experiments. For Area 5C, modal recovery rates were 2.7% (44.5 cm), 2.3% (38.5 cm), and 1.5% (32.5 cm), excluding the 9.0% rate at 26.5 cm which involved only two recoveries. The Area 5D results exhibited one prominent mode of 0.4% (34.5 cm), and two doubtful modes (based on one recovery each) of 0.7% (28.5 cm) and 0.5% (44.5 cm). Recovery rates exhibited a generally inverse relationship with length at release for the Area 5C experiment, but no relationship was apparent for the Area 5D experiment, probably due to the paucity of recoveries. The poly-modal distribution of recovery rates among length intervals is not readily explainable.

Notable was the inverse relationship between recovery rate and size composition of the released fish in the four earlier Butterworth experiments described by Ketchen (1982). Recovery rates and percent of tagged fish less than 31 and 36 cm are as follows:

Year	Per cent recovered	Per cent released	
		<31 cm	<36 cm
1947	27.0	8.5	57.4
1948	16.0	14.6	43.6
1958	1.7	55.8	92.3
1959	2.6	39.9	89.1
This study	11.7	23.9	68.8

However, Ketchen (op. cit.) noted that recovery rate during 1958-60 was inhibited by the excessive abundance of small rock sole on the grounds, which, in turn, inhibited the fishery.

Area 5C. Among sub-experiments, size compositions of tagged rock sole were uni-modal for all three sub-experiments--32.5 cm for Cumshewa, and 38.5 cm for Reef Island Flats and Reef Island Gully (Table 5). No recoveries were reported from the Cumshewa sub-experiment, while recovery rates were 2.2% for the "Flats" sub-experiment, and 1.1% for the "Gully" sub-experiment. Recovery rates were polymodal among length intervals for both sub-experiments. Modal rates were 4.9% (44.5 cm), 3.1% (38.0 cm), and 1.3% (32.5 cm) for the "Flats" sub-experiment; and 2.0% (42.5 cm) and 1.3% (32.5 cm) for the "Gully" sub-experiment.

The lack of recoveries is evidently not entirely due to relatively smaller fish tagged, since both the "Flats" and "Gully" sub-experiments exhibited modal recovery rates at 32.5 cm (the modal size of tagged rock sole released at Cumshewa).

The generally inverse relationship between recovery rate and length at tagging is probably due to greater viability of larger fish, and the size-selectivity of the fishery. No explanation is evident for the polymodal distributions of recovery rates among length intervals of tagged fish.

Area 5D. Among sub-experiments, size composition of tagged rock sole was bi-modal for Seal Rocks-S (32.5 and 42.5 cm), and uni-modal for Seal Rocks-N (36.5 cm) and Butterworth (32.5 cm) (Table 6). Corresponding recovery rates were 0.6, 0.2, and 11.7%, respectively. There was no apparent relationship between recovery rate and size composition. Among length intervals, recovery rates were multi-modal for all the sub-experiments, although only Butterworth produced sufficient recoveries to adequately delineate modes--17.4% (40.5 cm) and 13.5% (32.5 cm). All the "modes" (0.3-1.3%) for the Seal Rock sub-experiments were based on only one or two recoveries. Not surprisingly, no relationship was apparent between recovery rate and length at release for the Seal Rocks sub-experiments. The Butterworth sub-experiment did exhibit a proportional relationship. Its bi-modal distribution of recovery rates (17.4% @ 40.5 cm; 13.5% @ 32.5 cm) among length intervals is not explainable.

Length frequencies of rock sole sampled from commercial landings from 1982-85 are listed in Appendix table 3.

Sex ratio at release

Sex ratio of rock sole tagged and released was deduced from biological samples taken at each locality during the tagging experiment (Harling et al. 1982). A summary of this information is shown in Table 7. Size composition and sex ratio for fish recovered from each locality in the experiment are summarized in Table 8. The mean percent females tagged for the Reef Is. and Seal Rocks and Butterworth sub-experiments were 61.5%, 74.4%, and 50% respectively. The percent females tagged differed significantly between Reef Island and Seal rocks ($\chi^2 = 25.668$, $P < .01$) and Seal rocks and Butterworth ($\chi^2 = 7.343$, $P < .01$). However, the percent females tagged at Reef Island and Butterworth were statistically similar ($\chi^2 = 1.415$, $P > .30$). There is an evident inverse relationship between recovery rate and percent females tagged since recovery rates at Reef Island and Butterworth were 1.7% and 11.7% respectively compared to 0.3% for Seal rocks.

The inverse relationship between percent females tagged and recovery rate may be a function of the maturity stage of females tagged. In fact, 22% and 23% of females tagged at Reef Is. and Seal Rocks were spent or recovering from spawning while none of the females tagged at Butterworth were recovering from spawning. These results are based on maturity data collected during each tagging experiment by Harling et al. 1982.

Condition at release

Only 8.9% of the rock sole tagged and released were deemed in poor condition--4.4% in Area 5C, and 12.9% in Areas 5D (Table 9). Recovery rate was greater for fish in good condition (0-12.2%) than for those in poor condition (0-9.2%), but not significantly so in the three testable cases--Grand total ($\chi^2=1.351$; $P>.20$), Area 5D sub-total ($\chi^2=0.189$; $P>.50$), and Butterworth ($\chi^2=0.453$; $P>.30$). Interestingly, the Reef Island sub-experiments had a lower proportion of releases in poor condition (3.7 and 5.3%) and a higher recovery rate (1.1 and 2.3%) than the Seal Rocks sub-experiments (7.9 and 14.0% in poor condition; 0.6 and 0.2% recovered).

Size compositions of rock sole released in poor condition were dissimilar to those released in good condition. For all Area 5C sub-experiments, size compositions of releases in good condition were uni-modal, while those for releases in poor conditions were all polymodal (Table 10). In no case did the modes coincide. Among the Area 5D sub-experiments, size compositions were uni-modal for fish in good and poor condition. For the Seal Rocks sub-experiments, modal size was smaller for fish in poor condition, while for the Butterworth sub-experiment, the modal size was the same for fish released in good and poor condition (Table 11).

Harling et al. 1982 noted that mortality of fish prior to tagging was high and fish appeared quite lethargic even without the use of anaesthetic.

Number released per haul

In the Reef Island sub-experiments, 23-457 rock sole were tagged and released from each of 17 hauls (Fig. 5; Table 12). Recovery rates ranged from 0% (one haul) to 6.8%. Recovery rates were 0-6.8% for the 7 hauls from which less than 200 were tagged per haul. For the remaining 10 hauls, where numbers released were 328-459, recovery rates ranged from 0.3 to 1.9%.

In the Seal Rocks sub-experiments, 32-386 rock sole were tagged and released from each of 30 hauls (Fig. 6; Table 12). Recovery rates ranged from 0% (21 hauls) to 1.6%. No recoveries were recorded from hauls in which less than 152 fish were released.

Excluding 0% recoveries, there was a slight inverse relationship between recovery rate and numbers released for both areas.

Use of anaesthetic

In the Reef Island sub-experiments, 2979 rock sole were anaesthetized prior to tagging while 2185 rock sole were not anaesthetized. There were 43 recoveries from the anaesthetized group and 33 recoveries from the non-anaesthetized group. Chi-square results showed no significant difference in recoveries for the two groups ($\chi^2=0.054$, $P>.90$).

In the Sea Rocks sub-experiments, 731 fish were anaesthetized prior to tagging while 4517 received no anaesthetic. There were 2 recoveries from the anaesthetized group and 13 recoveries from the non-anaesthetized group. Chi-square tests were not necessary in this case because expected and observed recoveries for both groups were identical.

Chi-square tests for the Butterworth sub-experiment were not performed with regard to use of anaesthetic because no anaesthetic was used in this sub-experiment.

Water temperatures

The rock sole is a species whose geographical distribution ranges from the Bering sea to southern California (Hart 1973). The species' abundance is, however, notably low in the warmer waters south of British Columbia. Warm ocean temperatures have a negative effect on survival rates and hence abundance of rock sole year classes (Forrester and Thomson, 1969, Fargo 1985). Warm ocean temperatures also affect the availability and distribution of the species as indicated by the decreasing catch rates for rock sole with decreasing latitude indicated by B.C. trawl catch data. Low recovery rates of rock sole released in May-June 1982 were unexpected, based on the cool bottom-water temperatures, at 50 m and 100 m, during June 1982 (7.7 and 7.5°C), compared to those in 1983 (9.3-10.0°C and 7.5-8.3°C) (Table 13). Similar results were evident from more detailed records for April.

Similarly, for past Two Peaks-Butterworth experiments, recovery rates did not vary consistently with water temperatures. The relatively large recovery rates for the 1947 (27.0%) and 1948 (16.0%) experiments (Table 2) (Ketchen 1982) were associated with relatively cool water temperatures (4.7-7.0°C) during February-April at the "nearby" Langara Island Lighthouse (at the western end of Dixon Entrance). The low recovery rates of the 1958 (1.7%), and 1959 (2.7%) experiments were not related to "warm" surface-water temperatures necessarily--7.2-9.1°C during February-April 1958, and 5.8-7.1°C during February-April 1959 (Table 14).

