Final Results of the September 1979 Dover Sole Tagging Experiment in Northern Hecate Strait, 1979-1999

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FINAL RESULTS OF THE SEPTEMBER 1979 DOVER SOLE TAGGING EXPERIMENT IN NORTHERN HECATE STRAIT, 1979-1999

by

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ABSTRACT

Fargo, J., and Westrheim, S.J. 2007. Final results of the September 1979 dover sole tagging experiment in northern Hecate Strait, 1979-1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2813: iv + 30 p.

During September 21-26, 1979, 5,146 Dover sole were tagged and released at two locations in Area 5D (Figure 1). Recovery results through 1984 were published in Fargo *et al.* (1985). We analyzed the final recovery information for the tagging through 1999. Time at liberty was 20 years for the last recovery, and 15 recoveries were at liberty at least 10 years. During 1979-99 recovery rates were not significantly different for the two tagging grounds. Incidence of recovered tags (nos/100t) was substantially larger in Area 5D than in Area 5E. Recovery rates generally varied directly with length at tagging. The sex ratio was similar for tagged fish recovered from the commercial fishery in the two Areas, but not so in samples taken from commercial landings. There was a differential bathymetric migration of the sexes, also demonstrated in earlier studies in U.S. waters. Namely, female Dover sole tagged in “shallow” water in Hecate Strait migrated during winter into “deep” water off the west coast of the Queen Charlotte Islands for spawning. The migration of males to deepwater spawning areas preceded that of females.

RÉSUMÉ

Fargo, J., and Westrheim, S.J. 2007. Final results of the September 1979 dover sole tagging experiment in northern Hecate Strait, 1979-1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2813: iv + 30 p.

Du 21 au 26 septembre 1979, 5 146 soles à petite bouche ont été marquées et relâchées dans deux sites du secteur 5D (figure 1). Les résultats des récupérations effectuées jusqu'en 1984 ont été publiés dans Fargo *et al.* (1985). Nous avons analysé les données sur la récupération finale d'individus marqués jusqu'en 1999. Le temps en liberté était de 20 ans pour la dernière récupération, et 15 individus récupérés avaient été en liberté pendant au moins 10 ans. Pendant la période 1979-1999, les taux de récupération des deux sites de marquage n'étaient pas significativement différents. L'incidence des individus marqués récupérés (nombre de marques/100 t) était substantiellement plus grande dans le secteur 5D que dans le secteur 5E. Les taux de récupération variaient généralement directement en fonction de la longueur du poisson au moment du marquage. Le rapport des sexes des poissons marqués récupérés par la pêche commerciale était sensiblement semblable pour les deux secteurs, mais ce n'était pas le cas dans les échantillons prélevés dans les débarquements commerciaux. Cela s'explique par la migration bathymétrique qui diffère selon le sexe, également montrée dans des études antérieures dans les eaux états-uniennes. Ainsi, les soles à petite bouche femelles marquées en eaux « peu profondes » dans le détroit d'Hécate migraient à l'hiver vers les eaux « profondes » au large de la côte ouest des îles de la Reine-Charlotte en vue de frayer. La migration des mâles vers les frayères en eaux profondes précédait celle des femelles.

INTRODUCTION

In 1985, a working group was established by the Technical Subcommittee of the Canada-United States Groundfish Committee to collate available coastwide information, from tagging studies, on stock delineation of Dover sole (*Microstomus pacificus*). The report of the working group was published (Westrheim *et al*. (1992). Results of tagging studies by the fisheries agencies of California, Oregon, and Washington, were "complete" when the coastwide analyses closed off in 1984. However, the Canadian study, which began in 1979, was deemed "incomplete", based on the results of the earlier U.S. studies, where maximum years at liberty commonly exceeded 10. The purpose of this report is to complete the analysis of the tagging studies of Dover sole in Canadian waters.

The tag type was a Floy FD688 anchor. Recoveries were dependent on the vigilance and cooperation of fishermen, processing-plant employees, and the Department's port liaison officers. During September 21-26, 1979, 5,146 Dover sole were tagged and released, all in Area 5D. On September 21, 420 were tagged on Two Peaks Ground, and during September 21-26, 4,726 were tagged on the adjacent Dundas Ground.

MATERIALS AND METHODS

TAGGING

A full description of the tagging was reported in Stocker *et al*. (1980), and a brief description in Fargo *et al*. (1985). Tag type was the Floy FD688 anchor. Tagged fish were measured for total length to the nearest centimeter, and grouped into 2-cm intervals, such that the mid-points were even numbers +0.5 (Fargo *et al.* 1985).

TAG RECOVERY

No effort was expended to directly determine the incidence of tagged Dover sole in the commercial landings. Recoveries were dependent upon the vigilance and cooperation of fishermen, processing-plant employees, and the Department's port liaison officers stationed in Prince Rupert (Area 5D) and Vancouver (Area 4B) (Fig. 1). Recoveries were arranged by year and quarter-year for this analysis.

DISPERSION

Dispersion rate was not estimated, because recoveries after 1984 occurred only in two adjacent major areas, 5E and 5D. However, the substantial difference in tag incidence (tags/100t) between the two areas was investigated.

MORTALITY RATE

The instantaneous total mortality rate (Z) was estimated by regressing ln tags/100t landings on year, following the procedures of Fargo *et al*. (1985).

EXTINCTION

Extinction year for the study was estimated by dividing the intercept by the slope in the regression used to estimate mortality rate, following the procedure of Fargo *et al*. (1985).

RESULTS

TAGGING

During September 21-26, 1979, 5,146 Dover sole were tagged and released in Area 5D (Table 1). On September 21, 420 were tagged on Two Peaks Ground, and during September 21-26, 4,726 were tagged on Dundas Ground.

TAG RECOVERY

Numbers

The last recovery occurred in February 1999. The 1985-99 recoveries totaled 108 (2.1%), 7 (1.7%) from the Two Peaks tagging, and 101 (2.1%) from the Dundas tagging (Table 1). Comparable values for the 1979-84 recoveries were 745 (14.5%), 70 (16.7%), and 675 (14.3%). The 1979-99 recoveries totaled 853 (16.6%), 7 (18.3%) from the Two Peaks tagging, and 776 (16.4%) from the Dundas tagging. Recovery rates did not differ significantly between tagging Areas, based on a two-way contingency table analysis using actual recoveries (Dixon and Massey 1969, p. 242). For 1979-84, Chi-square was 1.579 ($P > 0.20$), and for 1979-99, 0.832 ($P > 0.30$).

Location

The last recovery was from Area 5E. Recoveries during 1985-99 were reported from only two Areas (5E and 5D), compared to five during 1979-84 (5E, 5D, 5C, 5B, and 3A) (Table 2). These results are not surprising. For 1979-84, recoveries of known Area totaled 586, and only 11 (1.9%) occurred in Areas other than 5E or 5D. The likelihood of recoveries after 1984 was poor, considering the estimated instantaneous total mortality rates of 0.25 or 0.30 (Fargo *et al.* (1985). With such attrition rates[1], plus the "loss" of recovered tags (745), only 729 ($Z = 0.25$), or 403 ($Z = 0.30$) tagged fish would have still been at liberty after 1984. After 1992, the numbers would have been 93 or -3.

Quarter-years

During 1985-99, Quarters I+II predominated for recoveries in Area 5E (100%), and Quarters II+III in Area 5D (97%) (Table 2). Similar results were noted for 1979-84 (100 and 95%), and 1979-99 (100 and 95%) (Table 2). This seasonal, east-west, bathymetric migration, deep in Qtrs I+II and shallow in Qtrs II=III, was also reported elsewhere, south of British Columbia (Fargo *et al.* 1985).

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[1] $N_t = N_o e^{-Zt}$, where N = numbers of tagged fish, and t = numbers of years after tagging.

