Results of the September 1979 Dover Sole Tagging Experiment in Northern Hecate Strait, Through 1984

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RESULTS OF THE SEPTEMBER 1979 DOVER SOLE TAGGING EXPERIMENT IN NORTHERN HECATE STRAIT, THROUGH 1984

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by

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ABSTRACT

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In September 1979, 5145 trawl-caught Dover sole (Microstomus pacificus) were tagged and released in northern Hecate Strait (Area 5D), primarily for stock delineation. Through December 1984, 745 (14.5%) were recovered. Recovery rates varied inversely with length at tagging, at fork lengths $\leq$ 46.5 cm rates were lower for a few adverse "conditions at release"; butwere unaffected by overnight holding. Handling mortality was negligible. Maximum time at liberty is expected to be considerable, possibly as much as 14 years. Dispersion of tagged Dover sole was negligible--ca. 0.4% /annum southward. Most recoveries (98.2%) occurred on the "summering" grounds in Area 5D or the deep-water "wintering" grounds to the westward (Area 5E). Independent estimates of instantaneous total mortality rate were 0.25 (tag returns) and 0.30 (age-frequencies). Results of growth analysis, based on length-increments of tagged fish, and length-at-age (otoliths), were unsatisfactory, perhaps because of the lack of data on length-at-age of juvenile Dover sole.

Key words: Dover sole, tagging, stock delineation, mortality rate, growth, Hecate Strait

RESUME

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En septembre 1979, 5145 soles de Douvres (Microstomus pacificus) pêchées au chalut ont été marquées et relâchées dans le nord du détroit d'Hecate (Zone 5D) en vue de délinéer les stocks. En décembre 1984, 745 (14.5%) ont été récupérées. Les taux de récupération variaient inversement avec la longueur lors du marquage pour des longueurs de fourche $\leq$ 46.5 cm et les taux étaient inférieurs dans quelques mauvaises "conditions de remise à l'eau", mais n'étaient pas perturbés par la nuit de rétention. La mortalité due à la manipulation était négligeable. On s'attend à ce que le temps maximal en liberté soit considérable, peut-être jusqu'à 14 ans. La sole de Douvres marquée s'est peu dispersée - environ 0.14% par année vers le sud. La plupart des soles retrouvées (98.2%) se trouvaient dans des zones "d'été" dans l'Aire 5D ou dans des zones d'eaux profondes "d'hiver" vers l'ouest (Aire 5E). Des estimations indépendantes du taux total instantané de mortalité ont été établies à 0.25 (retours de poissons marqués) et de 0.3 (âge-fréquences). Les résultats de l'analyse de croissance, basés sur la croissance en longueur des poissons marqués et sur la longueur à un âge donné (otolithes), étaient insatisfaisants, peut-être à cause du manque de données sur la longueur à un âge donné de la jeune sole de Douvres.

Mots-clé: sole de Douvres, délinéation du stock, taux de mortalité, croissance, détroit d'Hecate

INTRODUCTION

In September 1979, we tagged Dover sole on Dundas and Two Peaks grounds primarily for the purpose of stock delineation (Stocker et al. 1980). This report presents the results through December 1984, with respect to pre-release mortality, recapture rates, time at liberty, dispersion, mortality rates and growth.

In 1969, a modest trawl fishery for Dover sole (Microstomus pacificus) suddenly developed in northern Hecate Strait (Area 5D) (Fig. 1). During 1956-68, Canada-U.S. landings ranged from 18 t to 110 t per annum (Fig. 2). In 1969, landings rose to 265 t, and in 1970, 965 t. During 1970-83, Canadian landings (U.S. vessels no longer trawled in Hecate Strait) ranged from 242 to 1001 t, with a mean of 675 t/annum. Interviewed trawl captains reported that improved market demand enabled them to increase their landings of Dover sole.

The principal source of Dover sole was Dundas Ground (@ 60-89 fath; 110-163 m), and the secondary source was the adjacent Two Peaks Ground (@ 50-69 fath; 92-126 m) (Fig. 3). The fishery was seasonal, and some 87% of the landings occurred during April-September. After September, Dover sole were virtually absent from these grounds.

The question then arose as to where to find these Dover sole in fall and winter.

Elsewhere, a seasonal bathymetric migration had been demonstrated off California, based on logbook analysis (Hagerman 1952); off Oregon, based on tagging (Harry 1956; Milburn 1966; Barrs 1982); and off Washington, based on logbook analysis (Alverson 1960) and tagging (Westrheim and Morgan 1963). In all the study areas, Dover sole generally occupied the continental shelf during spring and summer, and the nearby continental slope during fall and winter.

The nearest offshore "deep" water to Dundas and Two Peaks grounds was westward, in Dixon Entrance and north and south of Langara Island (Fig. 3). Accordingly, three trawl surveys were undertaken during 1977-78 to search Canadian waters for Dover sole--two in winter and one in summer. The February 1977 survey located substantial concentrations of Dover sole northwest of Langara Island in 250-270 fath, and west of Frederick Island in 270-290 fath (Harling, Sigmund, and Westrheim 1977). The January 1978 survey corroborated the Dover sole concentration off Frederick Island, but found none southward to Rennell Sound (Harling, Wallis, and Sigmund 1978). The July-August 1978 survey failed to find any Dover sole concentrations in the region surveyed during the winters of 1977 and 1978 (Harling, Fargo et al. 1978).

MATERIALS AND METHODS

TAGGING

A full description of the materials and methods employed during the tagging exercise has been reported elsewhere (Stocker et al. 1980). Briefly, Dover 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 the fish in the mid-body region about 2.5 cm below the dorsal fin. Tag number, fork length, (cm), and "condition" were recorded before transferring the tagged fish to the recovery tank. Tagged fish were held in the recovery tank a minimum of one hour prior to release. The recovery tank was hinged to the vessel rail and lifted upward by winch to release tagged fish en masse while the vessel was stationary. On three occasions, Dover sole tagged from the last, or last two hauls of the day were held overnight to assess short-term handling mortality.

Ancillary biological information, such as sex, gonad condition, and age structure, could not be collected from the Dover sole tagged and released. Therefore, a sample of Dover sole was collected for this purpose, from those caught in Haul No. 47, completed on Dundas Ground in 68-73 fath (124-134 m) (see Fig. 1 in Stocker et al. 1980). For each Dover sole in sample, the following data, relevant to this study were collected: fork length (nearest centimeter), sex, and both otoliths.

TAG RECOVERY

No effort was expended to directly determine the incidence of tags in the Dover 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 Dover sole were recovered at the processing plants. Principal port of landing was Prince Rupert, ca. 30 miles from the tagging area. Occasionally, tagged fish were detected in the catches at sea, and reported by the captain or a crew member. The 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 tagged Dover 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 Dover 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 Dover 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 Dover sole catch originated in two or more major areas, recovery location was listed as unknown.

FACTORS AFFECTING RECOVERY RATE

Four factors which might have affected recovery rate were investigated--length at release, condition at release, overnight holding, and numbers tagged per haul.

Chi-square tests were employed to compare recovery rates. Four types were utilized and are defined in Table 1. Three are two-way tests of independence (Types 1-3; Dixon and Massey 1969), and the third is the classical single classification. The correction for continuity was omitted for the two-way tests of independence, because observed values were generally large.

TIME AT LIBERTY

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

DISPERSION

A southward "dispersion rate" was estimated based on the linear relationship of the natural logarithm of tags recovered per hundred tonnes landed to recovery distance from Area 5D. The slope of the regression line was deemed an estimate of the "dispersion rate".

MORTALITY RATE

Two estimates of the instantaneous total mortality rate (Z) were computed--one from quasi-quantified tag recoveries, and the other from the age-frequencies derived from the sample of Dover sole otoliths collected from Haul 47. From the tagging data, ln (tags/100 t) was regressed on time (year) for annual recoveries in Area 5D, 1980-84. The slope of this regression is an estimate of Z (Ricker 1975). From the age-frequency data, ln (nos. at age, females only) was regressed on age (7-19). The slope of this regression is an estimate of Z. Otoliths were read by a specialist at the Pacific Biological

Station, using the break-and-burn method employed for several marine species (Chilton and Beamish 1982). Neither this method nor any other has been validated for Dover sole, here or elsewhere.

GROWTH

Three methods were employed to estimate von Bertalanffy growth parameters. Two of these (Fabens 1965; Munro 1982) utilized length increments of individual, recovered tagged Dover sole. The third method utilized mean lengths-at-age of females, based on otoliths. Furthermore, a response-surface analysis (Schnute and McKinnell 1984) was employed to display the relationship of growth increment at recovery to length at time of tagging, and time at liberty.

Fabens (1965) and Munro (1982) methods provided estimates of K and La, assuming $t_o=0$. Analysis was limited to female Dover sole recovered at least four months after tagging. Initially, only the Munro method was to be utilized, but Sundberg (1984) noted that the Fabens method produced better results, based on empirical tests.

Age-length data were derived from the biological sample collected from Haul 47. Von Bertalanffy growth-parameters (t_o, K, La) were estimated for males and females utilizing standard regression method, with mean lengths-at-age weighted by numbers of otoliths read, as suggested by Ricker (1975).

Shrinkage due to freezing, or near-freezing, conditions of storage (at sea and in processing plants) was corrected for, based on studies by Harry (1956). Fork length at recovery was increased by 0.75 cm for Dover sole stored at sea in the vessel's brine tank. For Dover sole, also stored in the freezer of the processing plant prior to recovery, fork length at recovery was increased by 1.0 cm.

RESULTS

GENERAL

During September 21-26, 1979, 5173 Dover sole were tagged, and 5145 of these were released (Table 2) (Stocker et al. 1980). The remaining 28 died in the recovery tank prior to release. Pre-release mortality was negligible, exclusive of overnight-holding experiments (see next section). Only two Dover sole (0.04%) died in the recovery tank out of 4979 tagged from the 41 hauls not involved in overnight-holding experiments. Recoveries through December 1984 totalled 745 (14.5%). On Dundas Ground, 4725 Dover sole were released, and 675 (14.3%) subsequently recovered. On Two Peaks Ground, 420 were

released, and 70 (16.4%) recovered. Recapture rates were not significantly different (Type - 1[a] χ^2 = 1.766; P>0.10) among the two sub-experiments.

Dover sole length-frequencies were similar for fish released, recovered, and landed commercially, from Area 5D (Fig. 4). All three were reasonably unimodal, with mean lengths of 47.6 ± .5 (tagged), 49.5 ± .4 (recovered), and 47.3 ± .4 (landings) cm, respectively. However, a greater proportion of small Dover sole were tagged and released on Two Peaks Ground than on Dundas Ground (Fig. 5). The two length-frequencies are significantly different (χ^2 = 48.9; P<.01) (Table 3). Both were bi-modal, but proportions under each mode differed substantially. The greater proportion of smaller fish among the tagged Dover sole released on Two Peaks Ground was probably due to the shallower depth of capture on Two Peaks Ground--50-69 fath vs 60-89 fath on Dundas Ground. Stocker et al. (1980) reported that mean lengths of tagged Dover sole varied directly with depth--45.7 cm @ 50-69 fath; 47.8 cm @ 70-79 fath; and 48.2 cm @ 80-89 fath.

For recoveries in Area 5D, sex ratio was 10.7% males (56/523) (Table 4). For all other areas combined, the sex ratio was 18.8% males (3/16) (Table 5). Comparable sex ratios in samples from commercial landings during 1979-84 ranged from 18.9 to 35.6% males from Two Peaks Ground, and 14.7-23.9% males from Dundas Ground (Table 6). For both grounds, sex ratios were heterogeneous among years. For Dundas Ground, χ^2 = 18.5 (P<.01), and for Two Peaks Ground, χ^2 = 26.1 (P<.01). Sex ratio was 42.6% males (121/284) in the biological sample collected from Haul No. 47 (Table 4). Possible cause of this anomalous sex ratio was the addition of a 19-mm (0.75-in) mesh cod-end liner in the cod-end for Haul No. 47.

FACTORS AFFECTING RECOVERY RATES

Analyses have been completed with respect to length at release, condition at release, overnight holding, and numbers tagged per haul.

Length at release

Chi-square tests of length-frequencies for recovered Dover sole with those tagged indicated a significant difference (χ^2 = 75; P<.01) for the Dundas sub-experiment, but no significant difference for the Two Peaks sub-experiment (χ^2 = 15.615; P>.05) (Table 7). Probable cause of the significant difference was the differential recovery rate with respect to fork length. Recovery rate per 2-cm FL interval increased gradually from 4.2% at 32.5 cm to 17.9% at 46.5 cm, then generally stabilized at 13.1-18.8% (excluding 29.2% @ 62.5 cm) for the remaining length intervals (Table 2). For the Two Peaks sub-experiment, recovery rate increased rapidly, from 4.5% at 34.5 cm to 23.1% at 38.5 cm, and remained reasonably stable thereafter, considering the relatively small numbers tagged and recovered.