Summary

Of the seven factors considered with respect to recovery rate, significantly different recovery rates were determined by location, and a general inverse relationship to length at release. Higher recovery rates, but not significantly so, were exhibited for females over males; and fish in good condition over those in poor condition at time of release. No relationship was evident for number released per haul, use of anaesthetic or water temperatures at the time of release.

TIME AT LIBERTY

A total of 122 recoveries provided usable records for analysis of time at liberty (Table 15; Appendix table 4). Rock sole tagged and released in 1982 exhibited a short life span. Maximum time at liberty ranged from 7 to

9 quarter-years among sub-experiments. The last recovery from the Reef Island sub-experiment occurred in June 1985. Comparable time was March 1984 for both the Seal Rocks and Butterworth sub-experiments.

For the Reef Island sub-experiment, principal time of recovery, after 1982, was Quarter II--41.8% in 1983; 20.9% in 1984; and 3.0% in 1985; or 65.7% of all recoveries. For the Seal Rocks sub-experiment, recovery periods exhibited no evident pattern. Principal periods were Quarters I (28.6%) and III (21.4%) in 1983, and Quarter IV (21.4%) in 1982; or 71.4% of all recoveries. For the Butterworth sub-experiment, principal recovery periods were Quarters IV (51.2%) and II (22.0%) in 1982; or 73.2% of all the recoveries.

In contrast, Ketchen (1982; Table 4) reported substantially greater maximum times at liberty for the four Butterworth experiments--year 9 for the 1947 and 1959 experiment; year 7 for 1948; and year 5 for 1958. The 1966 Bonilla (5C) experiment yielded recoveries through year 4, and the 1966 Dixon Entrance experiment, through year 3.

Time at liberty among the sexes was greater for females in the current study, and the last rock sole to be recovered from each sub-experiment was a female--June 1985 (44 cm FL when released) for Reef Island; and March 1984 for Seal Rocks (33 cm) and Butterworth (30 cm) (Table 15). Last recorded recovery of a male rock sole was May 1984 (36 cm) for Reef Island; July 1983 (41 cm) for Seal Rocks; and November 1982 (29 cm) for Butterworth. Presumably, the difference in time at liberty was due in part to the larger proportion of the releases being females.

Quantitative results (recoveries/100 t of landings) yielded little additional insight into the survival rate of the tagged rock sole (Table 15). Recovery rate peaked in Quarter II of 1983 (21.2 fish/100 t) for the Reef Island sub-experiment; Quarter III in 1983 (11.1 fish/100 t) for Seal Rocks; and Quarter IV in 1982 (20.8 fish/100 t) for the Butterworth sub-experiment.

DISPERSION

A total of 111 recoveries provided usable records of recovery locations--56 from the Reef Island sub-experiment, 14 from Seal Rocks, and 41 from Butterworth (Table 16). Distributions of individual recoveries, by location and month, are shown in Appendix table 5. None were recovered outside Hecate Strait.

Rock sole released at Reef Island (Area 5C) were recovered in near-equal proportions in Area 5C (57.1%) and 5D (42.9%). Within the Reef Island sub-experiment, the "Flats" tagging produced 13 (35.1%) recoveries in Area 5C and 24 (64.9%) recoveries in Area 5D, while the "Gully" tagging produced 19 recoveries in Area 5C, but none in Area 5D.

Rock sole released at Seal Rocks (5D) yielded 14 usable recoveries--all in Area 5D. Within this sub-experiment, Seal Rocks-S tagging yielded no recoveries at White Rocks, and Seal Rocks-N yielded no recoveries at Two Peaks. Both components yielded recoveries on intermediate grounds -- Shell and Butterworth.

Rock sole released at Butterworth (5D) yielded 41 usable recoveries--all in Area 5D. Most (28) recoveries occurred on Butterworth Ground, while the remainder were in close proximity at Two Peaks (4), Finger (1), and Shell (1).

Past rock sole tagging experiments were mostly located in Area 5D (6143 of 6395 releases), and the principal tagging location was Butterworth Ground (5356 of 6395 releases) (Table 2). Ketchen (1982) reported that 84.9% of the recoveries, after at least one year at liberty, were made within 10 miles of the tagging site, none were recovered outside Area 5D. However, during the time of these experiments, Canadian landings of rock sole from Area 5C were negligible, as were U.S. landings of rock sole from all of Hecate Strait (Ketchen 1982; Table 7).

The four minor past experiments (including one in Area 5C) yielded few recoveries, and all were reported from their respective release locations. Hence, Ketchen (1982) concluded that there is "no evidence of intermingling between Major Areas 5C and 5D and nothing to suggest significant movement among minor areas".

Quantitatively, rock sole released at Reef Island were nearly three times as prevalent in the landings from Area 5C (14.2 recoveries/100 t) as Area 5D (4.8 recoveries/100 t) (Table 17). Furthermore, in Area 5D landings, they were 1.7 times as prevalent as recoveries from releases at Seal Rocks (2.8/100 t). The overall superiority of Butterworth recoveries in Area 5D (8.3/100 t) is, of course, an understatement, since the numbers released (368) was only 8.0% and 7.1%, respectively, of those released at Reef Island (4592) or Seal Rocks (5171).

Evidently, rock sole occupying the Reef Island Flats area in April-May 1982 dispersed throughout Hecate Strait. However, the rock sole inhabiting Reef Island Gully, Seal Rocks, and Butterworth Grounds exhibited no such dispersal, Reef Island Gully produced no recoveries in Area 5D, while Seal Rocks and Butterworth provided no recoveries in Area 5C.

Equally interesting was the lack of recoveries outside Hecate Strait, particularly in Queen Charlotte Sound (Areas 5A and 5B), where a modest stock exists (Fig. 7).

MORTALITY RATES

Three estimates of the instantaneous total mortality rate (Z) were obtained--1.35 (Reef Island), 1.61 (Butterworth), and 1.57 (all sub-experiments) (Table 18). These estimates are exceptionally large compared to

those obtained for pleuronectids in Hecate Strait by other investigators--0.25 for Dover sole (Fargo, Westrheim, and Stocker 1985); 0.26-0.49 for English sole (Ketchen 1953); and 0.237-0.894 for rock sole (Forrester and Thomson 1969). It seems likely that a large component of the current mortality rate is accounted for by the relatively poor condition at release of the tagged rock sole (Harling et al. 1982). The untagged rock sole may well have suffered a similar mortality rate during 1982-85. The generally moribund condition of the fish before tagging precludes tagging as the primary cause of the high mortality rate.

SUMMARY AND CONCLUSIONS

In 1982, a rock sole tagging experiment was undertaken in Hecate Strait for the dual purposes of validation of age-determination methods, and stock delineation. This report dealt with the latter purpose.

During April 29-May 10, 1982, 10,677 rock sole were tagged and released--5078 in South Hecate Strait (Area 5C), and 5539 in North Hecate Strait (Area 5D). Through December 1985, 134 (1.3%) tagged rock sole were recovered--76 (1.5%) from the Area 5C releases, and 58 (1.0%) from the Area 5D releases. Recovery rates among sub-experiments were 0-2.3% from Area 5C, and 0.5-11.7% for Area 5D.

The relatively low recovery rates were investigated with respect to seven potentially adverse factors. Recovery rates were significantly different among locations of release, and exhibited a generally inverse relationship with length at release. Recovery rates were higher, but not significantly so, for females over males, and for fish in "good" condition over those in "poor" condition at time of release. No relationship was evident between recovery rate and numbers released per haul, use of anaesthetic, or water temperatures at time of release. We concluded that the principal cause of the low recovery rate was the generally poor condition of the rock sole when caught for tagging.

Maximum time at liberty was relatively short--7-9 quarter-years among sub-experiments. The last reported recovery occurred in June 1985 (Area 5C release). For all sub-experiments, the last rock sole recovered was a female. Among sub-experiments, principal recovery quarter-years exhibited no evident pattern.

Ketchen (1982) reported no tag recoveries from Hecate Strait during the Queen Charlotte Sound rock sole tagging experiments in the 1950s and 1960s or vice-versa. No recoveries of tagged rock sole were reported from outside Hecate Strait for this experiment either. Within Hecate Strait, rock sole released in Area 5C were recovered in Areas 5C and 5D, while none of those released in Area 5D were recovered in Area 5C. Among sub-experiments in Area 5C, Reef Island Flats releases produced all the recoveries in Area 5D, while the nearby Reef Island Gully releases produced recoveries only in Area 5C. Evidently, this tagging experiment has not resolved the stock delineation of rock sole in Hecate Strait.