Length-frequencies

Distributions, based on length at tagging, were multimodal among the tagged and recovered Dover sole, for Two Peaks+Dundas, Two Peaks, and Dundas (Table 3; Figs. 2a,b,c). Among 10-cm groups (30.5-38.5, 40.5-48.5, *etc*.), recapture rates generally varied directly with length. Two Peaks recovery rates for 1979-99 were 11.2, 19.0, 26.1, and 12.5%, respectively, for the "30s" (30-39 cm) through the "60s" (60-69 cm). Comparable values for Dundas were 5.9, 16.3, 19.5, and 20.8%.

Mean lengths of recovered Dover sole reflected the general increase in recovery rate with length at tagging. They were significantly larger for 1979-84 and 1985-99, than those of tagged specimens (Table 3). Two Peaks mean lengths were 44.8 cm $\pm$ 0.4 for tagged fish, *versus* 46.4 cm $\pm$ 1.1 (1979-84; N = 70) and 49.6 cm $\pm$ 1.7 (1985-99; N = 7) for recoveries. Mean length of all recoveries (1979-99) was 47.5 cm $\pm$ 0.8 (N = 77). Dundas mean lengths were 47.9 cm $\pm$ 0.1 (N = 4712) for tagged fish, *versus* 49.7 cm $\pm$ 0.3 (1979-84, N = 671) and 52.2 cm $\pm$ 0.5 (1985-99, N = 93) for recoveries. Mean length for all recoveries was 50.0 cm $\pm$ 0.2 (N = 764). The smaller mean lengths for Two Peaks fish was attributed to tagging in shallower water (Fargo *et al*. 1985). The authors reported a positive relationship between mean length and depth of capture. A Chi-square test of the respective distributions indicated that the Two Peaks recoveries did not differ significantly from those of the tagged specimens ($X^2 = 7.828$, $P > 0.30$) (Table 4). The Dundas and Total distributions differed significantly from their respective tagged distributions ($X^2 = 88.455$, $P < 0.01$; and 94.266, $P < 0.01$).

Sex Ratio (% males)

Relevant recoveries in Area 5E totaled 14 during 1979-99, 7 each during 1979-84 and 1985-99 (Table 5). Sex ratios were zero and 14.3%, respectively, and 7.1% overall. No statistical tests were warranted.

Relevant recoveries in Area 5D totaled 610 during 1979-99 (Table 5). Among recovery periods, sex ratios were 10.7% for 1979-84 (N = 523), 14.9% for 1985-99 (N = 87), and 11.3% for 1979-99 (N = 610). The rates for 1979-84 and 1985-99 were not significantly different, based on actual recoveries. The two-way contingency table test yielded a Chi-square of 0.202 ($P > 0.50$).

TIME AT LIBERTY

Recoveries which were at liberty at least 10 years totaled 15, and the maximum was 20 y[2] (Table 6). Comparable numbers from the U.S. taggings were: 10 (maximum = 15 y) for 3Cs[3]; 13 (22 y) for 2B/3A; and 21 (15 y) for Area 1C. Recovery rate (10+ y) for 5D was 1.8%, compared to 9.5% for 3Cs, 0.6% for 2B/3A, and 1.7% for 1C,.

[2] Actual recapture date is unknown.
[3] That portion of Area 3C lying in the U.S. Extended Economic Zone, established in 1977'

DISPERSION

During 1985-92, Dover sole landings totaled 13,399 t (Table 7). Principal Areas of catch were 3Cn[4] (36%) and 5D (31%). Area 5E proportion was 12%. In contrast, during 1979-84, principal Areas were 5D (47%) and 5E (16%). Area 3Cn proportion was 10%.

During 1979-92, mean annual landing for Area 5E was 192 t (S.D. = 115; C.V. = 60%), and for Area 5D, 512 t (S.D. = 136; C.V. = 27%) (Fig. 3). Annual fluctuations were substantial, but without trend. The respective regression slopes were +0.010 and -0.006, neither of which differed significantly from zero (P = 0.35 and 0.52). In Area 5E, QI+II predominated during both periods; 98% in 1979-84, and 93% in 1985-92 (Table 7). In Area 5D, QII+III predominated similarly; 87% in 1979-84, and 84% in 1985-92.

Tag incidence (nos/100t landed) differed substantially between Areas 5E and 5D. In Area 5E, values never exceeded 3.0, during 1980-92, compared to 4.9-40 in Area 5D, during 1980-86, but 0-1.9 after 1986 (Fig. 4; Table 8). Sex ratio was reasonably similar for tagged fish recovered in Areas 5E (7.1%; N = 14) and 5D (11.3%; N = 610) (Table 5). However, the sex ratio in 5E of Dover sole sampled, during l980-92, from the commercial landings was 74% in Quarter I (N = 2775) and 71% in Quarter II (N = 2860), but 20% in Quarter III (N = 314) (Table 9). Thus, the predominantly female Dover sole tagged in "shallow" water migrated into "deep" water to join a group of predominantly male Dover sole, which resulted in a "dilution" of the tag incidence. This phenomenon suggests a differential bathymetric distribution of the sexes, as demonstrated for tagged Dover sole in Area 3A (Westrheim et al. 1992, p. 178).

MORTALITY RATE

Estimated instantaneous mortality rate (Z) was 0.43, based on the regression of ln tags/100t on year, for recoveries in Area 5D during 1980-92 (Table 10; Fig. 5). A second estimate, based on years 1980-86 was 0.33. The corresponding estimate for 1980-84 was 0.25, similar to the estimate of 0.30, based on an age-frequency sample collected during the tagging operations (Fargo *et al*. 1985).

EXTINCTION RATE

Estimated numbers of years to extinction is the quotient of intercept/slope in the regression formula producing the estimate of the instantaneous total mortality rate (Fargo *et al*. 1985, p. 9). For 1980-92, the estimated extinction year was 1989 (10.2 y), and for 1980-86, 1991 (12.2 y) (Table 10). Corresponding estimate for 1980-84 was 1995 (14.9 y) (Fargo *et al*. 1985). The apparent extinction year was 1999.

[4] That portion of Area 3C lying in the Canadian Extended Economic zone, established in 1977

SUMMARY AND DISCUSSION

During September 21-26, 1979, 5,146 trawl-caught Dover sole were tagged (Floy FD68B anchor) and released in northern Hecate Strait (Area 5D). There were 420 fish tagged on Two Peaks Ground, and 4,726 tagged on the adjacent Dundas Ground.

During 1979-99 recovery rates were not significantly different for the two tagging grounds. Only four recoveries occurred after 1989, all from the Dundas tagging area.

Recoveries were largely limited to the tagging area (5D) and the adjacent Area (5E). Recovery rate generally varied directly with length at tagging. The sex ratio did not differ for recoveries between 1979-84 and those between 1985-99.

Time at liberty was 20 y for the last recovery, and 15 recoveries had been at liberty at least 10 y. Comparable numbers (and maximum time at liberty) from the U.S. taggings were 21 (15 y) for Area 1C, 13 (22 y) for 2B/3A, and 10 (15 y) for 3Cs. Since tagged fish were similar in size to the presumably mature specimens in the commercial samples, Dover sole appear to be a long-lived species.

The incidence of recovered tags was substantially larger in Area 5D than Area 5E. During 1979-84 and 1985-99, principal quarter years for landings and tag recoveries from Area 5D were II and III and from Area 5E, I and II. This seasonal migration between “shallow” (5D and “deep” (5E) Areas was demonstrated earlier in Areas south of British Columbia based on logbooks, landings and tagging. The sex ratio was reasonably similar for tagged fish recovered in the two Areas, but not so for samples from commercial landings. This is indicative of a differential bathymetric migration.

Estimated instantaneous total mortality rates (Z) differed according to the range of years and method used. The estimate using the latest year’s recoveries was considered to be excessive, because of the precipitous decline in tag incidence after 1986. The method used to estimate extinction year for the tagging project appeared to be of limited value.