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[a] see Table 1.

Harry (1956) reported a similar phenomenon for Dover sole tagged aboard commercial trawlers in Area 3A (Fig. 1) during spring-summer 1948 and 1949, as follows (from his Table 14):

Fork length	1948		1949	
(cm)	Tagged	% Recovered[a]	Tagged	% Recovered[b]
<37	91	3.3	262	4.6
37-46	253	8.7	828	9.7
47-56	115	14.8	323	13.6
>56	13	7.7	74	18.9

[a]Through December 1951.

[b]Through December 1952.

The deep-water tagging experiment in Area 3A during April 1955, produced similar results for recoveries through April 1962 (Westrheim and Morgan 1963). Recovery rates were 0.2% for Dover sole <35 cm (1-61 tagged); 13-16% for 35-46 cm (106-300 tagged); and 0-26% for those 47-62 cm (1-100 tagged). Most of the tagged fish were males.

Interestingly, in the Area 5D experiment, size composition, based on size at release, of recovered Dover sole (during April-September) did not vary appreciably among years (Table 8). Mean lengths ranged from 48.6 cm (1983) to 50.1 cm (1982), and standard deviations, 6.01 (1983) to 7.26 (1980). One might have expected the larger (older) tagged specimens to disappear from the tagged population at a greater rate than smaller (younger) specimens.

Condition at release. Almost 88% (4510) of the Dover sole tagged and released were rated "good" condition, while the remaining 12% (635) were rated less than good, due to various "handicaps" (Table 9). Recapture rate was 14.9% for Dover sole rated condition "good". Surprisingly, this rate was exceeded, but not significantly, by that for 63 Dover sole "dropped" (20.6%; Type-1 $\chi^2 = 1.618$; $P>.20$); and for 12 with an abrasion at the tag wound (16.7%; χ^2 not testable). Even the 101 tagged and released in "poor" condition yielded a 13.9% return (Type-1 $\chi^2 = 0.081$; $P>.70$), not significantly different from 14.9%. For the six categories (bleeding, cuts, eye injury, scale loss, multiple injuries, slime loss) yielding less than 10% recoveries (5.0-9.1%)--the composite return rate was 7.5% (25/332), and was significantly different from that for "good" condition (Type-1 $\chi^2 = 13.6$; $P<.01$).

Curious indeed would be the "logical" conclusions one might draw from these results--"dropping fish improves recapture rate"; "poor-condition" fish survive as well as those in "good" condition. However, more likely is the conclusion that the Dover sole in "good" and "poor" conditions were indeed both in "fair" condition. The basis for the latter conclusion lies in Stocker et al. (1980, p. 2) wherein they state that: "Fish were quite lethargic after

being recaptured and use of anesthetic was not necessary as part of the tagging procedure." The junior author participated in the April 1955 Dover sole tagging experiment off Washington State (Westrheim and Morgan 1963), and well remembers the difficulties in tagging "lively", non-anesthetized Dover sole.

The lethargy of the Dover sole captured for tagging is difficult to explain since trawl hauls were short (15-34 min), and depth of capture modest (50-89 fath; 92-163 m). Abnormal water temperatures may have been a factor. Surface and bottom temperatures were apparently above-average, as can be seen by the following records collected during late-August through mid-October:

Year	Temperature (°C) Surface	120-150 m	Source
1954	11.6-13.4	5.9-6.3	POG, 1955
1961	10.1-10.4	5.8-6.4	Crean et al. 1962
1962	10.5-11.1	6.0-6.1	Crean et al. 1963
1975	9.9-10.3	6.5	Harling, Davenport et al. 1976
1979	11.7-12.7	7.0-7.5	Westrheim, Foucher et al. 1980
1983	12.2	7.5	Westrheim, Foucher and Cooper 1984

Based on Dodimead's (1980) Figure 48, bottom temperatures were below average (~0.4°C) in 1954 and 1962, but above average (~0.4°C) in 1961.

Harry (1956) reported recovery rates for the combined 1948-49 experiment were 12.5% for Condition No. 1 (lively, no injuries), 8.1% for Condition No. 2 (less lively, minor injuries), and 4.1% for Condition No. 3 (poor and/or serious injuries). For Dover sole >42 cm, he reported recovery rates of 8.1% for all fish, and 14.9% for those rated Condition No. 1 at release.

Westrheim and Morgan (1963) reported that only Dover sole in "good" condition were tagged. Recapture rates for optimal sizes (see previous sub-section) were 13-16% for the period April 1955 - April 1962.

Overnight holding. Stocker et al. (1980) conducted three overnight-holding experiments to assess short-term tagging mortality, and their results are summarized in Table 10. Overnight mortality rates were 1.8% (1/56), 2.7% (1/37), and 27.7% (39/141). In the latter case, mortality rates were not significantly different between tagged (30.1%; 22/73) and untagged (25.0%; 17/68) Dover sole--Type 1 $\chi^2 = 0.464$; $P>.30$. The substantially higher mortality rates in the third experiment may well have been caused by excessive numbers of fish in the holding tank.

Overall recovery rate of Dover sole held overnight prior to release was 12.0% (17/142) (Table 10). For comparable hauls (15, 16, 41, 45, 46) on September 22, 25, and 26, overall recapture rate for Dover sole not held overnight was 12.2% (124/1016), and evidently not significantly different from 12.0%.

Numbers tagged per haul. The numbers tagged and released per haul varied from 8 to 399 (Table 11). Recovery rates per haul ranged from 3.6 to 25.9%, with little relationship to numbers tagged (Fig. 6). Parameters for the regression of percent recovered on numbers tagged were: a = 17.0; b = 0.013; $R2$ = 0.065. It should be noted that most of the variance originated from hauls in which 70 or less fish were tagged. Approximately 325 fish may have been the upper limit for optimum recovery rate in this experiment. Four hauls involving 260-294 tagged fish yielded recovery rates of 16.9-17.2%. For the four hauls in which more than 300 fish were tagged, recovery rates were 13.1% (335 tagged), 13.4% (337), 9.4% (350), and 9.8% (399). Only the latter two recovery rates were significantly different from the overall rate of 14.1% (Type-1 χ^2 = 6.654 and 7.620; P<.01), or that for the four hauls (17.1%: Type-1 χ^2 = 12.0 and 12.1; P<.01) in which 260-294 fish were tagged.

Harry (1956) reported an overall recovery rate of 15.1% for sub-experiments involving less than 40 Dover sole per haul; and 11.6% from sub-experiments involving 60-103 fish/haul.

Summary. Recovery rates were shown to be affected, at least in part, by length at release, condition at release, and numbers tagged per haul. Overnight holding had no effect on the recovery rate of the survivors. Recovery rates varied inversely with length at release for Dover sole <46.5 cm, but were relatively constant for fish ≥46.5 cm. Condition at release only reduced recovery rates for selected categories (bleeding, cuts, eye injury, scale loss, multiple injuries, and slime loss). Otherwise, recovery rates were unaffected by condition. Absolute condition was probably "fair" for most of the Dover sole released, perhaps due to abnormal water temperatures during tagging. Numbers tagged per haul had no overall effect (R^2=.0625), but variance was substantial for hauls in which 70 or less fish were tagged. Recovery rates were distinctly smaller for sub-experiments involving >300 fish/haul.

TIME AT LIBERTY

Month of recovery was determined for 722 (96.9%) of the 745 Dover sole tags recovered through December 1984 (Table 12). Proportions recovered each year during 1980-84, from all sources, were 31.6, 33.7, 14.7, 6.4, and 13.3%, respectively. Although 65.3% of the recoveries were made during 1980-81, recoveries are expected to continue for several years after 1984. The 96 tags recovered in 1984 represented 1.9% of the numbers released. By comparison, the April 1955 experiment, in deep water off Washington State, yielded 13 recoveries (0.5% of 2406 released) in the fifth year (Westrheim and Morgan 1963; Table 2), and the last recovery occurred in 1969, 14 years after tagging (pers. comm. R. L Demory).

Principal quarter-years of recovery were II and III in all areas except 5E (I and II). Not surprisingly, landing records follow the same pattern (Table 13).

Among quarter-years, during 1979-84, sex ratio of Dover sole recovered in Area 5D ranged from 2.6% (1/39) to 20.0% (4/20) males for

quarter-years yielding at least 12 recoveries (Table 14). None of the testable sex ratios ($M' \geq 5$) differed significantly from the overall ratio--10.7% males.

DISPERSION

Recovery location was determined for 588 (78.9%) of the 745 tagged Dover sole recovered through December 1984 (Table 15). Recoveries within Area 5D comprised 96.3%. Proportions recovered from other areas were: 1.9% from Area 5E; 1.5% from Area 5C; and 0.2% each from Areas 5B and 3A. Detailed records for recoveries outside Area 5D are listed in Table 6. Area 5E appears to be the "wintering" area for the Area 5D Dover sole, as shown in the preceding section, with respect to season of recoveries and landings. That is, principal "activity" quarter-years were II and III in Area 5D, and I and II in Area 5E. Only limited trawling occurs in either area during Quarter IV.

Similar qualitative dispersions were noted for tagged Dover sole in other experiments (Table 16). Proportions recovered within the tagging area were 97.6-99.2% for three experiments in Area 3A, and 90.0% for the Area 2B experiment. Comparable rate for the current study is 98.2% (Area 5D & 5E). In both Areas 3A and 2B, the "summering" and "wintering" grounds lie in the same area.

Quasi-quantitative recovery rates (tags/100 t landed) for 1980-84, were 22, 4.1, and 0.6, respectively, for Areas 5D, 5C, and 5B (Table 17). Approximate distances between principal recovery sites were 120 nautical miles from 5D to 5C, and 200 miles from 5D to 5B. The regression of quantified recovery rate (on tags/100 t) on distance from the "center" of Area 5D recoveries is linear (Fig. 7). The formula is $Y = 3.22-0.018X$ ($R^2 = 0.98$). The slope of this line is an estimate of the exponential "dispersion rate" southward during 1980-84. Hence, the corresponding annual rate is $(1-e^{-.018})/5 = 0.00357$, or 0.4%. There is no fishery for Dover sole northward of 5D, although Dover sole are common in the Gulf of Alaska (Alverson et al. 1964).

MORTALITY RATE

Instantaneous total mortality rate (Z), based on quasi-quantified tag recoveries from Area 5D during 1980-84 (Table 17), was estimated to be 0.25. Regression formula was $Y = 3.73 - 0.25X$; $R^2 = 0.76$ (Fig. 8). Based on this regression, the "extinction" year is approximately 1995 (3.729/.25 = 14.9).

Fortuitously, perhaps, a second, independent estimate of Z=0.30 was obtained, based on the age-frequency sample collected from Haul 47 (Table 18; Figs. 10, 11). The ln (numbers of males & females at age) regressed on age was linear (Fig. 9). Four estimates of Z were computed, which utilized different combinations of age-classes, as follows:

Age classes	Parameters		
	a	b	R^2
7-18	5.48	-0.30	.72
7-19	4.84	-0.24	.58
8-18	5.03	-0.27	.64
8.19	4.29	-0.20	.47

The combination of age-classes 7-18 yielding Z = 0.30 was selected, because R^2 was maximal.

GROWTH

Results of the quantitative growth analysis were disappointing. The estimated parameters for female Dover sole are listed below:

Source	Method	Sex	Parameters		
			t_0	K	L_∞
Tags	Fabens (1965)	Females[a]	-	0.05	72.9
	Munro (1982)	Females[a]	-	0.01	135
Otoliths	Ricker (1975)	Males	-6.65	0.11	47.2
		Females	-3.96	0.12	57.4

[a]Recoveries of tagged male Dover sole were too few for analysis.

Neither Fabens (op. cit.) nor Munro (op. cit.) methods yielded "realistic" parameters. Sundberg (1984) had concluded that the Fabens method was superior based on empirical tests. Conventional regression analysis yielded "reasonable" estimates of K, but t_0 values were excessive, and L_∞ values unrealistic.

The inter-relationships for tagged female Dover sole of length-at-release, length increment at recovery, and time-at-liberty is displayed as a response surface in Figure 12. Relatively large growth increments can be achieved by fish 30-40 cm FL, moderate increments at 41-50 cm, and small increments for those >50 cm FL. Growth slows dramatically after 60 cm, and this length is analogous to L_∞.