Estimates of instantaneous total mortality rate (Z), based on quantitative recovery rates over time, were excessively high, for pleuronectids--1.35 for Reef Island releases; 1.61 for Butterworth releases; and 1.57 for total releases. These high rates have been attributed to the poor condition of the rock sole caught for tagging. Presumably the rock sole stock(s) must also have been suffering an above-average mortality rate, at least during 1982.

DISCUSSION

Results of the current study of rock sole stock delineation have corroborated the conclusions of earlier studies that no intermingling occurs between rock sole in Hecate Strait and those in Queen Charlotte Sound. Furthermore, more extensive tagging in the current study has revealed some intermingling of rock sole of Area 5C with those in Area 5D, but none in the reverse direction. Stock delineation of rock sole in Hecate Strait remains incomplete.

The current study was handicapped by two adverse factors which may well have been serious. These are: (1) the poor condition of the rock sole caught for tagging; and (2) the area closure in Area 5C during 1981-83 for conservation.

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Table 1. Recovery rates (%), by area and ground of release, of rock sole tagged in Hecate Strait during April-May 1982. (Recoveries through December 1985.)

Area	Ground	Numbers released	Numbers recovered	% recovered
5C	Cumshewa	486	-	0
	Reef Island Flats	2,363	54	2.3
	Reef Island Gully	2,229	22	1.0
	Sub-total	5,078	76	1.5
5D	S.W. Seal Rocks-S	1,446	7	0.5
	S.W. Seal Rocks-N	3,725	8	0.2
	Butterworth ^a	368	43	11.7
	Sub-total	5,539	58	1.0
Total		10,617	134	1.3

^aUnscheduled sub-experiment.

Table 2. Recovery rates (%), by area and ground of release, of rock sole tagged in Hecate Strait during June-August 1947-66. (From Table 2 in Ketchen 1982.)

Area	Released			Recovered	
	Ground	Time	Numbers	Nos.	%
5C	S. Bonilla	1966 Jun	252	6	2.4
5D	Bonilla	1958 Aug	187	0	0
	White Rocks	1958 Aug	600	1	0.7
	Butterworth	1947 Jun	1,237	334	27.0
		1948 Aug	1,519	243	16.0
		1958 Aug	1,300	22	1.7
1959 Jul		1,300	34	2.6	
Total			6,395	640	10.0

Table 3. Length-frequencies (%) of rock sole from Hecate Strait; (1) tagged and released, April-May 1982; (2) recoveries during 1982-85; and (3) commercial landings, 1983-85.

Fork length ^a (cm)	Releases (1982)	Recoveries (1982-85)	Landings (1983-85)
24.5	T	-	0.1
6	0.7	3.0	0.1
8	3.2	4.5	0.3
30.5	9.1	11.2	2.2
2	14.4	<u>14.2</u>	6.6
4	15.9	<u>12.7</u>	13.7
6	<u>16.3</u>	11.2	13.9
8	<u>14.0</u>	<u>17.9</u>	<u>15.7</u>
40.5	11.4	<u>11.2</u>	<u>15.6</u>
2	7.9	6.7	15.1
4	4.7	6.7	10.8
6	1.8	0.7	4.2
8	0.5	-	1.3
50.5	0.2	-	0.3
2	0	-	0.2
4	0	-	-
56.5	T	-	-
Total	100.1	100.0	100.1
N	10,614	134	1,516
-			
X	36.6	36.2	39.1

^aLength at release.

Table 4. Recovery rates (%), by 2-cm length interval, for rock sole tagged and released in Areas 5C and 5D^a during April-May 1982. (Recoveries through December 1985.)

Fork length ^b (cm)	Area 5C			Area 5D ^a		
	Released (nos.)	Recovered		Released (nos.)	Recovered	
		Nos.	%		Nos.	%
24.5	2	-	0	-	-	-
6	22	2	<u>9.1</u>	29	-	0
8	132	0	0	145	1	<u>0.7</u>
30.5	334	1	0.3	543	<u>2</u>	<u>0.4</u>
2	550	8	<u>1.5</u>	900	1	0.1
4	682	<u>6</u>	<u>0.9</u>	<u>949</u>	<u>4</u>	<u>0.4</u>
6	792	9	1.1	<u>908</u>	<u>3</u>	<u>0.3</u>
8	<u>821</u>	<u>19</u>	<u>2.3</u>	637	1	0.2
40.5	<u>759</u>	<u>14</u>	<u>1.8</u>	445	1	0.2
2	506	8	1.6	334	1	0.3
4	299	8	<u>2.7</u>	198	1	<u>0.5</u>
6	129	1	<u>0.8</u>	58	-	0
8	39	-	0	15	-	0
50.5	11	-	0	6	-	0
2	-	-	-	0	-	-
4	-	-	-	0	-	-
56.5	-	-	-	1	-	0
Sub-total	5,078	76	1.5	5,168	15	0.3
Unknown	-	-	-	3	-	0
Total	5,078	76	1.5	5,171	15	0.3

^aExcluding Butterworth (in Table 6).

^bLength at release.

Table 5. Recovery rates (%), by release location and 2-cm length interval, for rock sole tagged and released in Area 5C (S. Hecate Strait) during April-May 1982. (Recoveries through December 1985.)

Fork length ^b (cm)	Cumshewa ^a	Reef Island Flats			Reef Island Gully		
	Rel.	Rel.	Rec.	% Rec.	Rel.	Rec.	% Rec.
24.5	-	1	-	0	1	-	0
6	7	4	<u>2</u>	<u>50.0</u>	11	-	0
8	33	29	0	0	70	-	0
30.5	54	87	1	1.1	193	-	0
2	<u>86</u>	229	5	<u>2.2</u>	235	<u>3</u>	<u>1.3</u>
4	71	354	5	1.4	257	1	0.3
6	64	413	8	1.9	315	1	0.3
8	55	<u>447</u>	<u>14</u>	<u>3.1</u>	<u>319</u>	<u>5</u>	1.6
40.5	53	398	9	2.0	308	<u>5</u>	1.6
2	38	223	3	1.3	245	<u>5</u>	<u>2.0</u>
4	15	122	<u>6</u>	<u>4.9</u>	162	2	1.2
6	8	35	1	2.9	86	-	0
8	2	18	-	0	19	-	0
50.5	-	3	-	0	8	-	0
Total	486	2,363	54	2.2	2,229	22	1.1

^aNo recoveries

^bLength at release.

Table 6. Recovery rates (%), by release location and 2-cm length interval, for rock sole tagged and released in Area 5D (N. Hecate Strait) during April-May 1982. (Recoveries through December 1985.)

Fork length ^a (cm)	Seal Rocks - South			Seal Rocks - North			Butterworth		
	Rel.	Rec.	% Rec.	Rel.	Rec.	% Rec.	Rel.	Rec.	% Rec.
26.5	9	-	0	20	-	0	3	-	0
8	55	-	0	93	1	<u>1.1</u>	23	2	8.7
30.5	167	1	<u>0.6</u>	376	1	0.3	62	5	8.1
2	<u>256</u>	1	0.4	644	0	0	<u>89</u>	<u>12</u>	<u>13.5</u>
4	207	<u>2</u>	1.0	742	<u>2</u>	<u>0.3</u>	76	10	13.2
6	158	<u>2</u>	<u>1.3</u>	<u>750</u>	1	0.1	53	7	13.2
8	100	0	0	537	1	0.2	27	3	11.1
40.5	75	0	0	370	1	<u>0.3</u>	23	4	<u>17.4</u>
2	<u>86</u>	1	<u>1.2</u>	248	0	0	7	-	0
4	52	-	0	146	1	<u>0.7</u>	2	-	0
6	15	-	0	43	-	0	2	-	0
8	8	-	0	7	-	0	0	-	-
50.5	5	-	0	1	-	0	1	-	0
2	-	-	-	0	-	-	-	-	-
4	-	-	-	0	-	-	-	-	-
56.5	-	-	-	1	-	0	-	-	-
Sub-total	1,193	7	0.6	3,975	8	0.2	368	43	11.7
Unknown	1	-	0	2	-	0	-	-	-
Total	1,194	7	0.6	3,977	8	0.2	368	43	11.7

^aLength at release.

Table 7. Sex ratio by tagging location and Chi-square results as determined from biological samples collected during the rock sole tagging experiment April-May 1982.

Location	M	F	T	m	f	χ^2	P
Reef Island	275	440	715	232	483	11.798	
Seal rocks	155	451	606	198	408	13.870	
Total	430	891	1321			25.668	<.01
Reef Island	275	440	715	278	437	.053	
Butterworth	13	13	26	10	16	1.362	
Total	288	453	741			1.415	>.20
Seal rocks	155	451	606	161	445	0.305	
Butterworth	13	13	26	7	19	7.038	
Total	168	464	632			7.343	<.01

Table 8. Length-frequencies (nos.), by release location and sex, of rock sole recovered from releases in Hecate Strait during April-May 1982. (Recoveries through December 1985.)