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Table 1. Numbers of Dover sole tagged September 21-26, 1979, and recovered, by year and tagging site, for Dover sole from the Two Peaks and Dundas grounds, 1979-99. (Source: Appendix table 1)

	Two Peaks	Dundas	Total
Nos. tagged	420	4726[a]	5146
Nos. recovered			
1979-84	70	675	745
% recovered	16.7	14.3	14.5
1985	5	35	40
1986	1	37	38
1987	0	2	2
1988	1	11	12
1989	0	12	12
1990	0	0	0
1991	0	1	1
1992	0	2	2
1999	0	1	1
1985-99	7	100	107
% recovered	1.7	2.1	2.1
1979-99	77	775	852
% recovered	18.3	16.4	16.6

[a] Dover sole tag no. F7776602 was recaptured February 18, 1989, on Dundas Ground (Area 5D). No record of this tag appeared in the tagging records. However, on September 22, 1979 (Haul No. 11), a discontinuity in the tag series occurred. Tag numbers 76583 and 76585-76624 were not applied, because they were defective. Unfortunately, the above mentioned tag (76602) was not defective.

Table 2. Numbers of tagged Dover sole recovered, by Area, year, and quarter-year, from the September 1979 study. (Source: Fargo et al. 1985; PBS Groundfish Files)

Year	I	II	III	IV	Total	I	II	III	IV	Total
			Area 5E					Area 5D		
1979-84[a]	8	3	0	0	11	0	145	392	27	564
%	72.7	27.3	0	0	100.0	0	25.7	69.5	4.8	100.0
1985	1	1	0	0	2	0	10	24	0	34
1986	0	0	0	0	0	1	5	28	0	34
1987	0	0	0	0	0	0	0	2	0	2
1988	0	2	0	0	2	0	2	8	0	10
1989	4	0	0	0	4	0	1	4	1	6
1991	0	0	0	0	0	1	0	0	0	1
1992	0	0	0	0	0	0	1	1	0	2
1999	1	0	0	0	1	0	0	0	0	0
1985-99	6	3	0	0	9	2	19	67	1	89
%	66.7	33.3	0	0	100.0	2.2	21.3	75.3	1.1	100.0
1979-99	14	6	0	0	20	2	164	459	28	653
%	70.0	30.0	0	0	100.0	0.3	25.1	70.3	4.3	100.0
			Area 5C					Area 5B		
1979-84[a]	0.0	4	5	0	9	0	0	1	0	1
%	0	44.4	55.6	0	100.0	0	0	100	0	100.0
	Area 3A									
1979-84[a]	0	0	1	0	1					
%	0	0	100	0	100.0					

[a] Derived from Table 12 in Fargo et al. 1985.

Table 3. Length-frequencies (nos.) of Dover sole tagged and released (T), and recovered (R), during 1979-99, from the September 1979 releases on at Two Peaks and Dundas grounds in Area 5D. (Source: Appendix table 1).

		Two Peaks								
FL	1979	1979-84			85-99			79-99		
(cm)	T	R	%R		R	%R		R	%R	
28.5	...	...	...		...	...		...	...	
30.5	3	0	...		0	...		0	...	
32.5	9	0	...		0	...		0	...	
34.5	22	1	4.5		0	...		1	4.5	
36.5	61	5	8.2		0	...		5	8.2	
38.5	39	9	23.1	11.2	0	...	0	9	23.1	11.2
40.5	34	4	11.8		0	...		4	11.8	
42.5	30	7	23.3		1	0.3		8	26.7	
44.5	31	5	16.1		0	0		5	16.1	
46.5	32	4	12.5		1	0.3		5	15.6	
48.5	36	7	19.4	16.6	2	0.6	0.2	9	25.0	19.0
50.5	36	9	25.0		0	0		9	25.0	
52.5	25	3	12.0		2	0.6		5	20.0	
54.5	15	2	13.3		0	0		2	13.3	
56.5	21	4	19.0		1	0.3		5	23.8	
58.5	18	9	50.0	23.5	0	...	2.6	9	50.0	26.1
60.5	4	0	0.0		0	...		0	0	
62.5	2	1	50.0		0	...		1	50.0	
64.5	2	0	...		0	...		0	...	
66.5	...	...	...		...	...		...	...	
68.5	...	...	...	12.5	...	...	0	...	...	12.5
Sub-total	420	70	16.7		7	2.0		77	18.3	
Mean	44.8	46.4			49.6			47.5		
S.D.	7.6	9.1			4.6			7.2		
S.E.	0.4	1.1			1.7			0.8		
Unknown	0	0			1			1		
Total	420	70	16.7		8	2.3		78	18.6	

Table 3 Length-frequencies (nos.) of Dover sole tagged and released (T), and recovered (R), during 1979-99, from the September 1979 releases on at Two Peaks and Dundas grounds in Area 5D. (Source: Appendix table 1).

				Dundas						
FL	1979	79-84			85-99			79-99		
(cm)		R	%R		R	%R		R	%R	
28.5	1	0	...		0	...		0	...	
30.5	5	0	...		0	...		0	...	
32.5	24	1	4.2		0	...		1	4.2	
34.5	118	5	4.2		0	...		5	4.2	
36.5	270	16	5.9		1	0.4		17	6.3	
38.5	283	18	6.4	5.7	0	0	0.4	18	6.4	5.9
40.5	293	27	9.2		1	0.3		28	9.6	
42.5	351	49	14.0		3	0.9		52	14.8	
44.5	495	67	13.5		5	1.0		72	14.5	
46.5	469	84	17.9		5	1.1		89	19.0	
48.5	405	76	18.8	15.1	12	3.0	6.2	88	21.7	16.3
50.5	400	61	15.3		13	3.3		74	18.5	
52.5	411	54	13.1		12	2.9		66	16.1	
54.5	394	65	16.5		14	3.6		79	20.1	
56.5	346	63	18.2		16	4.6		79	22.8	
58.5	250	46	18.4	16.0	8	3.2	17.5	54	21.6	19.5
60.5	117	20	17.1		1	0.9		21	17.9	
62.5	48	14	29.2		1	2.1		15	31.3	
64.5	24	4	16.7		1	4.2		5	20.8	
66.5	7	1	14.3		0	...		0	...	
68.5	1	0	...	19.8	0	...	7.1	0	...	20.8
Sub-total	4712	671	14.2		93	2.0		764	16.2	
Mean	47.9	49.7			52.2			50.0		
S.D.	7.2	6.5			5.0			6.4		
S.E.	0.1	0.3			0.5			0.2		
Unknown	13	4			7			11		
Total	4725	675	14.3		100	2.1		775	16.4	

Table 4. Chi-square test, by ground, of Dover sole length-frequencies (nos.) for tagged (E) and recovered (O) specimens, 1979-99. (Length at tagging for recovered specimens) (Source: Table 3)

Total length (cm)	Total				Two Peaks				Dundas			
	E'	O R	E T'	(O-E)^2/E	E'	O R	E T'	(O-E)^2/E	E'	O	E	(O-E)^2/E
28.5	1								1	0		
30.5	8				3	0			5	0		
32.5	33	1	5.4		9	0			24	1	3.9	
34.5	140	6	22.9	12.511	22	1	4.0		118	5	19.1	10.439
36.5	331	22	54.2	19.165	61	5	11.2	3.419	270	17	43.8	16.379
38.5	322	27	52.8	12.583	39	9	7.2	0.479	283	18	45.9	16.946
40.5	327	32	53.6	8.696	34	4	6.2	0.800	293	28	47.5	8.010
42.5	381	60	62.4	0.095	30	8	5.5	1.136	351	52	56.9	0.424
44.5	526	77	86.2	0.981	31	5	5.7	0.082	495	72	80.3	0.850
46.5	501	94	82.1	1.725	32	5	5.9	0.128	469	89	76.0	2.208
48.5	441	97	72.3	8.464	36	9	6.6	0.873	405	88	65.7	7.596
50.5	436	83	71.4	1.867	36	9	6.6	0.873	400	74	64.9	1.289
52.5	436	71	71.4	0.003	25	5	4.6	0.038	411	66	66.6	0.006
54.5	409	81	67.0	2.914	15	2	2.8		394	79	63.9	3.577
56.5	367	84	60.1	9.465	21	5	3.9		346	79	56.1	9.348
58.5	268	63	43.9	8.291	18	9	3.3		250	54	40.5	4.473
60.5	121	21	19.8	0.069	4	0	0.7		117	21	19.0	0.217
62.5	50	16	8.2	7.437	2	1	0.4		48	15	7.8	6.693
64.5	26	5	4.3		2	0			24	5	3.9	
66.5	7	0							7	0		
68.5	1	0							1	0		
Total	5132	841	841.0		420	77	77.0		4712	764	764.0	
X^2				94.266				7.828				88.455
Df				14				8				14
P				<0.01				>0.30				<0.01