DISCUSSION

The September 1979 Dover sole tagging study has yielded a number of useful results, and one disappointment, based on recoveries through December 1984. Stock delineation and mortality estimates will be useful to managers, and factors affecting recovery rate will prove useful in planning future experiments.

The Dundas-Two Peaks stock of Dover sole appears to be primarily limited geographically to the northern portions of Areas 5D and 5E. A low rate (~0.4%/annum) of dispersion southward was estimated. Similar, unquantified, results were reported for three tagging studies conducted in the Washington-Oregon Region--Areas 3A and 2B.

Instantaneous total mortality rate (Z) is relatively low, based on two independent estimates (0.25 and 0.30). Despite the evident flaws in both estimates, corroborative evidence is available--prolonged period at liberty of Dover sole tagged elsewhere, and the longevity of Dover sole in Area 5D. Furthermore, the estimate based on the age-frequency sample (Z = 0.30) may have been an overestimate. Haul 47 contained a greater proportion of small (and male) Dover sole, and hence the slope of the regression should have been steeper.

The disappointing results of growth analysis (estimating von Bertalanffy parameters) is not unexpected. The lack of data on juveniles is a serious disadvantage for any such analysis. Furthermore, a second handicap is the prolonged period in later life (~>20 y) when annual length increments are very small. Since numerous age-classes can occupy a single centimeter length interval, the mean annual length increment of a tagged fish could range from nearly zero to perhaps 2-4 centimeters, depending upon its age.

Handling mortality was probably low, but the general lethargy of all Dover sole tagged and released is of some concern. If indeed, above-average water temperatures were a factor, future experiments should be planned accordingly.

The lack of a clear, inverse relationship between recovery rate and condition at release may have been due to inexperience. The current study is the first of its kind for Dover sole in British Columbia waters. Absolute condition at time of tagging was probably "fair" rather than "good", for most of the Dover sole released.

Interestingly, the short-term holding capacity for the tank was substantially greater (~325 fish) than the overnight holding capacity (<150 fish).

SUMMARY

1. During September 21-26, 1979, 5145 trawl-caught Dover sole were tagged and released in northern Hecate Strait (Area 5D), primarily for stock delineation. Through December 1984, 745 (14.5%) were recovered.

2. Size composition of the tagged Dover sole was significantly different between the two sub-experiments--Dundas (larger) and Two Peak grounds. Recapture rates were not significantly different--14.2% (675/4725) from Dundas, and 16.4% (70/420) from Two Peaks grounds.

3. Recovery rates varied inversely with fork length at tagging (up to 46.5 cm), selected conditions at release (not including "poor"), and numbers tagged per haul (>300), although not necessarily significantly. Overnight holding had no effect on recovery rate of the survivors.

4. Time at liberty is expected to be extensive. After five full years, recovery rate is still substantial--a common feature of Dover sole tagging experiments elsewhere.

5. Dispersion of tagged Dover sole was slight. Most movement occurred between the relatively shallow "summering" grounds (Area 5D), where tagging took place, and "wintering" grounds in deep water (Area 5E) to the westward--98.2% of all recoveries came from Areas 5D & 5E. A southward "dispersion" rate (to Queen Charlotte Sound), based on quantified recoveries, was estimated to be approximately 0.4% per year. One tagged Dover sole was caught south of Queen Charlotte Sound--off Washington State (589 nm). No fishery exists northward on which to base a dispersion rate.

6. Instantaneous total mortality (Z) was estimated to be 0.25, based on quantified recoveries (tags/100 t) during 1980-84. An independent estimate of 0.30 was obtained from the female age-frequency (7-18 y) of otoliths collected from a post-tagging haul by the charter vessel.

7. Von Bertalanffy growth parameters were estimated for female Dover sole, with mixed results, by three methods. Estimates of K ranged from 0.01 to 0.12, and for L_∞, 47.2-135 cm. None were deemed satisfactory.

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Table 1. Inventory of Chi-square tests employed in this study.

Type	Chi-square	Degrees of freedom
1[a]	$(AC-BD)^2N/(A+B)(C+D)(A+C)(B+D)$	1
2[b]	$\sum_{i=1}^{n} [\frac{(Ai-a_i)^2}{a_i} + \frac{(B_i-b_i)^2}{b_i}]$	n-1
3[c]	$\sum_{i=1}^{n} [4[A_i-(A_i+B_i)/2]^2/(A_i+B_i)]$	n-1
4[d]	$\sum_{i=1}^{n} \frac{(O_i-E_i)^2}{E_i}$	n-1

[a] A, B, C, D are observed values in the four respective cells.
$N = A + B + C + D$.

[b] A_i and B_i = observed values in the two cells of category i.
a_i = expected value of $A_i = A_T\ (A_i + B_i)/(A_T + B_T)$.
b_i = expected value of $B_i = (A_i + B_i) - a_i$.
n = number of categories.

[c] A_i and B_i = observed values in the two cells of category i.
n = number of categories.

[d] O_i = observed value in category i.
E_i = expected value in category i.
n = number of categories.

Table 2. Length-frequencies (nos.) of Dover sole tagged and released (T), and recovered (R) through December 1984, from the September 1979 experiment in Area 5D, by sub-experiment.

Fork Length[a] (cm)	Total			Dundas			Two Peaks		
	T	R	% R	T	R	% R	T	R	% R
28.5	1	-	-	1	-	-	-	-	-
30.5	8	-	-	5	-	-	3	-	0
2	33	1	3.0	24	1	4.2	9	-	6
4	140	6	4.3	118	5	4.2	22	1	4.5
6	331	21	6.3	270	16	5.9	61	5	8.2
8	322	27	8.4	283	18	6.4	39	9	23.1
40.5	327	31	9.5	293	27	9.2	34	4	11.8
2	381	56	14.7	351	49	14.0	30	7	23.3
4	526	72	13.7	495	67	13.5	31	5	16.1
6	501	88	17.6	469	84	17.9	32	4	12.5
8	441	83	18.8	405	76	18.8	36	7	19.4
50.5	436	70	16.1	400	61	15.3	36	9	25.0
2	436	57	13.1	411	54	13.1	25	3	12.0
4	409	67	16.4	394	65	16.5	15	2	13.3
6	367	67	18.3	346	63	18.2	21	4	19.0
8	268	55	20.5	250	46	18.4	18	9	50.0
60.5	121	20	16.5	117	20	17.1	4	0	0
2	50	15	30.0	48	14	29.2	2	1	50.0
4	26	4	15.4	24	4	16.7	2	-	0
6	7	1	14.3	7	1	14.3	-	-	-
68.5	1	-	-	1	-	-	-	-	-
Sub-total	5132	741	14.4	4712	671	14.2	420	70	16.4
Unknown	13	4		13	4		-	-	
Total	5145	745	14.5	4725	675	14.3	420	70	16.4

[a]At time of tagging.

Table 3. Chi-square test of length-frequencies (nos.) for Dover sole tagged and released on Dundas (O) and Two Peaks-Butterworth (E) grounds, September 1979.

Fork length (cm)	O (Dundas)		E (TP-BU)		χ^2[a]	P
28.5	-		0.1			
30.5	3		0.4			
2	9	34	2.1	13.1	9.274	<.01
4	22		10.5			
6	61		24.1		16.000	<.01
8	39		25.3		2.919	<.01
40.5	34		26.2		1.011	>.10
2	30		31.2		0.024	>.80
4	31		44.2		2.317	<.05>.02
6	32		41.9		1.326	>.10
8	36		36.0		0.000	>.99
50.5	36		35.6		0.002	.95
2	25		36.6		2.184	>.05
4	15		35.0		8.000	<.01
6	21		30.7		1.820	>.05
8	18		22.2		0.439	>.30
60.5	4		10.5			
2	2	8	4.3	17.6	3.600	<.05>.02
4	2		2.1			
6	-		0.6			
68.5	-		0.1			
Total	420		419.7		48.916 Df=13	<.01

[a]Type-3. See Table 1.

Table 4. Length-frequencies (nos.) by sex, of Dover sole: (a) recoveries from Area 5D, 1979-84; (b) biological sample from Haul no. 47, September 1979.

Fork length[a] (cm)	Recoveries				Haul No. 47		
	Total	M	F	Unk	Total	M	F
28.5	-	-	-	-	1	-	1
30.5	-	-	-	-	1	1	0
2	1	-	1	-	5	4	1
4	5	2	2	1	27	19	8
6	19	7	11	1	42	30	12
8	19	8	10	1	42	22	20
40.5	26	5	17	4	37	19	18
2	41	9	26	6	34	11	23
4	55	7	47	1	25	9	16
6	68	10	55	3	9	2	7
8	64	3	58	3	7	3	4
50.5	51	2	43	6	10	1	9
2	43	1	39	3	14	-	14
4	52	0	51	1	11	-	11
6	48	0	44	4	11	-	11
8	37	1	35	1	1	-	1
60.5	14	1	13	0	5	-	5
2	12	-	10	2	1	-	1
4	4	-	4	-	1	-	1
66.5	1	-	1	-	-	-	-
Total	560	56	467	37	284	121	163
% Males		10.7				42.6	

[a]Length at tagging.

Table 5. Detailed records of individual tagged Dover sole recaptured in areas other than 5D, 1979-84.

Area	Ground	Recovery time		Fork length (cm)		Sex
		Year	Month	Rel.	Rec.	
5E	N. Frederick Is.-Langara Deep	1980	Feb	44	45	F
				48	49	F
				51	UNK[a]	UNK
				53	53	F
		1984	Mar	56	57	F
				UNK	51	F
			Apr	50	53	F
	Rennell Sound	1980	Apr	47	48	F
			May	57	UNK	UNK
	Unknown	1984	Jan	38	UNK	M
				42	UNK	F
5C	S. Moresby Gully	1980	May	49	UNK	UNK
			Jun	39	UNK	UNK
				55	56	F
				59	60	F
			Jul	34	37	M
				43	44	F
				46	47	F
				47	48	M
				51	UNK	UNK
5B	S. Goose Is. Bank	1983	Aug	48	50	F
3A	Gray's Harbor	1982	Aug	45	49	UNK

[a]UNK=Unknown.

Table 6. Chi-square tests of sex ratios of Dover sole landed from Dundas and Two Peaks grounds, May-September 1979-84.

Year	Months	Nos. sampled M	F	T	% M	χ^2	Pa
		Dundas Ground					
1979	May-Jul	162	517	679	23.9	9.742	<.01
1981	Sep	41	219	260	15.8	2.006	>.01
1982	Jun-Aug	292	1229	1521	19.2	0.004	.95
1983	Sep	44	256	300	14.7	3.660	>.05
1984	Jun	46	255	301	15.3	3.076	>.05
Total		585	2476	3061	19.1	18.488[b]	<.01
		Two Peaks Ground					
1980	Jun; Sept	83	355	438	18.9		
1982	Aug	109	197	306	35.6		
Total		192	552	744	25.8	26.149[c]	<.01
		Dundas versus Two Peaks (1982)					
Dundas		292	1229	1521	19.2		
Two Peaks		109	197	306	35.6		
Total		401	1427	1827	21.9	40.080[c]	<.01

[a]p = probability of 2 larger Chi-square value due to chance alone.
[b]Type-2. See Table 1.
[c]Type-1. See Table 1.

Table 7. Chi-square test of Dover sole length-frequencies for tagged (E) and recovered (O) specimens. (Length at time of tagging for recovered specimens.)

Fork length (cm)	Total			Dundas			Two Peaks		
	O	E		O	E		O	E	
28.5	-	0.2		-	0.2		-	-	
30.5	-	1.2	26.4	-	0.7	30.1	-	0.5	
2	1	4.8		1	3.4		-	1.5	15.8
4	6	20.2		5	16.8		1	3.7	
6	21	47.8		16	38.5		5	10.1	
8	27	46.5		18	40.3		9	6.5	
40.5	31	47.2		27	41.7		4	5.7	
2	56	55.0		49	50.0		7	5.0	
4	72	75.9		67	70.4		5	5.2	
6	88	72.1		84	66.7		4	5.3	
8	83	63.6		76	57.7		7	6.0	
50.5	70	63.0		61	57.0		9	6.0	
2	57	63.0		54	58.5		3	4.2	6.5
4	67	59.1		65	56.1		2	2.5	
6	67	53.0		63	49.3		4	3.5	
8	55	38.7		46	35.6		9	3.0	7.8
60.5	20	17.5		20	16.7		0	0.7	
2	15	7.2		14	6.8		1	0.3	
4	4	3.8		4	3.4	11.4	-	0.3	
6	1	1.0	5.0	1	1.0		-	-	
68.5	-	0.2		-	0.2		-	-	
Total	741	741.0		671	671.0		70	70.0	
$\chi 2^a$	74.436			75.045			15.615		
DF[b]	14			14			9		
p[c]	<.01			<.01			>.05		

[a]Type-4.0 $\chi^2 = \sum[(O-E)^2/E]$.
[b]Degrees of freedom.
[c]p = probability of a larger Chi-square value due to chance alone.