Fork length ^a (cm)	Reef Island			Seal Rocks			Butterworth		
	M	F	Unk.	M	F	Unk.	M	F	Unk.
26.5	-	1	1	-	-	-	-	-	-
8	-	0	0	-	1	-	1	-	1
30.5	-	1	1	1	0	1	<u>2</u>	3	-
2	1	4	2	0	1	-	1	11	-
4	0	3	3	<u>2</u>	<u>2</u>	-	<u>3</u>	7	-
6	2	6	1	1	<u>2</u>	-	1	6	-
8	<u>4</u>	<u>12</u>	2	0	1	-	-	3	-
40.5	-	<u>12</u>	2	1	0	-	-	4	-
2	-	8	1	-	1	-	-	-	-
4	-	8	-	-	1	-	-	-	-
46.5	-	1	-	-	-	-	-	-	-
Total	7	56	13	5	9	1	8	34	1
% females		88.9			64.3			81.0	
% recovery (all fish)		1.7			0.3			11.7	

^aLength at release.

Table 9. Recovery rates (%), by condition at release and release site, for rock sole tagged and released in Hecate Strait during April-May 1982. (Recoveries through December 1985.)

Release location	Releases			Recoveries			% Recovered	
	Good	Poor	% P	Good	Poor	% P	Good	Poor
5C Cumshewa	469	17	3.5	-	-	-	0	0
Reef Is. Flats	2,238	125	5.3	51	1	1.9	2.3	0.8
Reef Is. Gully	2,147	82	3.7	24	-	0	1.1	0
Sub-total	4,854	224	4.4	75	1	1.3	1.5	0.4
5D Seal Rocks - S	1,099	94	7.9	7	1	12.5	0.6	1.1
Seal Rocks - N	3,418	557	14.0	7	-	0	0.2	0
Butterworth	303	65	17.7	37	6	14.0	12.2	9.2
Sub-total	4,820	716	12.9	51	7	12.1	1.1	1.0
Grand Total	9,674	940	8.9	126	8	6.0	1.3	0.9

Table 10. Length-frequencies (nos.), by ground and condition at release, of rock sole tagged in Area 5C (S. Hecate Strait) during April-May 1982 (recoveries through December 1985).

Fork ^b Length (cm)	Cumshewa ^a		Reef Island Flats				Reef Island Gully			
	Released		Released		Recovered		Released		Recovered	
	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor
24.5	-	-	1	-	-	-	1	-	-	-
6	6	1	4	-	1	-	11	-	1	-
8	30	<u>3</u>	28	1	0	-	67	3	0	-
30.5	54	0	82	5	1	-	183	<u>10</u>	1	-
2	<u>84</u>	2	212	17	4	1	226	9	<u>2</u>	-
4	68	<u>3</u>	335	19	5	-	247	<u>10</u>	1	-
6	62	2	391	<u>22</u>	8	-	<u>311</u>	4	1	-
8	52	<u>3</u>	<u>427</u>	20	<u>14</u>	-	307	<u>12</u>	5	-
40.5	52	1	379	19	8	-	299	9	<u>6</u>	-
2	37	1	215	8	3	-	237	8	5	-
4	14	1	111	<u>11</u>	<u>6</u>	-	152	<u>10</u>	2	-
6	8	-	33	2	1	-	85	1	-	-
8	2	-	18	0	-	-	15	<u>4</u>	-	-
50.5	-	-	2	1	-	-	6	2	-	-
Total	469	17	2,238	125	51	1	2,147	82	24	0
% Recovered					2.3	0.8			1.1	0

^aNo recoveries.

^bLength at release.

Table 11. Length-frequencies (nos.), by ground and condition at release, of rock sole tagged in Area 5D (N. Hecate Strait) during April-May 1982. (Recoveries through December 1985.)

Fork ^a Length (cm)	S.W. Seal Rocks - South				S.W. Seal Rocks - North				Butterworth			
	Released		Recovered		Released		Recovered		Released		Recovered	
	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor
24.5	-	-	-	-	-	-	-	-	-	-	-	-
6	9	-	-	-	15	5	-	-	18	5	2	-
8	49	6	-	1	74	19	-	-	17	5	2	3
30.5	150	17	1	-	298	78	1	-	46	16	2	3
2	239	17	1	-	529	115	0	-	72	17	10	2
4	192	15	2	-	648	94	2	-	64	12	10	0
6	142	16	2	-	663	87	1	-	47	6	7	0
8	93	7	0	-	464	73	1	-	21	6	2	1
40.5	72	3	0	-	337	33	1	-	21	2	4	-
2	82	4	1	-	220	28	0	-	6	1	-	-
4	47	5	-	-	123	23	1	-	2	-	-	-
6	14	1	-	-	41	2	-	-	2	-	-	-
8	7	1	-	-	7	-	-	-	0	-	-	-
50.5	3	2	-	-	1	-	-	-	1	-	-	-
2	-	-	-	-	0	-	-	-	-	-	-	-
4	-	-	-	-	0	-	-	-	-	-	-	-
56.5	-	-	-	-	1	-	-	-	-	-	-	-
Total	1,099	94	7	1	3,418	557	7	0	303	65	37	6
% Recovered			0.6	1.1			0.2	0			12.2	9.2

^aLength at release.

Table 12. Recovery rates (%), by haul, for rock sole tagged and released on the Reef Island and Seal Rocks grounds during April-May 1982. (Recoveries through December 1985.)

Reef Island ^a				Seal Rocks ^b			
Haul no. ^a	Nos. rel.	Recoveries		Haul no. ^b	Nos. rel.	Recoveries	
		Nos.	%			Nos.	%
1	147	10	6.8	14	34	-	0
2	71	4	5.6	18	301	2	0.7
3	64	1	1.6	19	184	3	1.6
4*	172	4	2.3	20	116	-	0
5*	328	6	1.8	22	108	-	0
6*	409	4	1.0	23	106	-	0
7*	388	3	0.8	24	54	-	0
8*	326	1	0.3	25	109	-	0
9*	459	6	1.3	26	32	-	0
10*	147	-	0	27	152	1	0.7
30	23	1	4.3	28*	51	-	0
31	30	2	6.7	29	250	2	0.8
32	361	6	1.7	37*	157	1	0.6
33	339	4	1.2	39*	322	-	0
34	416	8	1.9	40*	56	-	0
35	457	7	1.5	41*	140	-	0
36	455	9	2.0	42*	145	-	0
				43*	295	1	0.3
				44*	190	-	0
				45*	127	-	0
				46*	272	2	0.7
				47*	297	-	0
				48*	341	-	0
				49*	385	2	0.5
				50*	231	1	0.4
				51*	95	-	0
				52*	283	-	0
				53*	67	-	0
				54*	116	-	0
				55*	155	-	0
Totals	4,592	76	1.5		5,171	15	0.3

^aAsterisked hauls: release at Reef Island Gully.

^bAsterisked hauls: release at Seal Rocks - N.

Table 13. Water temperatures (°C) at 50 and 100 m in Hecate Strait, by 30-minute blocks of latitude, April 1982-85 and June 1982 and 1983.

Block ^a	1982		1983		1984		1985	
	50	100	50	100	50	100	50	100
<u>April^b</u>								
520	-	-	9.8	9.0	9.5	9.3	7.3	6.1
523	7.2	-	9.3	8.6	8.6	8.6	7.4	-
530	7.1	-	8.7	-	-	-	7.4	-
533	6.2	-	8.4	-	9.1	-	6.6	-
540	6.9	-	7.9	7.8	-	-	6.2	5.9
<u>June^c</u>								
520-540	7.7	7.5	-	-	-	-	-	-
520	-	-	9.4	7.8	-	-	-	-
523	-	-	9.3	8.0	-	-	-	-
530	-	-	9.5	8.3	-	-	-	-
533	-	-	-	-	-	-	-	-
540	-	-	10.0	7.5	-	-	-	-

^a520 = 52.00'-52°29'; 523 = 52°30'-52°59'; etc.

^bSources: 1982 -- Fargo et al. (1982); 1983 -- Fargo et al. (1983); 1984 -- Fargo et al. (1984a); 1985 -- Fargo et al. (1985).

^cSources: 1982 -- Harling et al. (1982); 1983 -- Fargo et al. (1984b).

Table 14. Mean monthly surface-water temperatures (°C) at Langara Lighthouse^a during February, March, and April for selected years.

Year	February	March	April
1940-85 Mean (S.D.)	6.1 (1.0)	6.3 (0.9)	7.1 (0.8)
1947	4.7	6.2	7.0
1948	4.9	5.9	6.7
1958	7.2	7.4	9.1
1959	5.5	6.7	7.2
1966	6.4	6.3	6.9
1982	5.8	6.3	7.1

^aUnpublished data

Table 15. Time at liberty (quarter-years), by release location, of recovered rock sole tagged and released in Hecate Strait during April-May 1982. (Recoveries through December 1985.)