Table 5. Sex ratios (% males), by recapture area and year, of Dover sole tagged in Area 5D, September 21-26, 1979. (Source: Fargo *et al.* 1985; PBS groundfish files)

Area	Year	Males	Females	Total	% males	Unk
5E	1979-84[a]	0	7	7	0	2
	1985	0	2	2	0	0
	1986	1	0	1	100	0
	1987	0	0	0	nil	0
	1988	0	0	0	nil	2
	1089	0	4	4	0	0
	1991	0	0	0	nil	0
	1992	0	0	0	nil	0
	1999	0	0	0	nil	0
	1985-99	1	6	7	14.3	2
	1979-99	1	13	14	7.1	4
5D	1979-84[a]	56	467	523	10.7	37
	1985	2	34	36	5.6	0
	1986	7	26	33	21.2	0
	1987	0	1	1	0.0	1
	1988	2	6	8	25.0	3
	1989	1	5	6	16.7	0
	1991	1	0	1	100	0
	1992	0	2	2	0	0
	1999	0	0	0	nil	1
	1985-99	13	74	87	14.9	5
	1979-99	69	541	610	11.3	42
5C	1979-84[a]	2	4	6	33.3	3
5B	1979-84[a]	0	1	1	0	0
3A	1979-84[a]	0	0	0	nil	1

[a] Fargo *et al.* 1985.

Table 6. Numbers of tagged Dover sole recovered 10 or more years after release, by Area of release. (Source: Westrheim et al.1992, Tables 1 and 3; this report, Table 1)

Recovery year[a]	Release area			
	1C	2B/3A	3Cs[b]	5D
	1969-71	1948-75	1968-71	1979
10	7	2	2	11
11	7	0	3	0
12	2	0	1	1
13	4	1	1	2
14	0	1	2	0
15	1	1	1	0
16	...	3	...	0
17	...	1	...	0
18	...	2	...	0
19	...	1	...	0
20	...	0	...	1
21	...	0	...	...
22	...	1	...	...
10-22	21	13	10	15
% 0-22	1.7	0.6	9.5	1.8
0-22[c]	1235	2190	105	852

[a]. Month of recovery disregarded (1969-79 = 10 years)
[b]. That portion of Area 3C lying in the U.S. Extended Economic Zone
[c]. All months. Includes those tags for which time of recovery is unknown

Table 7. Dover sole landings (t) and proportions (%), by Area, off British Columbia: (a) total for 1979-84, 1985-92, and 1979-92; (b) annual (tonnes only) for 1985-92; and (c) quarterly totals for 1979-84 and 1985-92. (Source: Fargo *et al*. 1985; PBS Groundfish Files)

Year	5E	5D	5C	5B	5A	3D	3Cn	4B	Total
1979-84	1056	3086	284	208	125	727	687	430	6603
%	16.0	46.7	4.3	3.2	1.9	11.0	10.4	6.5	100.0
1985	199	618	11	16	12	16	59	30	961
1986	333	684	10	16	33	16	61	4	1157
1987	148	327	28	42	36	13	25	15	634
1988	117	515	11	81	33	143	361	10	1271
1989	132	540	15	72	49	424	885	1	2118
1990	219	530	16	76	25	269	1217	16	2368
1991	221	382	23	137	23	459	942	10	2197
1992	268	486	50	193	44	392	1208	52	2693
1985-92	1637	4082	164	633	255	1732	4758	138	13399
%	12.2	30.5	1.2	4.7	1.9	12.9	35.5	1.0	100.0
1979-92	2693	7168	448	841	380	2459	5445	568	20002
%	13.5	35.8	2.2	4.2	1.9	12.3	27.2	2.8	100.0
1979-84									
I	64.3	2.4	0.6	1.2	0.6	17.9	15.1	0.9	
II	33.4	21.2	41.0	63.9	31.6	52.6	52.0	31.5	
III	0.5	66.1	47.6	29.6	51.3	21.4	26.0	48.0	
IV	1.9	10.4	10.8	5.3	16.5	8.2	7.0	19.6	
Total	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
1985-92									
I	39.1	0.1	...	...	...	...	...	...	
II	54.0	20.3	...	...	...	...	...	...	
III	2.9	64.0	...	...	...	...	...	...	
IV	3.8	15.6	...	...	...	...	...	...	
Total	99.8	100.0	...	...	...	...	...	...	

Table 8. Incidence (tags/100 t), by year and quarter-year, in Dover sole landings (t) from Areas 5E and 5D, 1980-92. (Sources: Fargo *et al.*1985, Table 17; This study, Table 2 and Appendix table 2)

Year	Area 5E					Area 5D				
	I	II	III	IV	Total	I	II	III	IV	Total
1980	2.4	6.9	0	0	3.0	0	48	39	34	40
1981	0	0	0	0	0	0	22	19	14	19
1982	0	0	0	0	0	0	24	24	0	22
1983	0	0	0	0	0	0	3.3	20	7.0	13
1984	3.8	0.5	0	0	1.7	0	16	14	0	14
1985	1.2	1.2	0	0	1.0	0	90	5.3	0	6.4
1986	0	0	0	0	0	0	4.1	6.3	0.0	4.9
1987	0	0	0	0	0	0	0	0.9	0	0.6
1988	0	4.3	0	0	1.7	0	3.1	2.5	0	1.9
1989	9.8	0	0	0	3.0	0	0.6	1.2	1.6	1.2
1990	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	>100	0	0	0	0.3
1992	0	0	0	0	0	0	1.0	0.3	0	0.4

Table 9. Sex ratio (% males), by month, for Dover sole landed from Area 5E, 1980-92. (Source: PBS Groundfish files)

Month	N[a]	Numbers			
		M	F	T	%M
Jan	3	712	199	911	78.2
Feb	2	387	184	571	67.8
Mar	5	942	351	1293	72.9
Q I	10	2041	734	2775	73.5
Apr	4	569	388	957	59.5
May	5	1160	413	1573	73.7
Jun	1	240	90	330	72.7
Q II	10	1969	891	2860	68.8
Q I+II	20	4010	1625	5635	71.2
Q III	1[b]	64	250	314	20.4
Q IV	0	nil	nil	nil	nil

[a] N = number of samples
[b] August.

Table 10. Regression of tag incidence (tags/100t) on year, for Dover sole recovered in Area 5D during 1980-92, from the September 1979 tagging in Area 5D. (Source: Fargo et al.1985, Table 17; This study, Table 8).

Year (x)	Tags/100 t (y) (ln y)	(y)	Parameters	Years 1980-92	80-86
1980	3.689	40			
1981	2.944	19	a	4.106	3.900
1982	3.091	22	b	-0.401	0.319
1983	2.565	13	r	0.955	0.955
1984	2.639	14	R^2	0.912	0.912
1985	1.856	6.4			
1986	1.589	4.9	Z	-0.40	0.32
1987	-0.511	0.6	Ext.[a]	10.2	12.2
1988	0.642	1.9			
1989	0.182	1.2			
1990		0			
1991	-1.204	0.3			
1992	-0.916	0.4			

[a] Estimated year of extinction (= a/b).