Table 8. Length-frequencies (nos.) of all tagged Dover sole recovered from all areas during April-September, 1980-84, from the September 1979 experiment.

Fork length[a] (cm)	Tagged	Recovered				
		1980	1981	1982	1983	1984
28.5	1	-	-	-	-	-
30.5	8	-	-	-	-	-
2	33	-	-	-	-	1
4	140	2	2	1	-	1
6	331	10	4	2	1	1
8	322	9	8	3	0	3
40.5	327	13	10	2	3	1
2	381	10	21	7	1	7
4	526	21	20	10	3	10
6	501	23	24	14	10	8
8	441	23	25	8	3	13
50.5	436	20	16	11	2	9
2	436	9	19	10	1	9
4	409	17	24	14	1	7
6	367	19	17	9	4	6
8	268	16	19	7	2	9
60.5	121	6	5	5	1	1
2	50	7	3	1	-	1
4	26	2	-	-	-	1
6	7	1	-	-	-	-
68.5	1	-	-	-	-	-
Total	5132	208	217	104	32	88
$\bar{L}$	47.6	49.4	49.4	50.1	48.6	49.6
S.D.	7.26	7.26	6.43	6.24	6.01	6.44

[a]At time of tagging.

Table 9. Numbers of Dover sole tagged and released (T), and recovered (R) through December 1984, from the September 1979 experiment in Area 5D, by condition at release and sub-experiment.

Condition	Total			Dundas			Two Peaks		
	T	R	% R	T	R	% R	T	R	% R
Good	4510 (87.7%)	671	14.9	4152 (87.9%)	609	14.7	358 (85.2%)	62	17.3
Excessive scale loss	144	10	6.9	139	7	5.0	9	3	33.3
Excessive slime loss	93	8	8.6	77	8	10.4	16	-	0
Flu damage	76	9	11.8	71	8	11.3	5	1	20.0
Dropped	63	13	20.6	54	11	20.4	9	2	22.2
Net damage	27	3	11.1	27	3	10.3	-	-	-
Cuts/wounds	25	2	8.0	22	2	9.1	3	-	0
Healing wounds	24	3	12.5	15	2	13.3	9	1	11.1
Eye injuries	20	1	5.0	20	1	5.0	-	-	-
Tag wound abrasion	12	2	16.7	10	2	20.0	2	-	0
Tag wound bleeding	11	1	9.1	6	1	16.7	5	-	0
Multiple injuries	39	3	7.7	35	3	8.6	4	-	0
Poor condition[a]	101	14	13.9	101	14	13.9	-	-	-
Sub-total	5145	740	14.4	4725	671	14.2	420	69	16.4
Unknown	-	4[b]	-	-	-	-	-	-	-
Grand total	5145	744	14.5	4725	671	14.2	420	69	16.4

[a]Multiple injuries & low viability.

[b]Tag numbers unreadable.

Table 10. Comparison of pre-release mortality rates and recapture rates for Dover sole held overnight and not held overnight.

Date (Sept)	Haul no.	Start (PDT)	Duration (min)	Nos. tagged	Mortalities		Nos. released	Recaptures	
					nos.	%		nos.	%
				Held overnight					
23	23	1628	30	38	1	2.6	37	7	18.9
	24	1728	17	18	-	-	18	1	5.6
				56	1	1.8	55	8	14.5
24	34	1557	34	29	1	3.4	28	1	3.6
	35	1729	24	8	-	-	8	2	25.0
				37	1	2.7	36	3	8.3
25	42	1827	15	73[a]	22	30.1	51	6	11.8
				(68)[b]	(17)[b]	(25.0)		-	-
Total							142	17	12.0
				Not held overnight					
22	15	1421	20	158	-	-	158	25	15.8
	16	1612	16	262	-	-	262	45	17.2
				420	-	-	420	70	16.7
25	41	1552	20	399	-	-	399	39	9.8
26	45	1423	33	50	-	-	50	5	10.0
	46	1620	26	147	-	-	147	10	6.8
				197	-	-	197	15	7.6
Total							1016	124	12.2

[a]Excluding two fish found on deck the following morning. Incorrectly listed as "untagged" in Stocker et al. (1980, p. 4).

[b]Untagged Dover sole. Incorrectly listed as "tagged" in Stocker et al.(1980, p. 4).

Table 11. Numbers of Dover sole tagged and released (T), and recovered (R), by haul.

Haul no.[a]	T	R	% R	Haul no.	T	R	% R
1	27	7	25.9	21	294	50	17.0
2	126	20	15.9	22	10	2	20.0
3	48	4	8.3	23	37[b]	7	18.9
4	73	11	15.1	24	18	1	5.6
5	48	8	16.7	25	54	8	14.8
6	34	8	23.5	26	94	10	10.6
7	36	6	16.7	27	27	4	14.8
8	28	5	17.9	28	67	14	20.9
9	19	4	21.1	29	30	6	20.0
10	107	17	15.9	30	12	2	16.7
11	260	44	16.9	31	41	7	17.1
12,13	337	45	13.4	32	154	11	7.1
14	96	20	20.8	33	164	13	7.9
15	158	25	15.8	34	28[b]	1	3.6
16	262	45	17.2	35	8	2	25.0
17	64	8	12.5	36	80	14	17.5
18	274[b]	47	17.2	37	45	8	17.8
19	141	25	17.7	38	335	44	13.1
20	218	37	17.0	39	94	23	24.5
				40	350[b]	33	9.4
				41	399	39	9.8
				42	51[c]	6	11.8
				43	75	15	20.0
				44	125	19	15.2
				45	50	5	10.0
				46	147	10	6.8
				Total	5145	740	14.1
				Unknown	-	4	-

[a]Haul nos. 1-8 on Two Peaks Ground.
[b]Excluding one dead in recovery tank.
[c]Excluding 22 dead in recovery tank.

Table 12. Time at liberty (%), by quarter-year and recapture area, for Dover sole tagged and released in Area 5D, September 1979.

		Recovery area						
Year[a]	Qtr	5E	5D	5C	5B	3A	UNK	Total
1	III	-	-	-	-	-	-	-
	IV	-	0.4	-	-	-	-	0.3
2	I	36.3	0	-	-	-	-	0.6
	II	18.2	11.9	44.4	-	-	2.2	10.5
	III	0	21.0	55.6	-	-	7.4	18.6
	IV	0	2.3	-	-	-	0.7	1.9
3	I	0	0	-	-	-	0	0
	II	0	7.5	-	-	-	9.6	7.6
	III	0	15.4	-	-	-	55.3	22.5
	IV	0	1.6	-	-	-	12.5	3.6
4	I	0	0	-	-	-	0.7	0.1
	II	0	3.6	-	-	-	0	2.8
	III	0	14.7	-	-	100.0	0.7	11.7
	IV	0	0	-	-	-	0.7	0.1
5	I	0	0	-	-	-	0.7	0.1
	II	0	0.4	-	-	-	0	0.3
	III	0	4.6	-	100.0	-	2.9	4.3
	IV	0	0.5	-	-	-	6.6	1.7
6	I	36.4	0	-	-	-	-	0.6
	II	9.1	2.3	-	-	-	-	1.9
	III	-	13.8	-	-	-	-	10.8
	IV	-	-	-	-	-	-	-
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0
N		11	564	9	1	1	136	722

[a]Year 1=1979.

Table 13. Annual Dover sole landings (t) and mean proportions (%) by quarter-year, from international statistical areas off British Columbia, 1979-84.

Year	4B	3C-N	3D	5A	5B	5C	5D	5E	Total
					Landings (t)				
1979	58	44	10	12	39	62	564	64	853
1980	76	162	109	44	48	111	494	201	1245
1981	85	204	50	5	37	87	712	36	1216
1982	164	164	24	18	31	5	474	27	907
1983	32	64	30	27	14	11	212	426	816
1984	15	49	49	19	39	8	630	302	1111
Total	430	687	272	125	208	284	3086	1056	6148
%	7.0	11.2	4.4	2.0	3.4	4.6	50.2	17.2	100.0
Quarter-year					Mean % Landed by Quarter-Year				
I	0.9	15.1	17.9	0.6	1.2	0.6	2.4	64.3	
II	31.5	52.0	52.6	31.6	63.9	41.0	21.2	33.4	
III	48.0	26.0	21.4	51.3	29.6	47.6	66.1	0.5	
IV	19.6	7.0	8.2	16.5	5.3	10.8	10.4	1.9	
Total	100.0	100.1	100.1	100.0	100.0	100.0	100.1	100.1	

Table 14. Sex ratio (% males), by quarter-year, for tagged Dover sole recovered in Area 5D, 1979-84. (Numbers recovered in parenthesis.)

Year	Quarter-year I	II	III	IV	Total
1979	X	X	X	0	0
				(1)	(1)
1980	-	10.0	14.0	16.7	12.8
	(0)	(60)	(107)	(12)	(179)
1981	-	2.6	7.2	0	5.5
	(0)	(39)	(83)	(6)	(128)
1982	-	20.0	11.1	-	12.9
	(0)	(20)	(81)	(0)	(101)
1983	-	-	7.7	0	6.9
			(26)	(3)	(29)
1984	-	7.7	13.9	-	12.9
	(0)	(13)	(72)	(0)	(85)
Total	-	9.1	11.4	9.1	10.7
	(0)	(132)	(369)	(22)	(523)

N.B. No testable ratios ($m' \geq 5$) were significantly different from the grand total (10.7%), on the basis of χ^2 tests--χ^2 values ranged from 3.274 ($P>.05$; 1981 Total) to 0.013 ($P>.90$; 1983, Qtr III). Total $\chi^2=4.174$; $Df=3$; $P>.10$).

Table 15. Numbers of tagged Dover sole recovered by location of recovery and tagging, 1979-84.

Recovery Area	Ground	Tagging: Dundas nos.	Dundas %	Two Peaks nos.	Two Peaks %	Total nos.	Total %
5D	Dundas	227		27		254	
	Two Peaks-Butterworth	90		8		98	
	MSA 4a	145		15		160	
	Unknown	50		4		54	
	Sub-total	512	96.4	54	94.7	566	96.3
5E	Langara Deep	6		-		6	
	Off Rennell Sound	2		-		2	
	Unknown	2		1		3	
	Sub-total	10	1.9	1	1.8	11	1.9
5C	S. Moresby Gully	8	1.5	1	1.8	9	1.5
5B	S.E. Goose Is. Bank	1	0.2	-	-	1	0.2
3A	Off Grays Harbour	-	-	1	1.8	1	0.2
Total		531	100.0	57	100.1	588	100.1
Unknown		144		13		157	
Grand total		675		70		745	

[a]Minor Statistical Area 4=northeast sector of Area 5D, including Dundas, Two Peaks, Butterworth, and Shell grounds.

Table 16. Distribution (%) of usable[a] recaptures of Dover sole, by area of recapture and experiment.

Time	Tagging Area	Nos.	Nos.	Recaptures % by Area					
This study--through December 1984									
Sep 1979	5D	5145	585	5D&5E 98.2		5C 1.5	5B 0.2	3A 0.2	
Milburn (1966)--through December 1965									
1961-64	3A	9015	748		2C 1.9	3A 98.1			
Westrheim and Morgan (1963)--through April 1962									
Apr 1955	3A	2406	251	1C 0.4	---	---	3A 97.6	3B 1.6	3C 0.4
Harry (1956)--through December 1952									
Apr-Oct 1948-49	3A		163		2C 0.8	3A 99.2			
Barrs (1982)--through December 1981									
1969-75	2B	2637	279	1C 1.4	2A 7.9	2B 90.0	3A 0.7		

[a]Area of recapture known.

Table 17. Distribution (Tags/100 t) of recovered Dover sole, by area and quarter-year, 1980-84. (Tonnes landed in parentheses.)