Year	Qtr.	Reef Island (5C)		Seal Rocks (5D)		Butterworth (5D)	
		(%)	(N/100 t)	(%)	(N/100 t)	(%)	(N/100 t)
1982	II	4.5	3.0	14.3	2.0	22.0	8.9
	III	3.0	3.1	-	-	7.3	4.7
	IV	11.9	7.9	21.4	3.0	51.2	20.8
1983	I	10.4	19.4	28.6	11.1	7.3	8.3
	II	41.8	21.2	7.1	0.8	9.8	3.0
	III	1.5	2.7	21.4	18.1	-	-
	IV	1.5	2.4	-	-	-	-
1984	I	-	-	7.1	1.4	2.4	1.4
	II	20.9	25.0	-	-	-	-
	III	1.5	2.9	-	-	-	-
	IV	-	-	-	-	-	-
1985	I	-	-	-	-	-	-
	II	3.0	12.5	-	-	-	-
	III	-	0	-	-	-	-
	IV	-	0	-	-	-	-
Total		100.0	9.1	100.0	1.9	100.0	5.5
Unknown		9.0		1.0		2.0	
Last recovery Location		Jun 85		Mar 84		Mar 84	
FL at release		Unk.		Shell (5D)		Finger (5D)	
Sex		44.0		33.0		30.0	
		F		F		F	

Table 16. Numbers of tagged rock sole recovered, by location of release and recovery, from the Hecate Strait experiment of April-May 1982. (Recoveries through December 1985.)

Recovery Location	Release locations						Butterworth (5D)
	Reef Island (5C)			Seal Rocks (5D)			
	Flats	Gully	Total	South	North	Total	
Area 5C ^a	1	-	1	-	-	-	-
MSA 2BE ^b	6	-	6	-	-	-	-
Cumshewa	3	2	5	-	-	-	-
Reef Is.	1	15	16	-	-	-	-
Horseshoe	2	1	3	-	-	-	-
S. Bonilla	-	1	1	-	-	-	-
5C Sub-total	13	19	32	-	-	-	-
Area 5D ^c	1	-	1	-	1	1	5
MSA 4 ^d	1	-	1	-	-	-	2
White Rocks	2	-	2	-	2	2	-
Shell	1	-	1	1	3	4	1
Fingers	-	-	-	-	-	-	1
Butterworth	8	-	8	2	2	4	28
Two Peaks	6	-	6	3	-	3	4
Dundas	2	-	2	-	-	-	-
McIntyre Bay	3	-	3	-	-	-	-
5D Sub-total	24	-	24	6	8	14	41
Total	37	19	56	6	8	14	41
Unknown	18	2	20	1	-	1	2
Grand Total	55	21	76	7	8	15	43
Nos. tagged and released	2,363	2,229	5,078	1,446	3,725	5,171	368

^aLocation within 5C unknown.

^bLocation within Minor Statistical Area 2BE unknown.

MSA 2BE (S.W. 5C) includes Cumshewa, Horseshoe, and Reef Island grounds.

^cLocation within 5D unknown.

^dLocation within Minor Statistical Area 4 unknown.

MSA 4 (N.E. 5D) includes Butterworth, Dundas, Fingers, and Two Peaks grounds.

Table 17. Recovery rates (nos./100 t) of tagged rock sole, by sub-experiment, recovery area, and quarter-year, 1982-85.

Year	Qtr	Landings (t)		Area 5C		Area 5D			
				Reef Island		Seal Rocks		Butterworth	
		5C	5D	5C	5D	5C	5D	5C	5D
1982	II	18	83	0	3.6	0	2.4	0	10.8
	III	26	26	2.6	3.8	0	0	0	11.5
	IV	9	92	22.2	6.5	0	3.3	0	22.8
1983	I	5	31	80.0	9.7	0	12.9	0	9.7
	II	32	100	56.3	8.0	0	1.0	0	4.0
	III	19	18	0	0	0	16.7	0	0
	IV	4	38	0	0	0	0	0	0
1984	I	8	63	0	0	0	1.6	0	1.6
	II	17	39	29.4	5.1	0	0	0	0
	III	19	15	0	6.7	0	0	0	0
	IV	20	7	0	0	0	0	0	0
1985	I	9	14	0	0	0	0	0	0
	II	1	15	1.0	0	0	0	0	0
	III	9	39	0	0	0	0	0	0
	IV	9	16	0	0	0	0	0	0
Total (N)		218	495	14.2 (31)	4.8 (24)	- (-)	2.8 (14)	- (-)	8.3 (41)

Table 18. Estimates of instantaneous total mortality rate (Z), by sub-experiment, for rock sole tagged and released in Hecate Strait during April-May 1982.

Year	Reef Island		Seal Rocks	Butterworth		Total	
	N/100 t	ln (N/100 t)	N/100 t	N/100 t	ln (N/100 t)	N/100 t	ln (N/100 t)
1982	4.9	1.589	1.9	12.4	2.518	19.2	2.955
1983	13.4	2.595	4.5	2.8	1.030	20.6	3.025
1984	4.3	1.459	0.5	0.5	-0.693	5.3	1.668
1985	0.9	-0.105	-	-	-	0.9	-0.105
a		4.02	-		4.16		4.66
b = -Z		-1.35	-		-1.61		-1.57
r		-0.996	-		-0.999		-0.997
S _{yx}		0.17	-		0.10		0.17
R ²		0.99	-		0.99+		0.99

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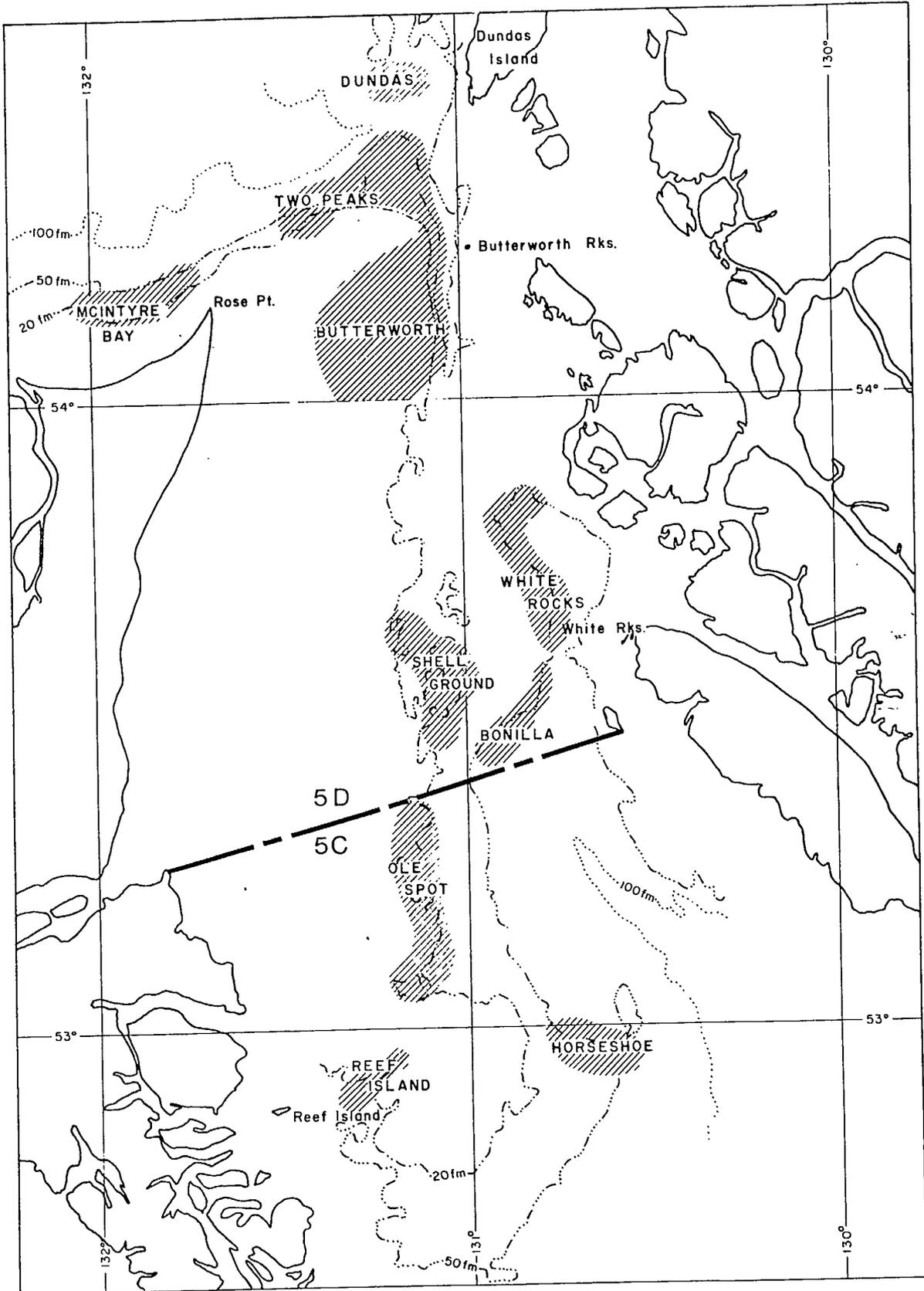


Fig. 1. Major trawling grounds in Hecate Strait, British Columbia.