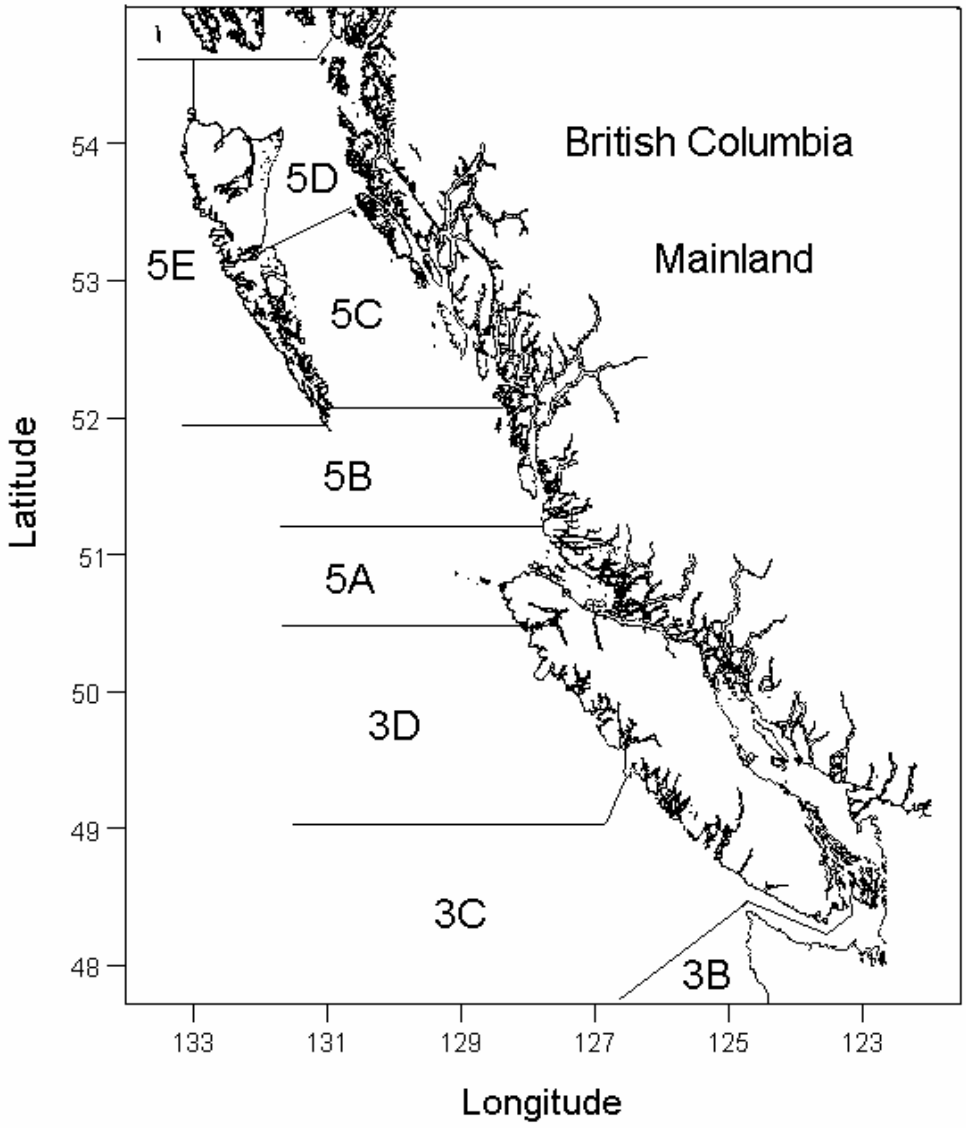

Figure 1. International groundfish statistical areas off Canada.

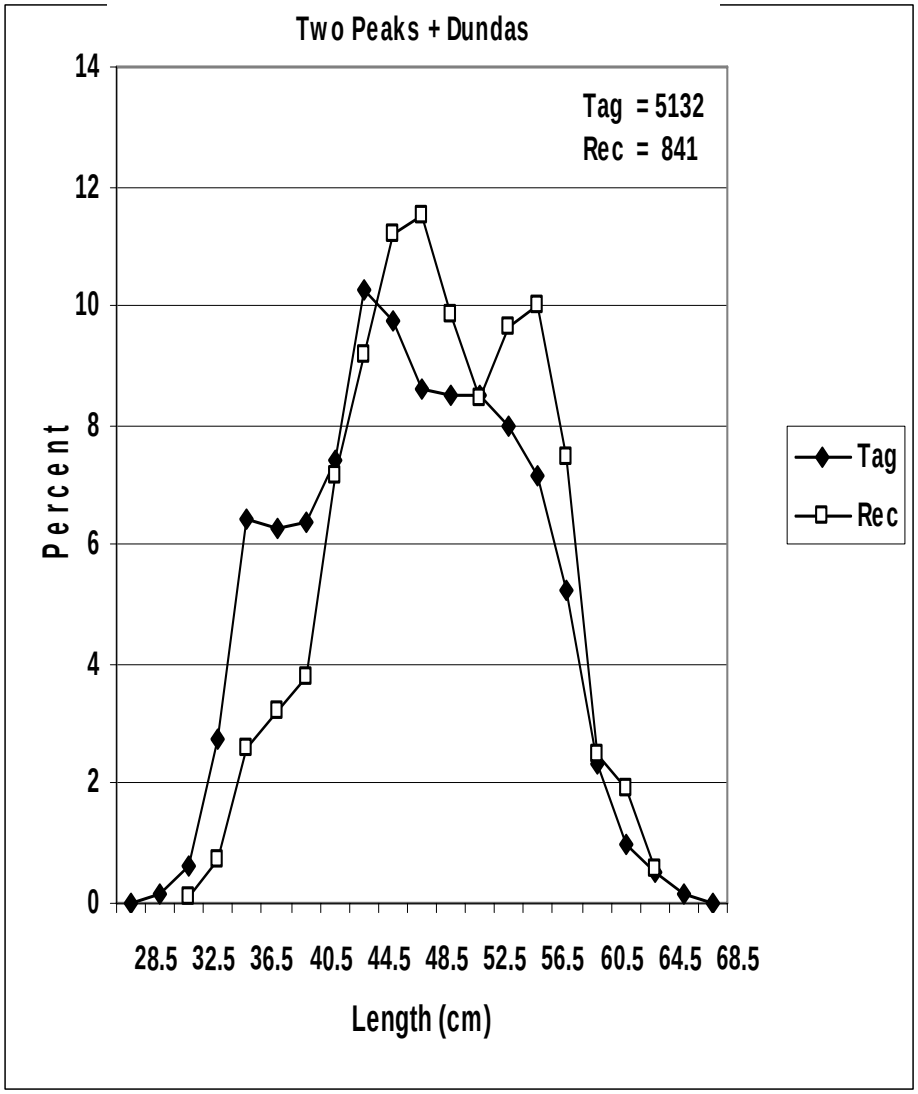

Figure 2a. Dover sole length-frequencies (%) for tagged (Tag) and recovered (Rec) specimens, 1979-99: combined tagging areas. (Length at tagging for recovered specimens) (Source: Table 3)