Year	Quarter-year					
	I	II	III	IV	Total	1980-84
			Area 5E			1.1 (992)
1980	2.4 (170)	6.9 (29)	- (2)	- (T)	3.0 (201)	
1981	- (35)	- (1)	- (T)	- (-)	- (36)	
1982	- (24)	- (3)	- (T)	- (T)	- (27)	
1983	- (180)	- (206)	- (T)	- (40)	- (426)	
1984	3.8 (106)	0.5 (190)	- (1)	- (5)	1.7 (302)	
			Area 5D			22 (2552)
1980	- (T)	48 (140)	38 (316)	34 (38)	40 (494)	
1981	- (-)	22 (190)	19 (458)	14 (64)	19 (712)	
1982	- (4)	24 (82)	24 (347)	- (41)	22 (474)	
1983	- (6)	3.3 (60)	20 (133)	7.0 (43)	13 (242)	
1984	- (T)	16 (82)	14 (518)	- (30)	14 (630)	

Table 17 (cont'd)

Year	Quarter-year I	II	III	IV	Total	1980-84
				Area 5C		4.1 (221)
1980	- (T)	9.1 (44)	9.6 (52)	- (15)	8.1 (111)	
1981	- (3)	- (15)	- (69)	- (T)	- (87)	
1982	- (T)	- (3)	- (1)	- (1)	- (5)	
1983	- (-)	- (2)	- (9)	- (-)	- (11)	
1984	- (-)	- (5)	- (-)	- (2)	- (7)	
				Area 5B		0.6 (172)
1980	- (-)	- (24)	- (20)	- (5)	- (49)	
1981	- (T)	- (34)	- (3)	- (-)	- (37)	
1982	- (T)	- (25)	- (6)	- (1)	- (32)	
1983	- (1)	- (11)	33 (3)	- (T)	6.7 (15)	
1984	- (T)	- (30)	- (7)	- (2)	- (39)	

Table 18. Age-frequencies (nos. sampled) and mean lengths (cm) at age, by sex, for Dover sole sampled from the charter vessel, September 1979.

Age	Numbers sampled				Mean length (cm)	
(y)	M	F	Total	%	M	F
4	7	3	10	3.5	34.1	35.0
5	24	14	38	13.4	35.6	35.9
6	23	22	45	15.9	37.3	38.7
7	25	27	52	18.3	38.6	40.6
8	9	15	24	8.5	39.0	42.5
9	10	13	23	8.1	40.3	42.8
10	3	5	8	2.8	41.7	45.2
11	3	5	8	2.8	44.3	46.2
12	1	7	8	2.8	37.0	47.1
13	0	1	1	0.4	-	51.0
14	2	1	3	1.1	42.0	54.0
15	0	2	2	0.7	-	49.5
16	1	5	6	2.1	45.0	52.8
17	1	0	1	0.4	-	-
18	0	2	2	0.7	45.0	54.5
19	2	3	5	1.8	42.0	52.7
20-24	4	13	17	6.0	-	-
25-29	2	5	7	2.5	-	-
30-34	0	11	11	3.9	-	-
35-39	2	4	6	2.1	-	-
40-44	2	4	6	2.1	-	-
45-49	-	1	1	0.4	-	-
Total	121	163	284	100.3		

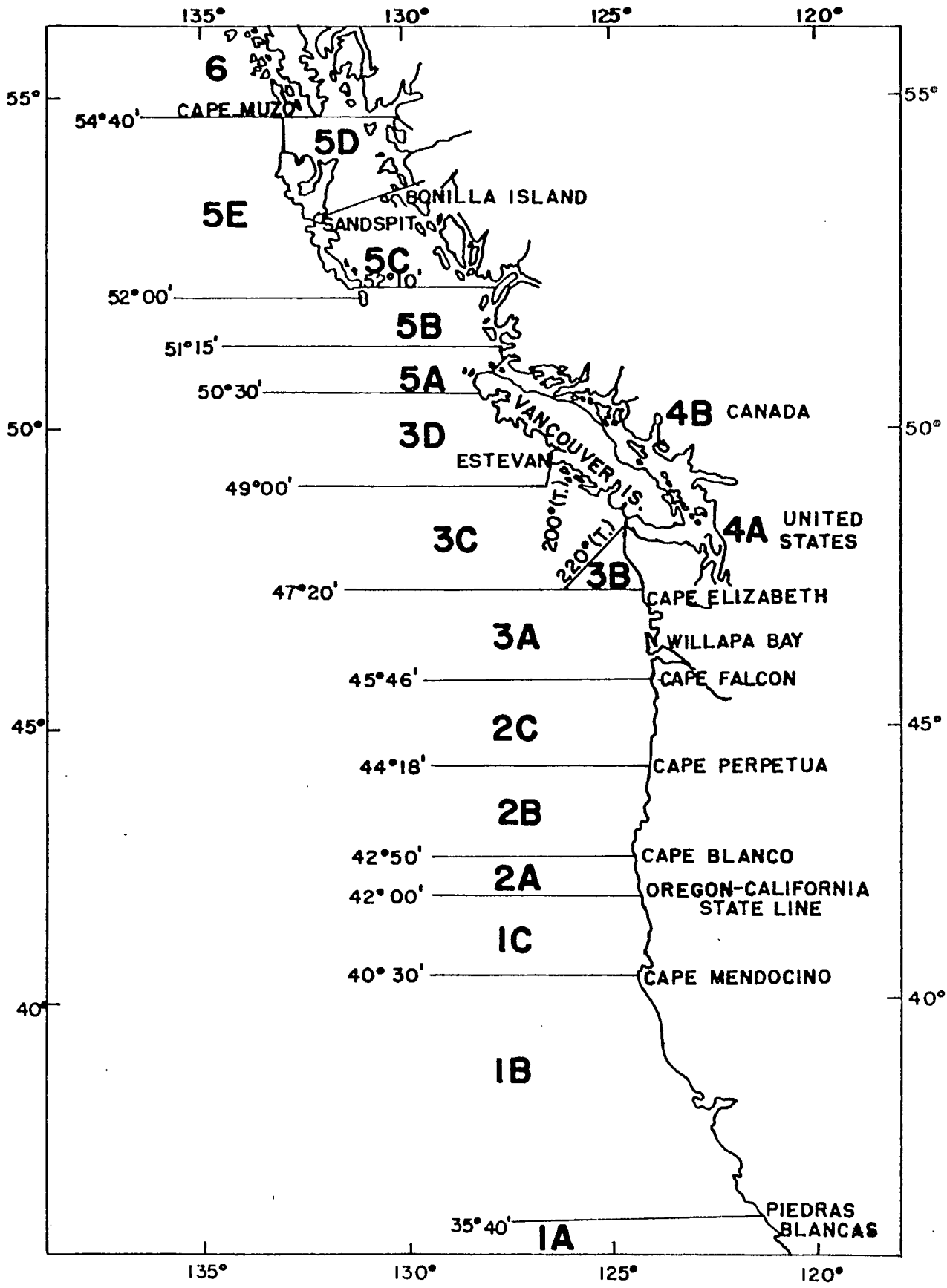

Fig. 1. Canada-U.S. Statistical area for groundfish landings (excluding halibut).

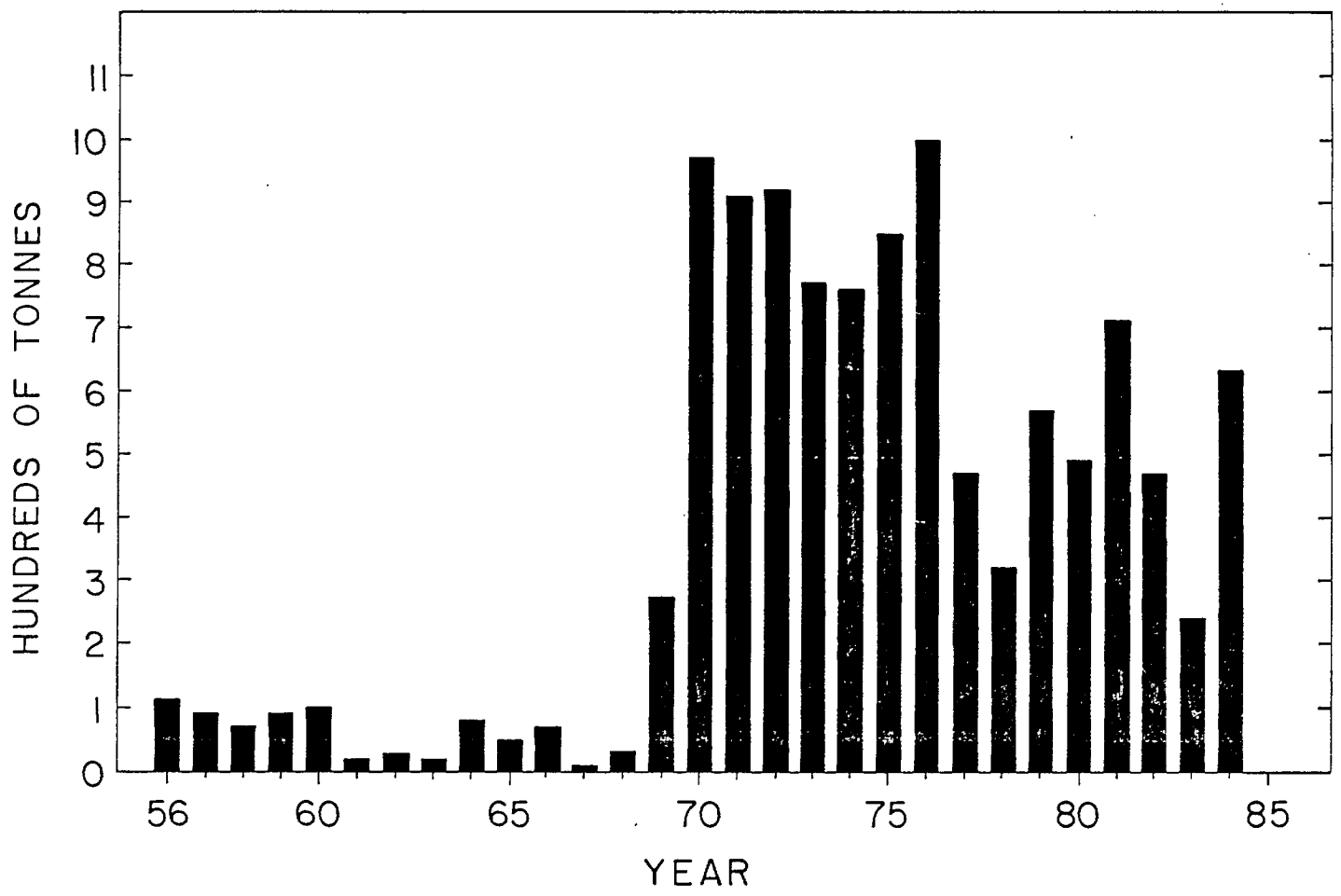

Fig. 2. Canada-U.S. Landings (t) of Dover sole from Area 5D, 1956-84.