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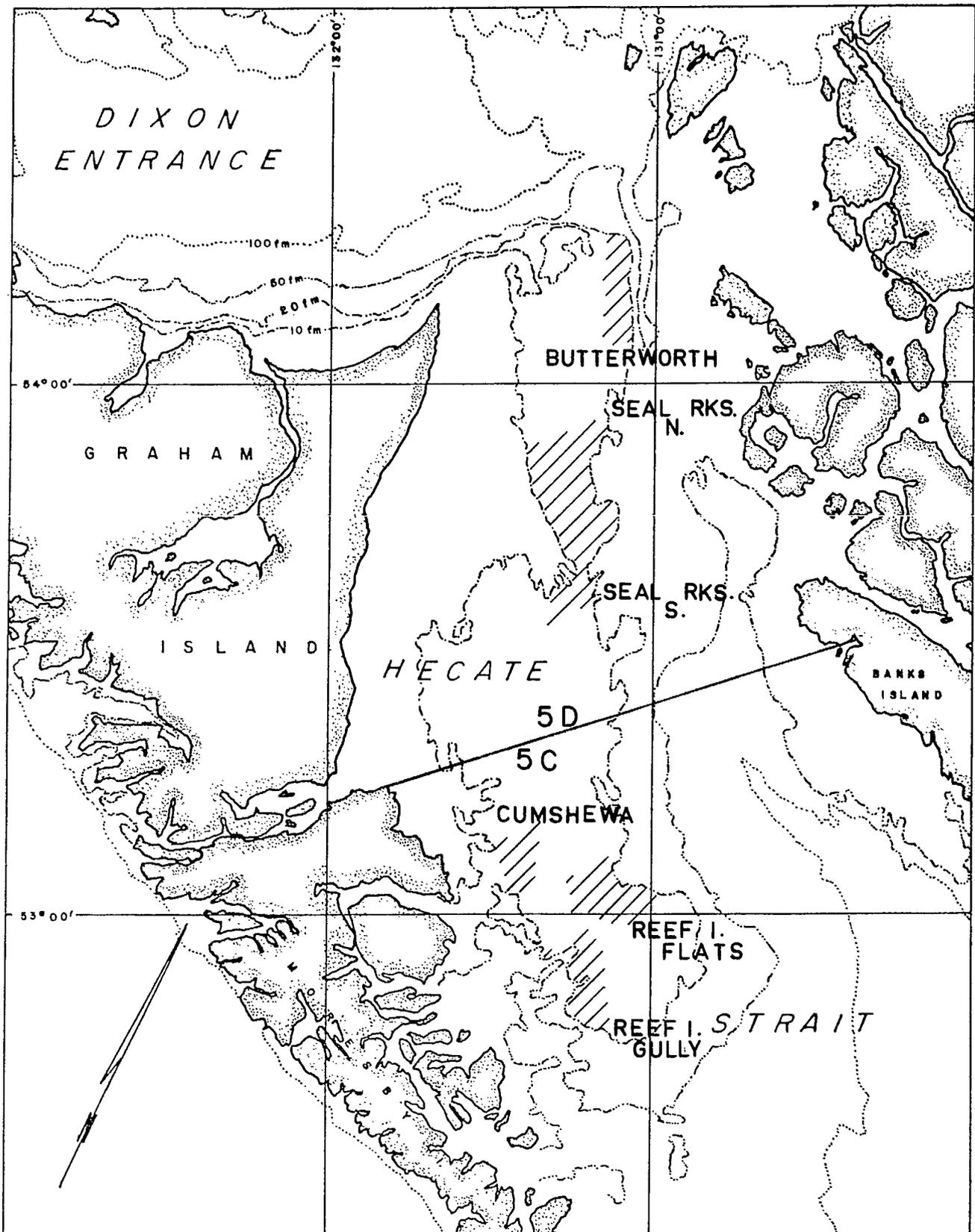


Fig. 2. Areas of tagging during the 1982 rock sole tagging experiment in Hecate Strait.

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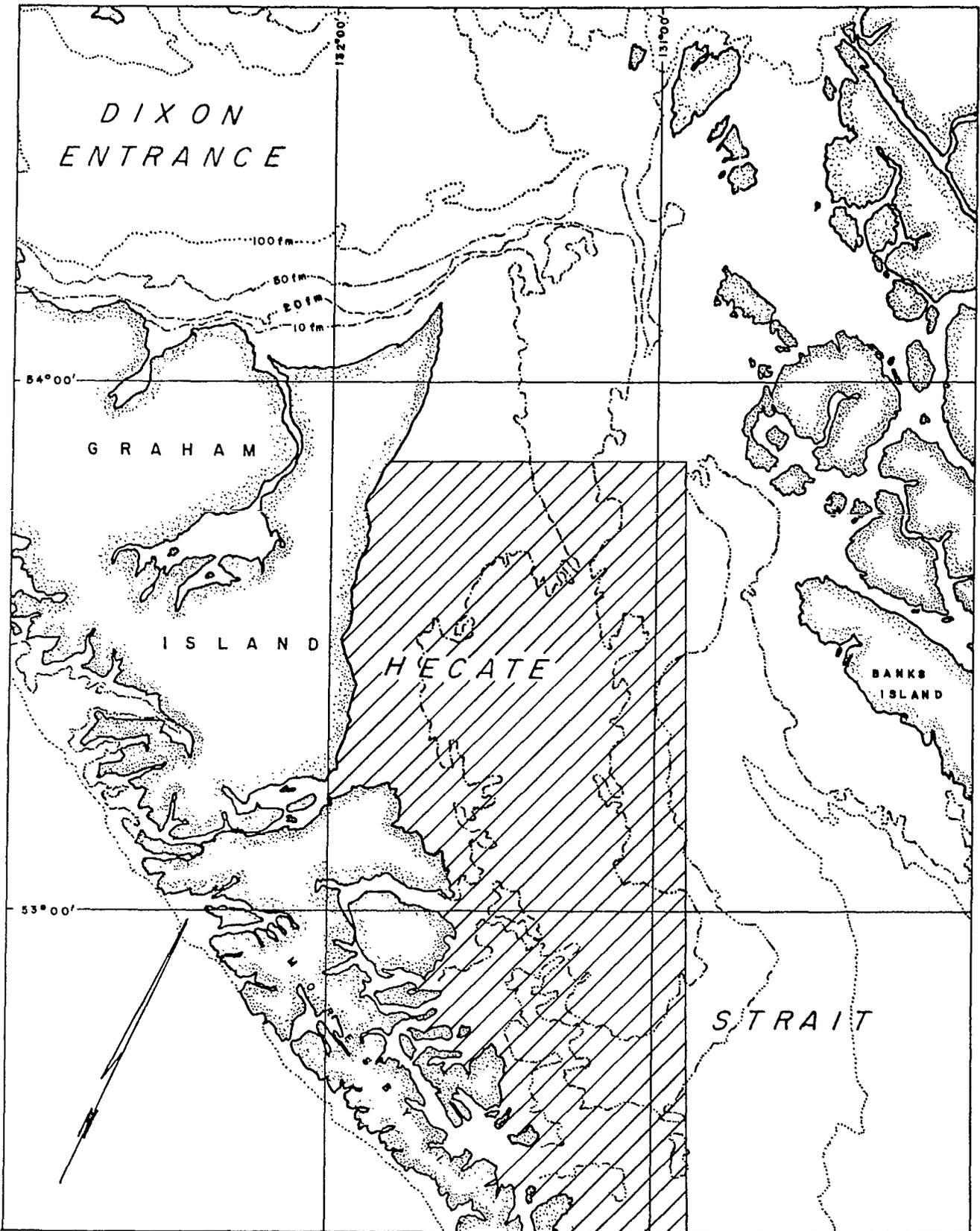