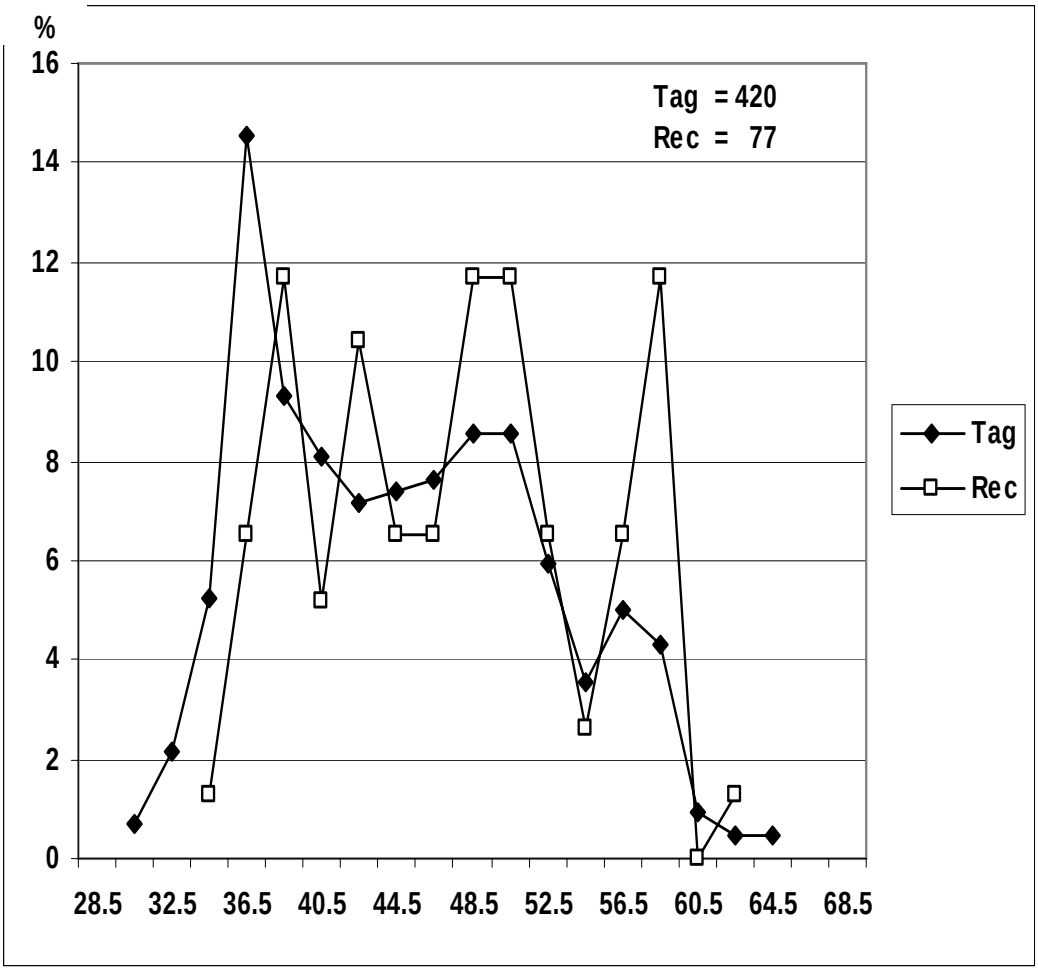

Figure 2b.Dover sole length-frequencies (%) for tagged (Tag) and recovered (Rec) specimens, 1979-99: Two Peaks. (Length at tagging for recovered specimens) (Source: Table 3).

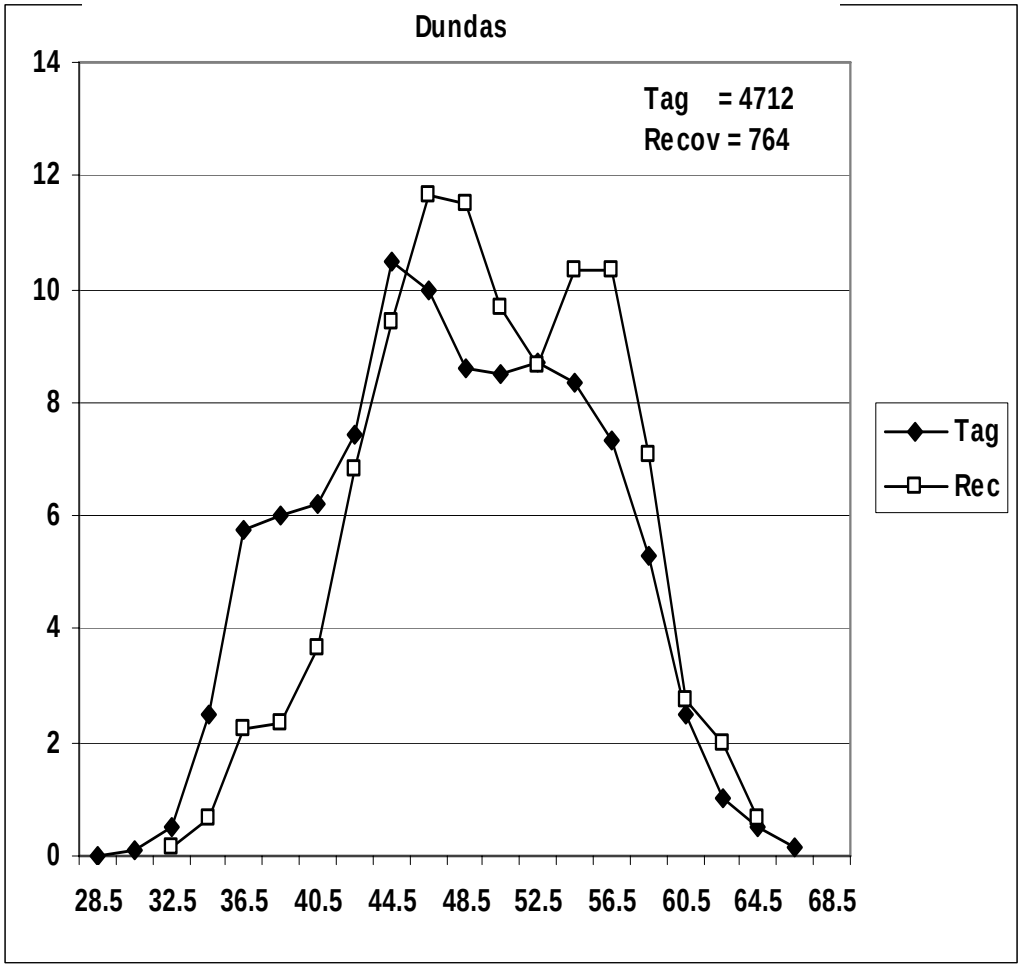

Figure 2c. Dover sole length-frequencies (%) for tagged (Tag) and recovered (Rec) specimens, 1979-99: Dundas. (Length at tagging for recovered specimens) (Source: Table 3)