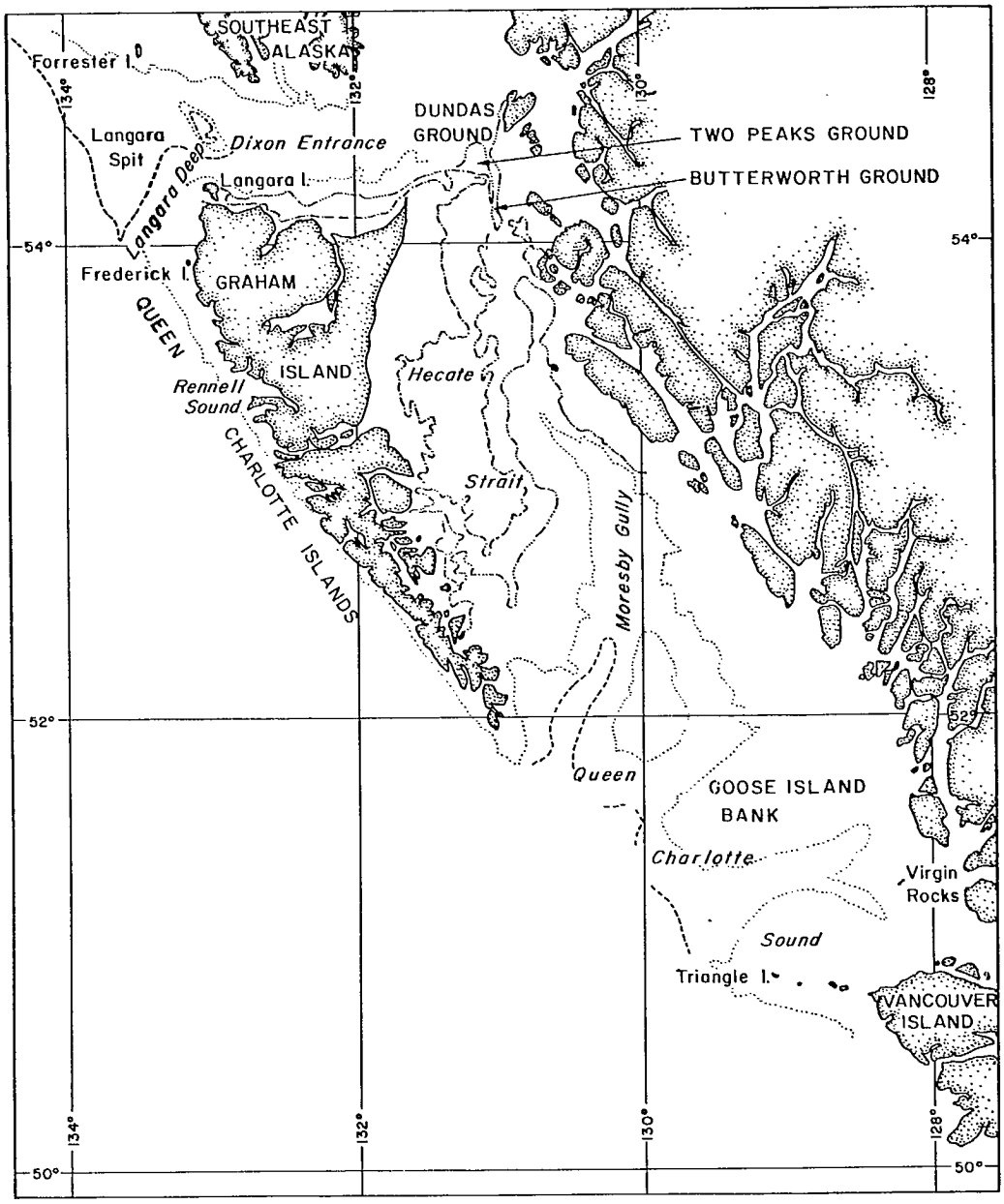

Fig. 3. Principal area of recapture for Dover sole tagged during September 1979 in northern Hecate Strait.

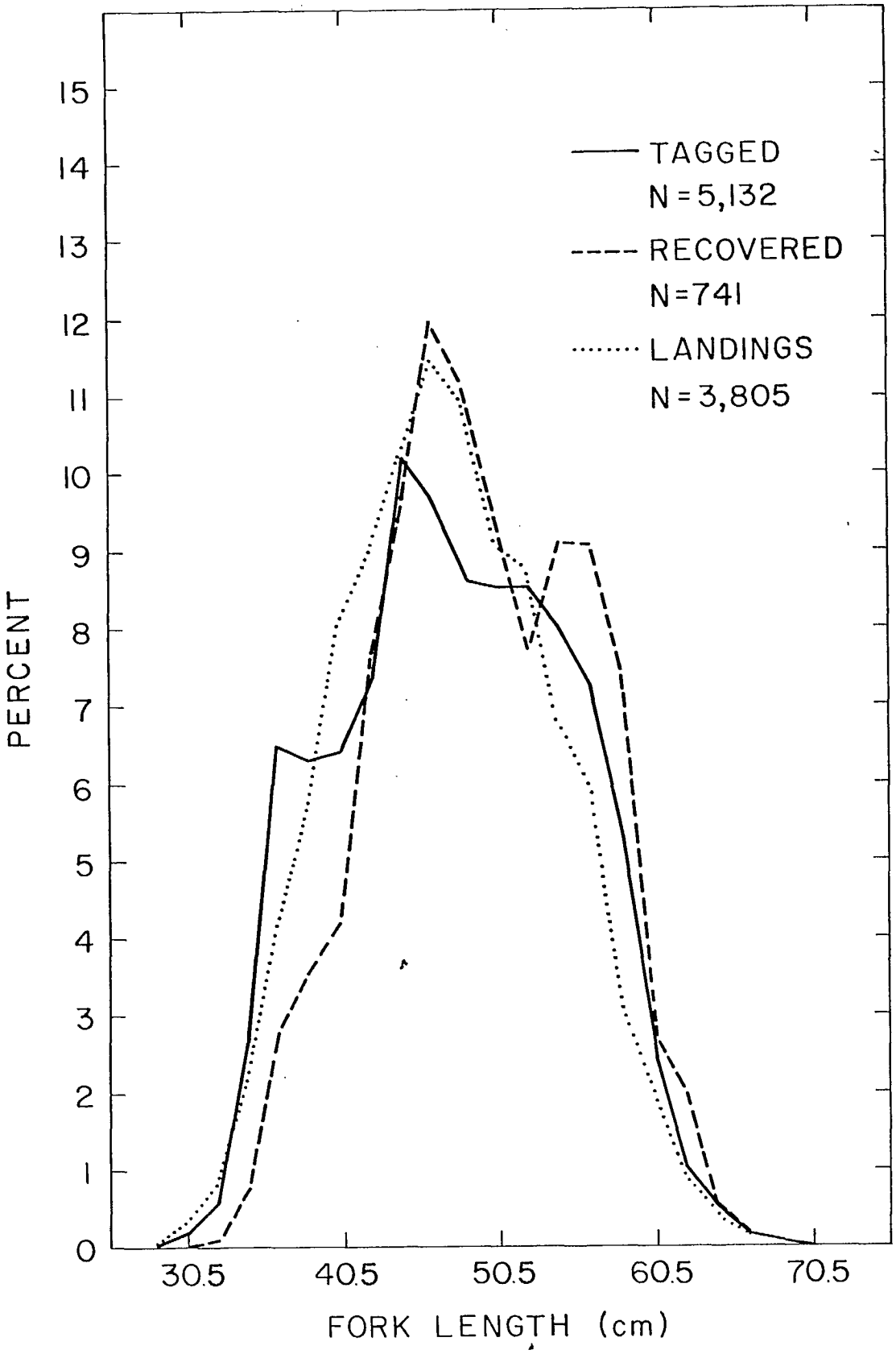

Fig. 4. Length-frequencies (%) of Dover sole: (a) tagged and released in Area 5D, September 1979; (b) recovered from all areas, 1979-84; and (c) sampled from commercial landings migrating from Area 5D, May-September 1979-84.

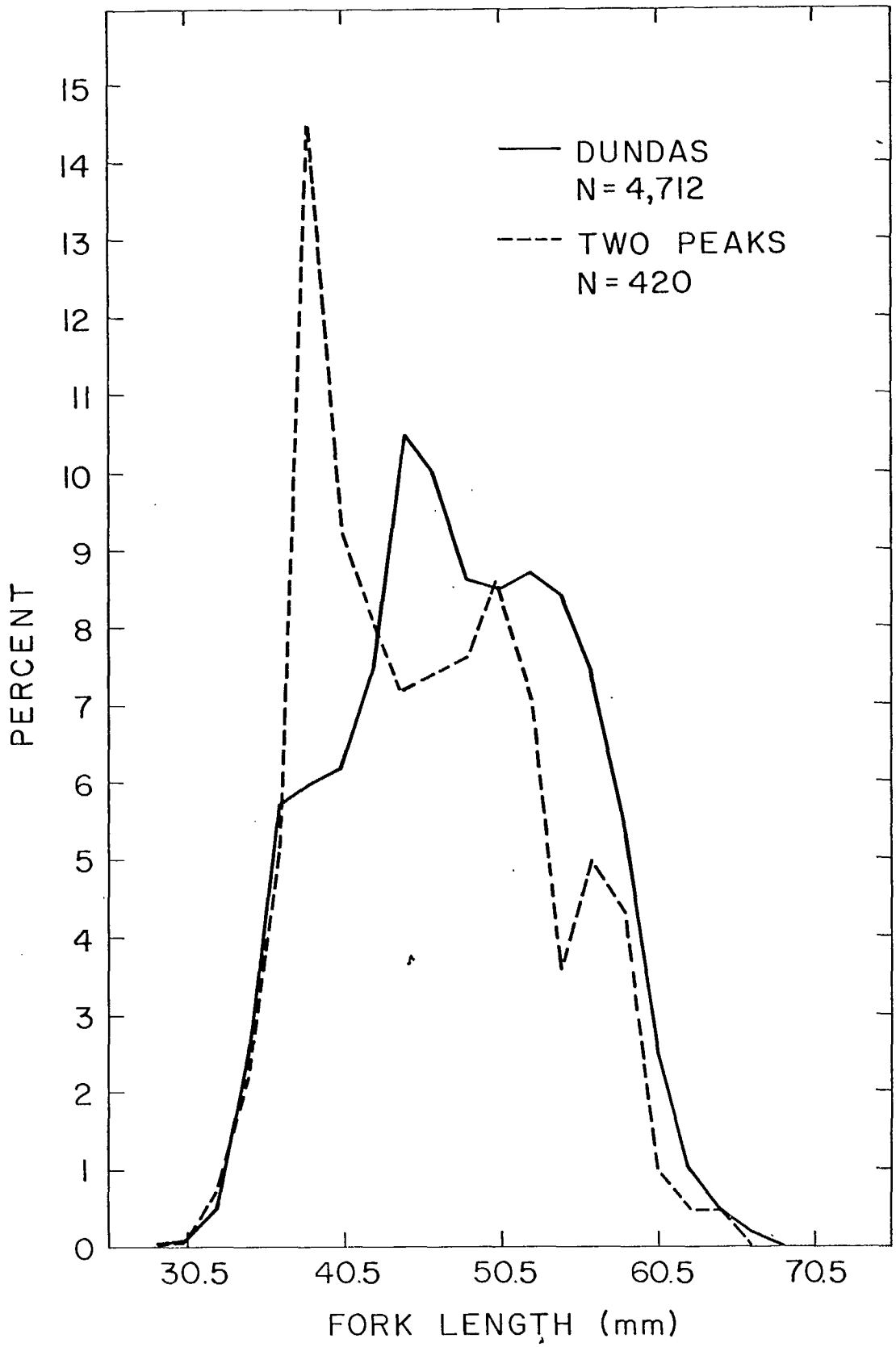

Fig. 5. Length-frequencies (%) of Dover sole tagged and released in Area 5D, by ground, September 1979.

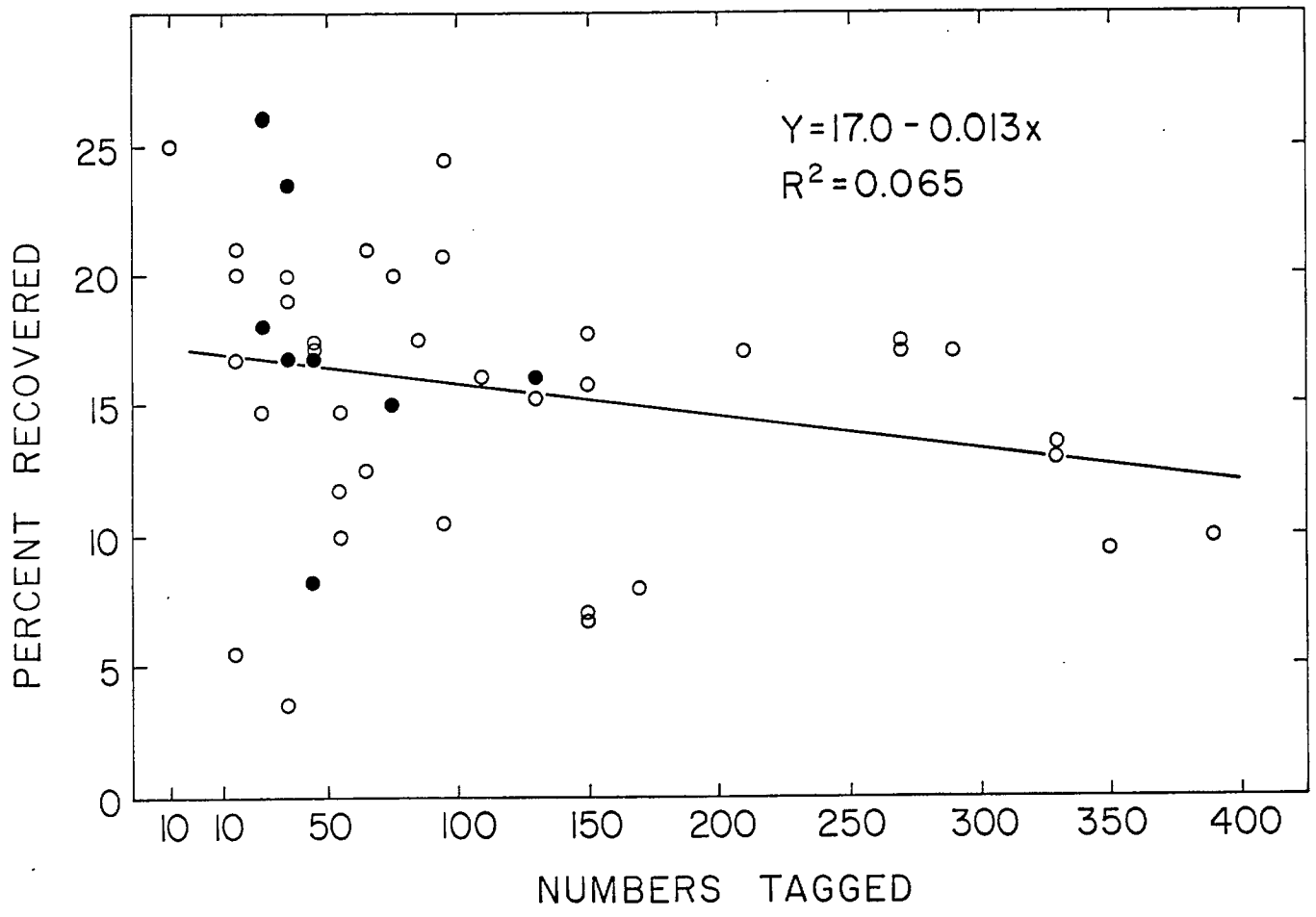

Fig. 6. Regression of percent recovered on numbers tagged and released, for Dover sole in the September 1979 experiment. (Solid circles = Two Peaks sub-experiment.)