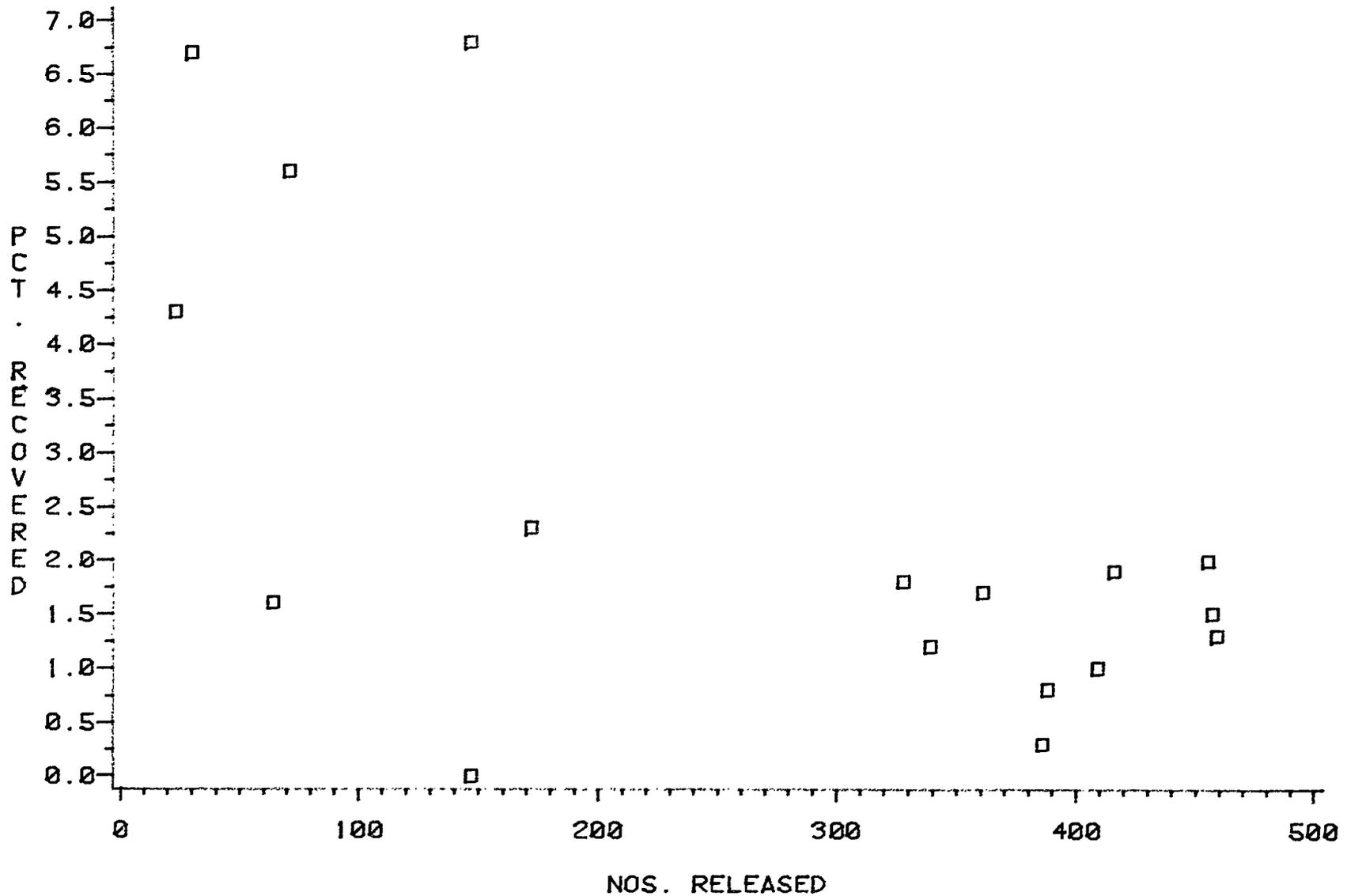
Fig. 4. Hecate Strait with hatched area representing the area closed to trawling during 1981-83 as a rock sole conservation measure.

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Fig. 5.

PCT. RECOVERED VS NOS. RELEASED--REEF ISLAND.

1982 HECATE ST. ROCK SOLE TAGGING EXPERIMENT.

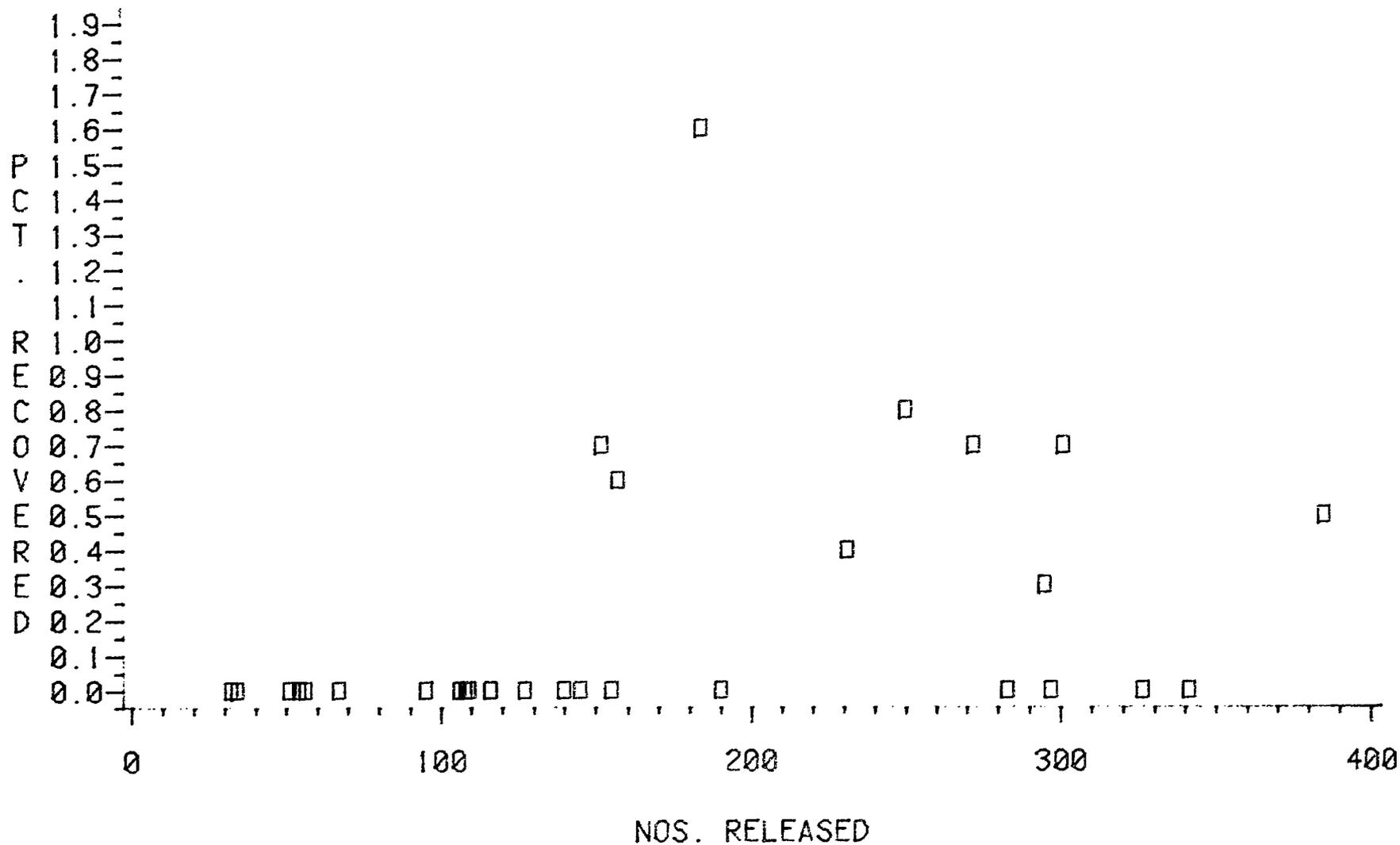


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Fig. 6.

PCT. RECOVERED VS NOS. RELEASED--SEAL ROCKS.