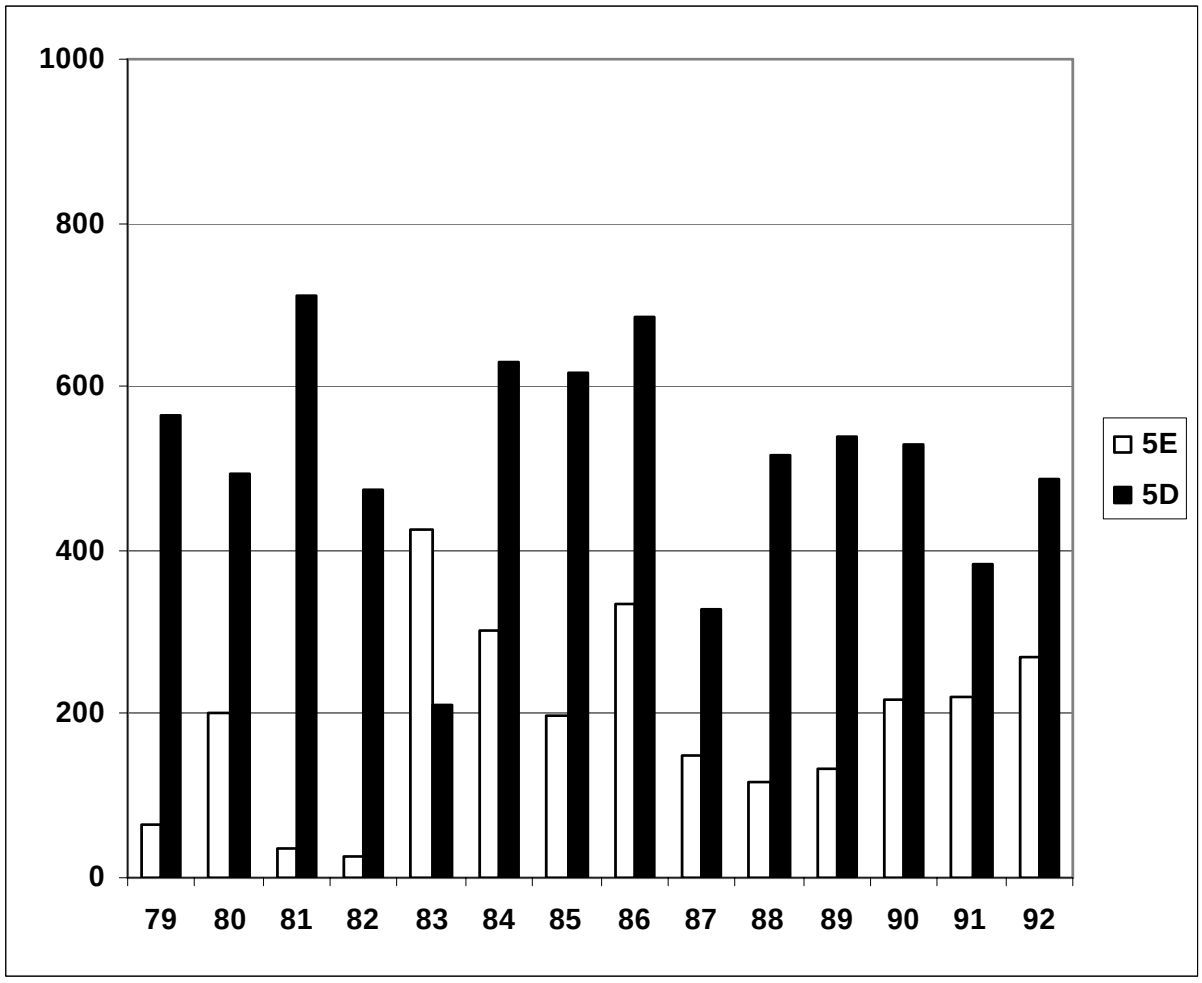

Fig. 3. Annual landings (t) of Dover sole from Areas 5D and 5E, 1979-92. (Source: Fargo *et al*. 1985, Table 13; This study, Table 7).

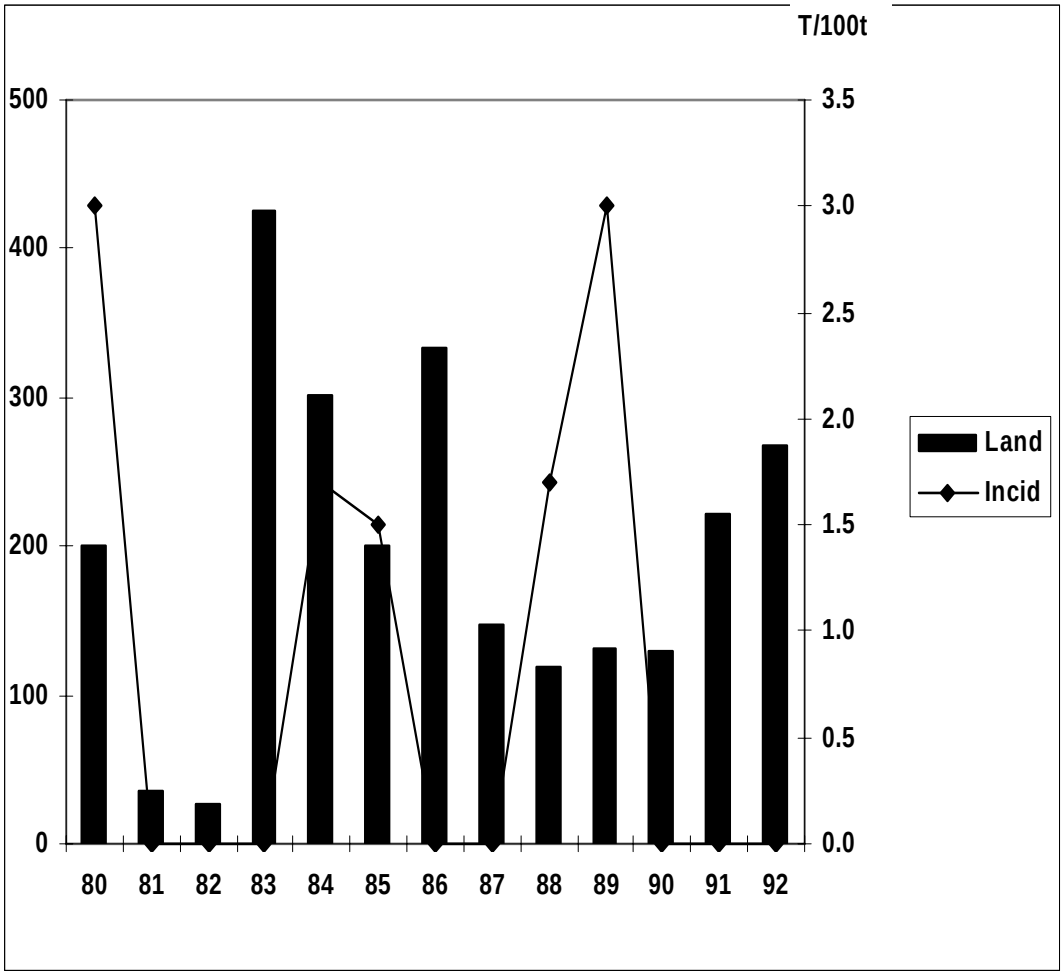

Figure 4a. Tag incidence (tags/100t) and landings (t) of Dover sole from Area 5E, 1980-92. (Source: Fargo *et al*. 1985, Table 17; This study, Table 8)

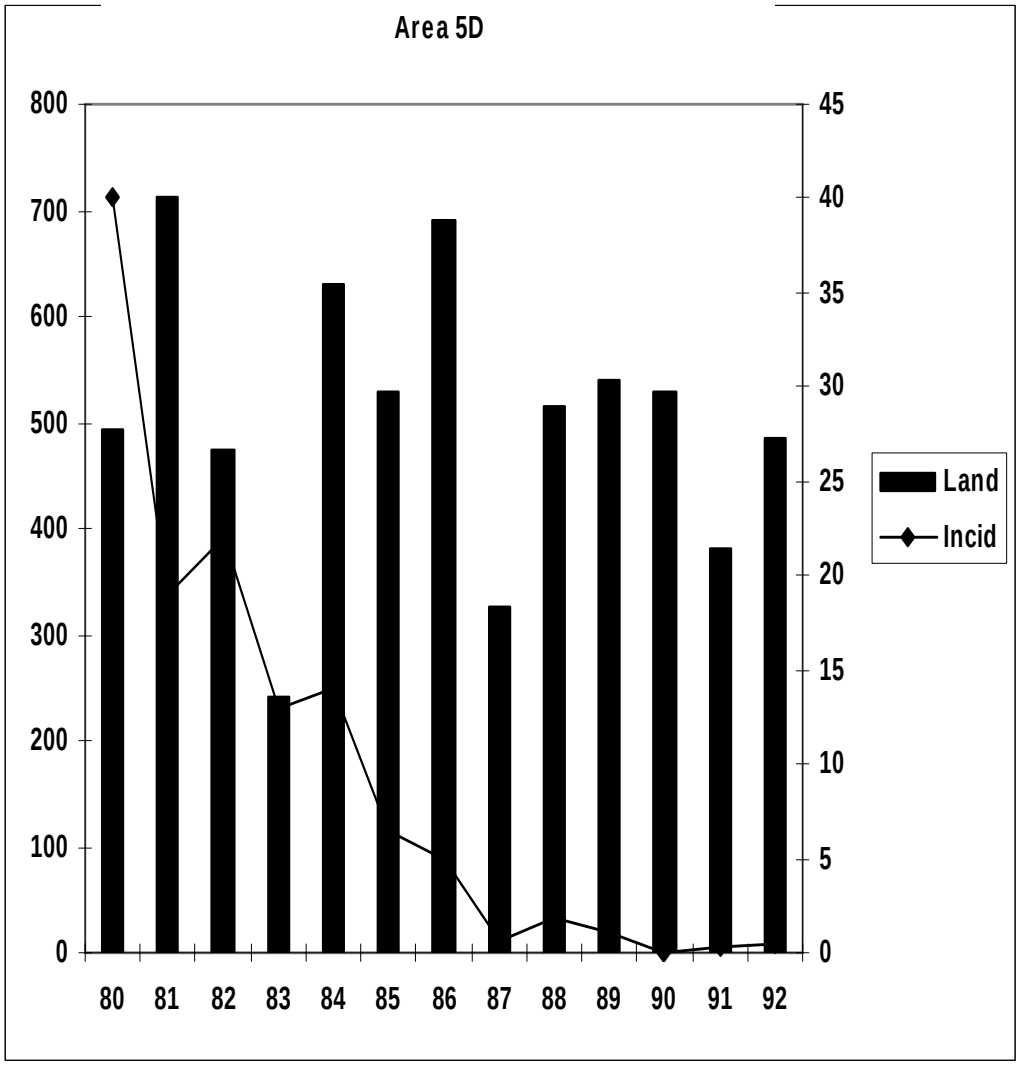

Figure 4b. Tag incidence (tags/100t) and landings (t) of Dover sole from Area 5D, 1980-92. (Source: Fargo *et al*. 1985, Table 17; This study, Table 8)