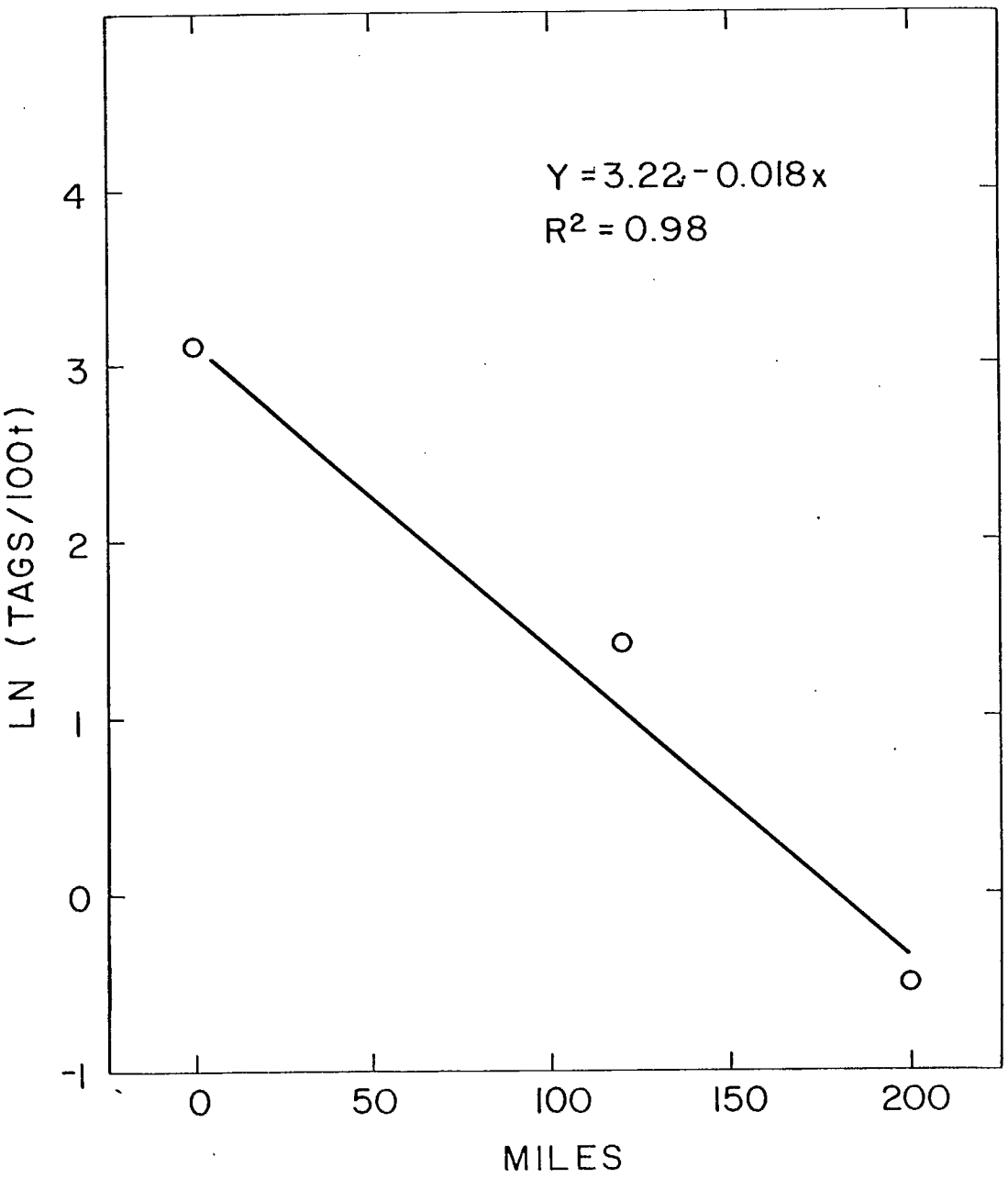

Fig. 7. Regression of ln (tags/100 t) on distance (nm) from the Area 5D tagging site for Dover sole recaptured in Areas 5D, 5C, and 5B during 1980-84.

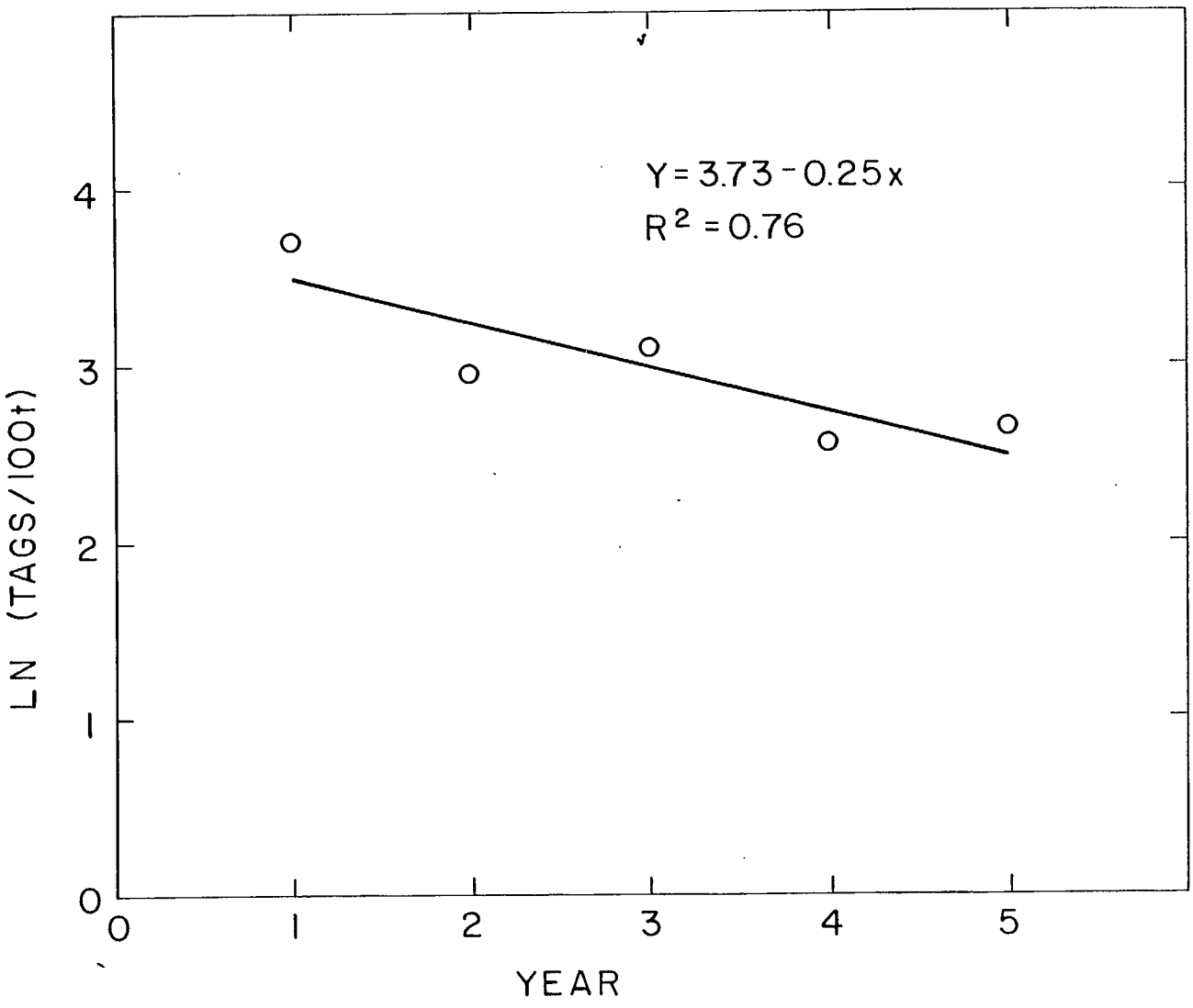

Fig. 8. Regression of ln (tags/100 t) on recovery year for Dover sole recovered in Area 5D, 1980-84, from the September 1979 experiment.

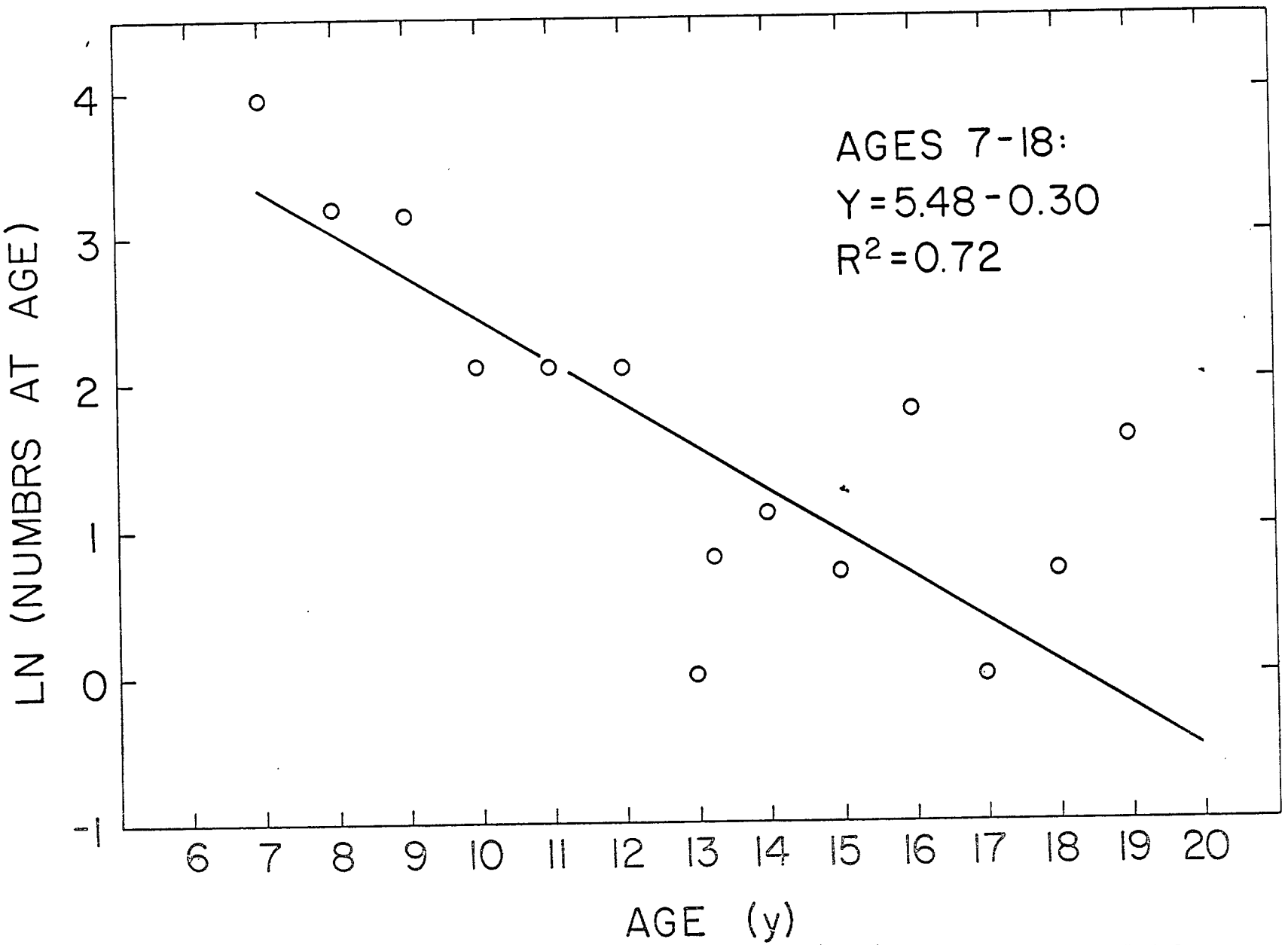

Fig. 9. Regression of ln (numbers-at-age, sexes combined) on age (7-18) for Dover sole sampled from Haul 47, on Dundas Ground, September 1979.