1982 HECATE ST. ROCK SOLE TAGGING EXPERIMENT.



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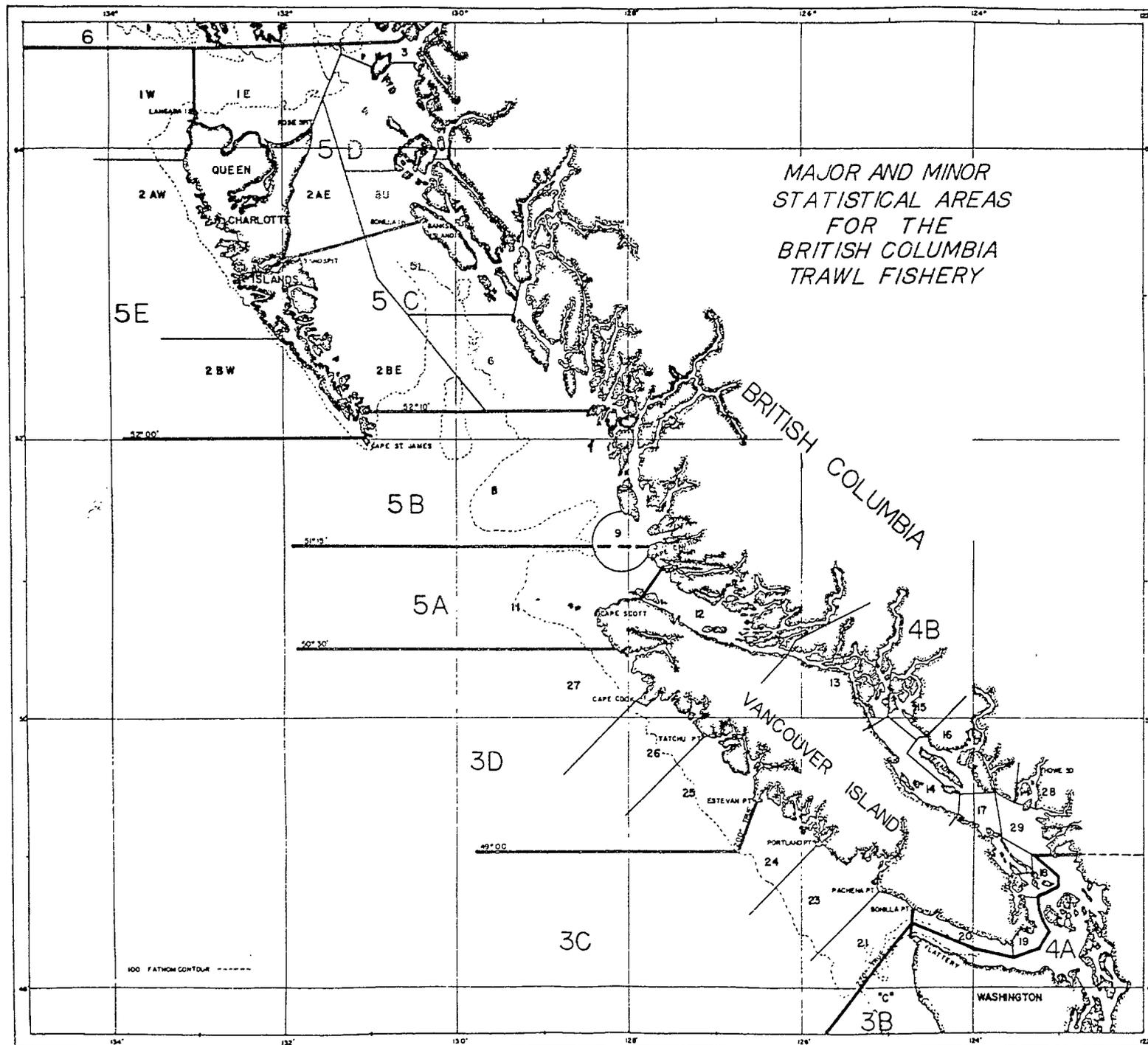


Fig. 7. Major and minor statistical areas for the British Columbia trawl fishery.

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Appendix table 1. Rock sole landings (t), by quarter-year, from Areas 5A, 5B, 5C, and 5D, 1982-85.

Year	Area 5A					Area 5B				
	I	II	III	IV	Total	I	II	III	IV	Total
1982	2	123	60	4	189	T ^a	20	106	29	155
1983	T	62	58	4	124	1	22	172	11	206
1984	T	103	30	6	142	T	10	73	5	87
1985	T	40	18	1	56	-	7	149	9	65

Year	Area 5C					Area 5D				
	I	II	III	IV	Total	I	II	III	IV	Total
1982	5	18	38	9	70	21	83	26	92	222
1983	5	32	19	4	60	31	100	18	38	187
1984	8	17	19	20	64	63	39	15	7	124
1985	9	1	9	9	28	14	15	39	16	84

^aT = trace = less than 0.5 t

Appendix table 2. Rock sole landings (t) from Hecate Strait, by important ground^a and quarter-year, 1982-85.

Year	Qtr.	Area 5C			Area 5D				
		HS	RI-CU	OS	WR-BO	SH	BU	TP	DU
1982	I	1	1	4	8	6	1	-	-
	II	16	-	-	2	25	37	18	-
	III	39	-	-	-	-	5	4	18
	IV	17	-	-	9	7	50	1	-
Total		63	1	4	19	38	93	23	18
1983	I	1	3	-	5	5	6	-	-
	II	23	2	7	3	12	32	37	-
	III	19	1	-	-	-	5	12	-
	IV	2	-	-	1	15	16	1	-
Total		45	6	7	9	32	59	50	-
1984	I	-	6	2	4	8	16	-	-
	II	1	16	-	1	2	21	9	-
	III	20	-	-	-	1	2	6	5
	IV	7	-	-	1	-	-	1	-
Total		28	22	2	6	11	39	16	5
1985	I	-	4	5	2	1	5	-	-
	II	1	1	-	1	2	10	1	-
	III	6	-	-	-	37	1	1	-
	IV	-	-	-	3	1	2	-	-
Total		7	5	5	6	41	18	2	-

^aGround: BU = Butterworth; DU = Dundas; HS = Horseshoe; OS = Ole Spot; RI-CU = Reef Island-Cumshewa; SH = Shell; WR-BO = White Rocks-Bonilla.

Appendix Table 3. Length-frequencies (nos. sampled) of rock sole landed from Hecate Strait, by major area and sex, 1983-85.

Fork length (cm)	Area 5C		Area 5D					
	1984		1983		1984		1985	
	M	F	M	F	M	F	M	F
24.5	-	-	1	-	-	-	-	-
6	-	-	0	-	-	-	1	-
8	-	-	1	-	-	2	2	-
30.5	5	2	5	4	-	3	12	3
2	19	6	12	12	3	12	31	5
4	<u>32</u>	22	<u>23</u>	15	3	22	<u>79</u>	11
6	<u>18</u>	23	<u>21</u>	23	1	42	<u>53</u>	30
8	8	36	22	32	2	<u>51</u>	18	69
40.5	1	<u>62</u>	6	<u>34</u>	1	<u>49</u>	-	84
2	1	<u>44</u>	-	<u>25</u>	-	34	-	<u>93</u>
4	-	29	-	25	-	34	-	<u>75</u>
6	-	3	-	15	-	16	-	29
8	-	-	-	5	-	7	-	8
50.5	-	-	-	3	-	-	-	-
52.5	-	-	-	3	-	-	-	-
Total	84	227	92	209	10	290	196	408
% females		73.0		69.4		96.7		67.5

Appendix table 4. Time at liberty (quarter-years), by release location and sex, of recovered rock sole tagged and released in Hecate Strait during April-May 1982. (Recoveries through December 1985.)

Year	Qtr	Reef Island				Seal Rocks				Butterworth			
		M	F	U	T	M	F	U	T	M	F	U	T
1982	II	1	1	1	3	-	2	-	2	3	6	-	9
	III	-	2	-	2	-	-	-	-	1	2	-	3
	IV	-	8	-	8	-	3	-	3	4	16	1	21
1983	I	-	7	-	7	4	-	-	4	-	3	-	3
	II	3	24	1	28	-	1	-	1	-	4	-	4
	III	1	-	-	1	1	2	-	3	-	-	-	-
	IV	-	1	-	1	-	-	-	-	-	-	-	-
1984	I	-	-	-	-	-	1	-	1	-	1	-	1
	II	2	5	7	14	-	-	-	-	-	-	-	-
	III	-	1	-	1	-	-	-	-	-	-	-	-
	IV	-	-	-	-	-	-	-	-	-	-	-	-
1985	I	-	-	-	-	-	-	-	-	-	-	-	-
	II	-	2	-	2	-	-	-	-	-	-	-	-
	III	-	-	-	-	-	-	-	-	-	-	-	-
	IV	-	-	-	-	-	-	-	-	-	-	-	-
Total		7	51	9	67	5	9	-	14	-	32	1	41
Unknown		-	5	4	9	-	-	1	1	-	2	-	2

Appendix table 5. Distribution of individual recovered rock sole by location of release, and location and time of recovery, tagged and released in Hecate Strait during April 29-May 10, 1982. (Recoveries through December 1985.)

Recovery location										
MSA 2BE	Cumshewa	Reef Island	Horseshoe	Area 5D	MSA 4	White Rocks	Shell	Finger	Butterworth	Two Peaks
<u>Reef Island - Cumshewa (Area 5C)</u>										
Nov 82 Feb 83 (4) Apr 83	Apr 84 (4) ^a May 85	May 83 (16)	Aug 82 Oct 82 May 83	Nov 82	Apr 83	Oct 82 (2)	Apr 83	-	May 82 (2) Jun 82 Nov 82 (3) Apr 83 May 84	Jul 82 May 83
<u>S. W. Seal Rocks (Area 5D)</u>										
-	-	-	-	Nov 82	-	Mar 83 (2)	Mar 83 (2) Jun 83 Mar 84	-	May 82 Jun 82 Nov 82 (2)	Jul 83
<u>Butterworth (Area 5D)</u>										
-	-	-	-	Nov 82 (5)	Nov 82 Apr 83	-	Mar 83	Mar 84	May 82 (6) Jun 82 (3) Sep 82 (3) Oct 82 Nov 82 (14)	Feb 83 May 83

^aNumbers in parenthesis indicate number recovered if more than one.