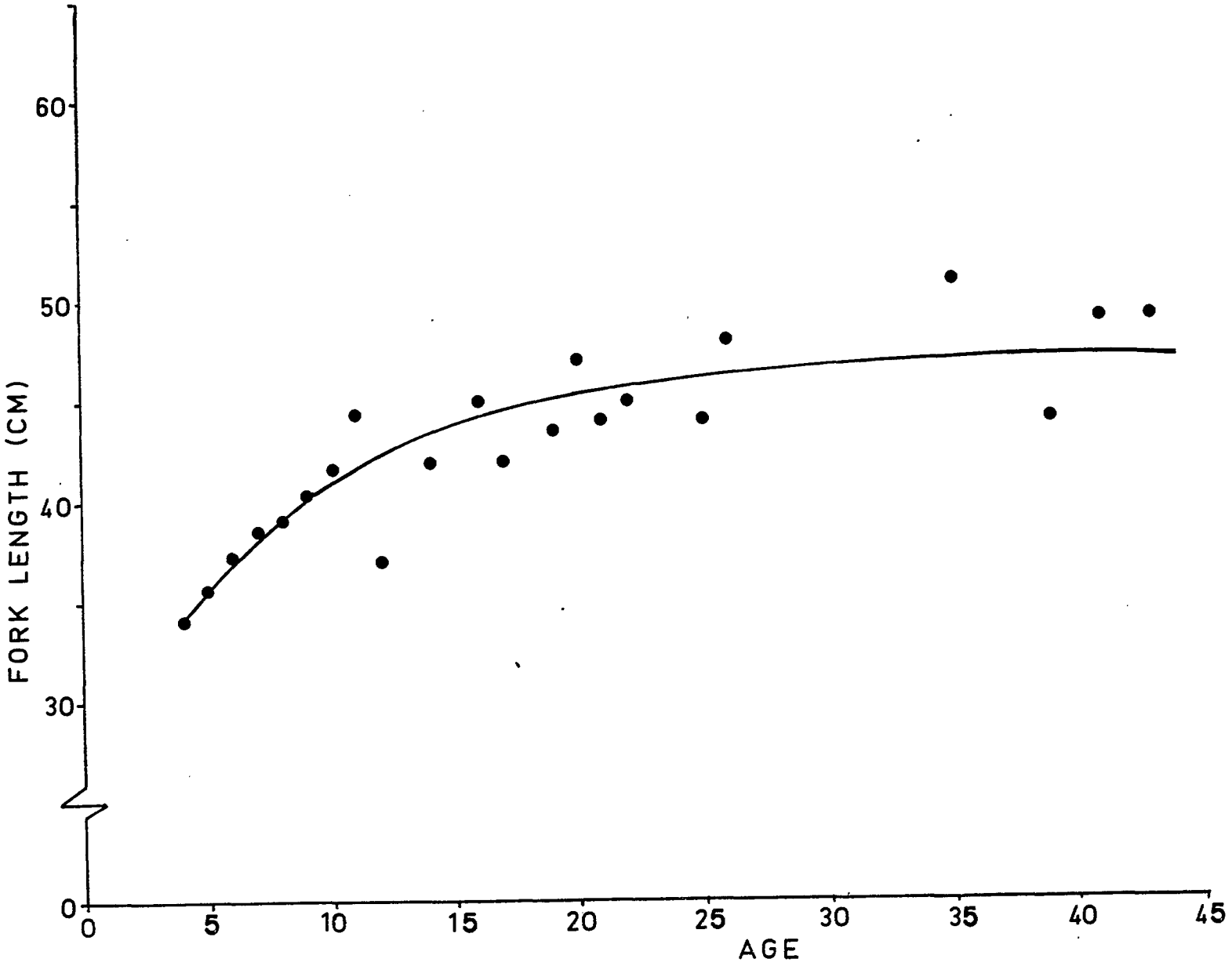

Fig. 10. Age-length relationship for 121 male Dover sole sampled from Haul 47, on Dundas Ground, September 1979.

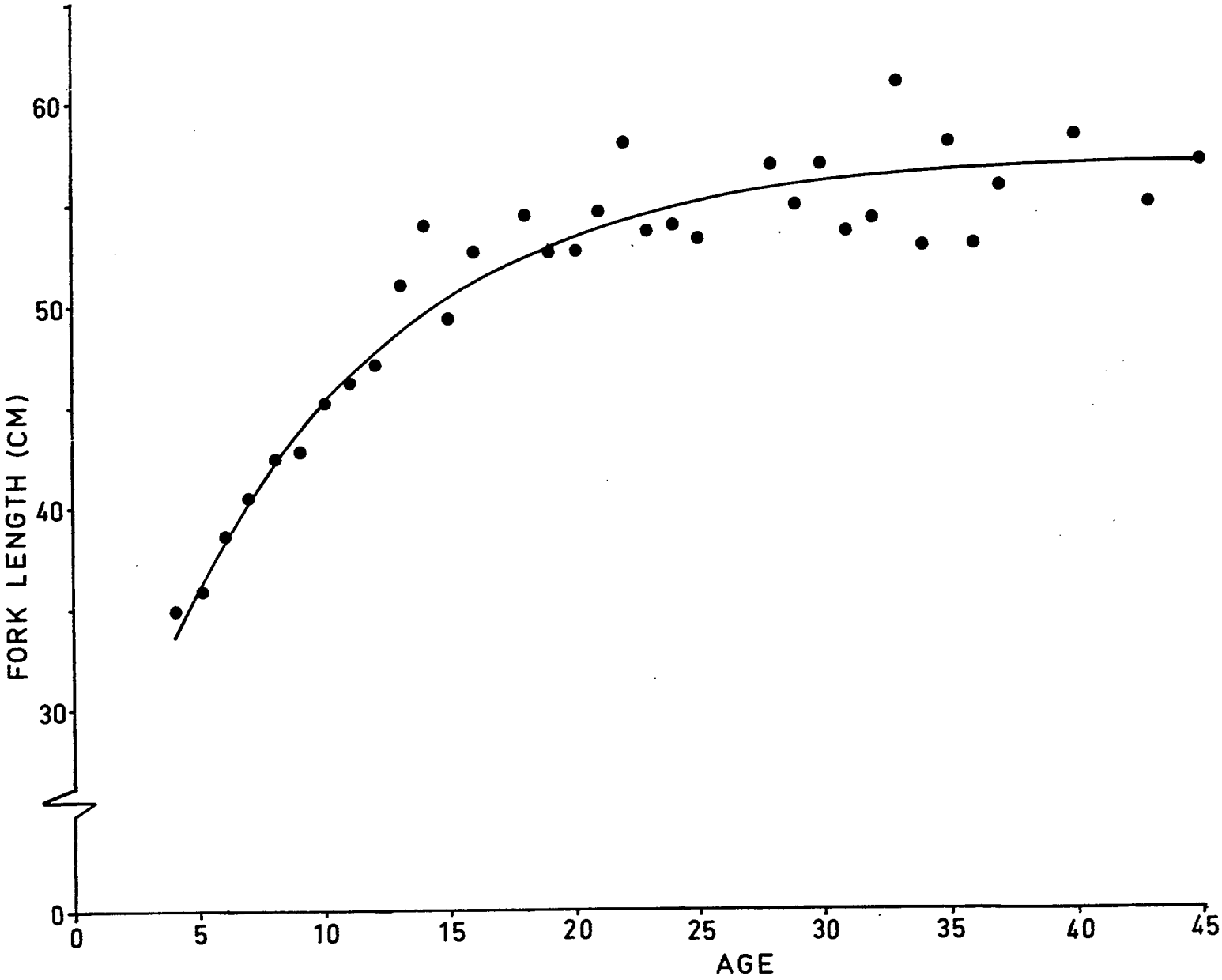

Fig. 11. Age-length relationship for 163 female Dover sole sampled from Haul 47, on Dundas Ground, September 1979.

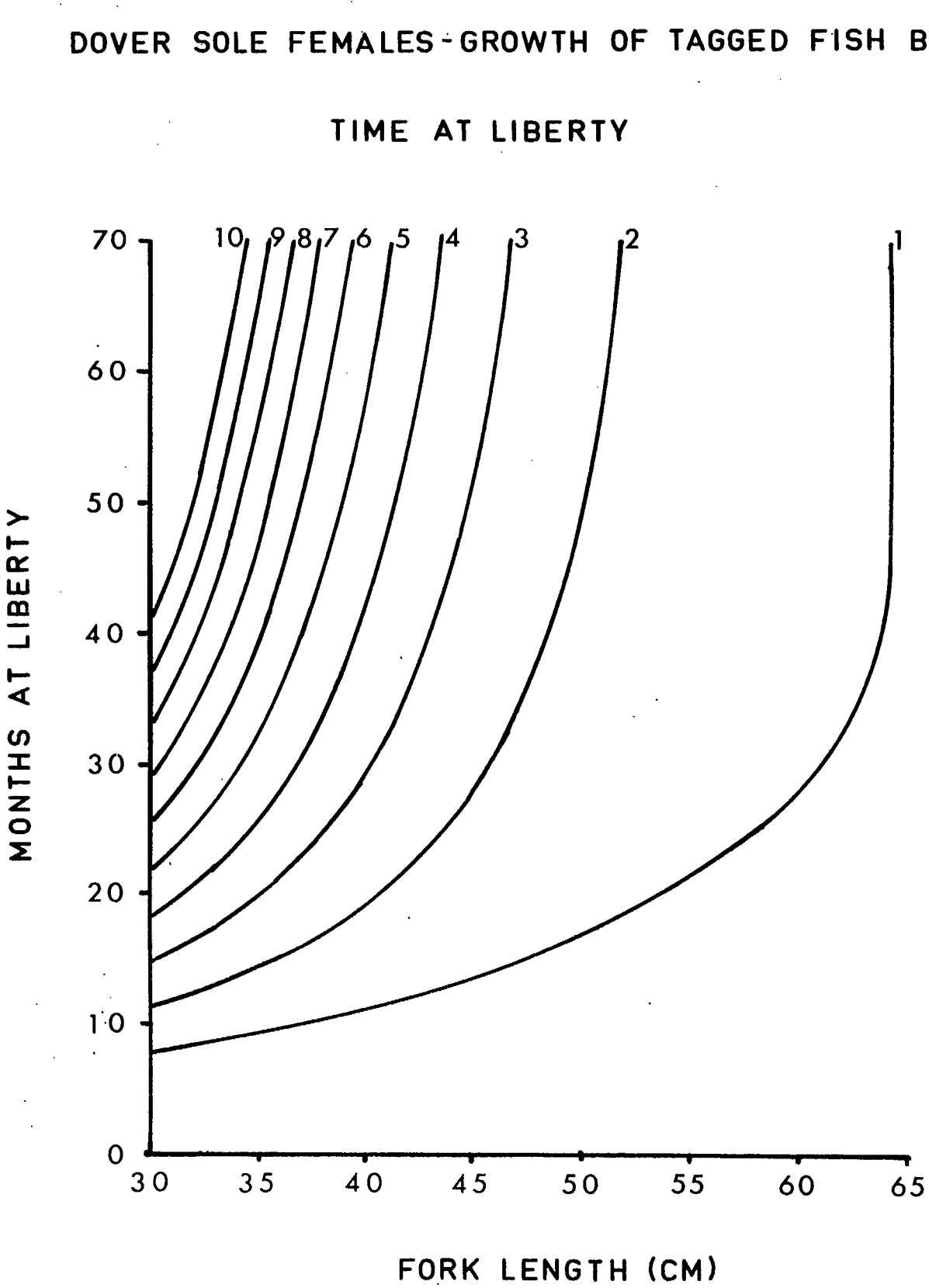

Fig. 12. Incremental growth (cm), by months at liberty and length at release, for female Dover sole recovered from all areas, 1979-84.