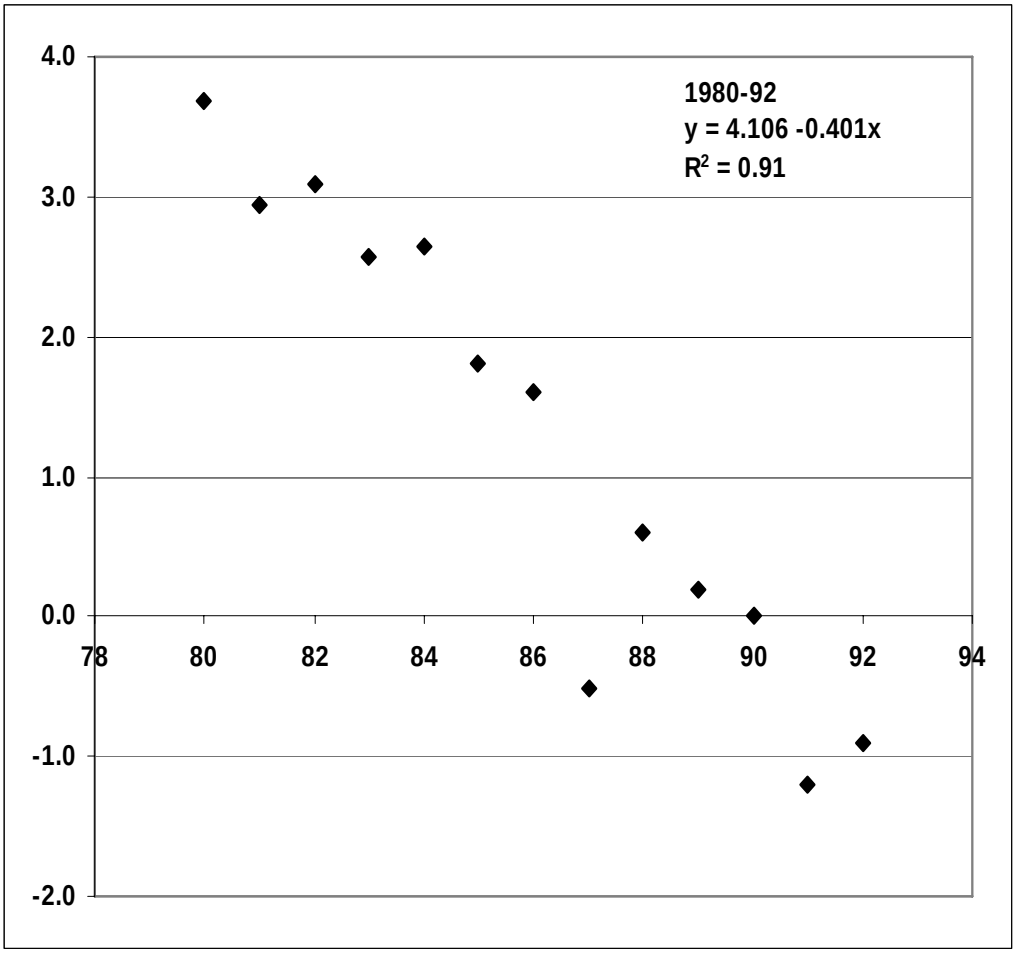

Figure 5. Regression of ln (tags/100 t) on year for tagged Dover sole recovered in Area 5D, 1980-92. (Source: Table 10)

Appendix table 1. Length-frequencies (nos.) of Dover sole tagged and released (T), and recovered (R), during 1979-84, and 1985-1999 by year, from the September 21-26, 1979, sub-experiments at Two Peaks and Dundas grounds, in Area 5D. (Source: Fargo et al.(1992, Table 2); PBS Groundfish files.)

FL	1979	1979-84		85	86	87	88	89	91	92	99	85-99	
(cm)	T	R	%R									Total	%R
				Two Peaks (Sep 21)									
28.5	...	...	...	...	...	...	...	...	...	...	...	...	...
30.5	3	0	0	...	...	...	...	...	...	...	...	...	...
32.5	9	0	0	...	...	...	...	...	...	...	...	...	...
34.5	22	1	4.5	...	...	...	...	...	...	...	...	...	...
36.5	61	5	8.2	...	...	...	...	...	...	...	...	...	...
38.5	39	9	23.1	...	...	...	...	...	...	...	...	...	...
40.5	34	4	11.8	...	...	...	...	...	...	...	...	...	...
42.5	30	7	23.3	1	0	0	0	0	0	0	0	1	0.3
44.5	31	5	16.1	0	0	0	0	0	0	0	0	0	0
46.5	32	4	12.5	0	1	0	0	0	0	0	0	1	0.3
48.5	36	7	19.4	2	0	0	0	0	0	0	0	2	0.6
50.5	36	9	25.0	0	0	0	0	0	0	0	0	0	0
52.5	25	3	12.0	1	0	0	1	0	0	0	0	2	0.6
54.5	15	2	13.3	0	0	0	0	0	0	0	0	0	0
56.5	21	4	19.0	1	0	0	0	0	0	0	0	1	0.3
58.5	18	9	50.0	...	...	...	...	...	...	...	...	...	...
60.5	4	0	0	...	...	...	...	...	...	...	...	...	...
62.5	2	1	50.0	...	...	...	...	...	...	...	...	...	...
64.5	2	0	0	...	...	...	...	...	...	...	...	...	...
66.5	...	...	...	...	...	...	...	...	...	...	...	...	...
68.5	...	...	...	...	...	...	...	...	...	...	...	...	...
Sub-total	420	70	16.7	5	1	0	1	0	0	0	0	7	2.0
Unknown	0	0		0	0	1	0	0	0	0	0	1	
Total	420	70		5	1	1	1	0	0	0	0	8	2.3

Appendix table 1 cont'd. Length-frequencies (nos.) of Dover sole tagged and released (T), and recovered (R), during 1979-84, and 1985-1999 by year, from the September 21-26, 1979, sub-experiments at Two Peaks and Dundas grounds, in Area 5D. (Source: Fargo et al. (1992, Table 2); PBS Groundfish files.)

FL	1979	1979-84		85	86	87	88	89	91	92	99	85-99	
(cm)	T	R	%R									total	%R
				Dundas (Sep 21-26)									
28.5	1	0	...	...	...	...	...	...	...	...	...	0	...
30.5	5	0	...	...	...	...	...	...	...	...	...	0	...
32.5	24	1	4.2	...	...	...	...	...	...	...	...	0	...
34.5	118	5	4.2	...	...	...	...	...	...	...	...	0	...
36.5	270	16	5.9	1	0	0	0	0	0	0	0	1	0.4
38.5	283	18	6.4	0	0	0	0	0	0	0	0	0	0
40.5	293	27	9.2	0	1	0	0	0	0	0	0	1	0.4
42.5	351	49	14.0	0	1	0	1	1	0	0	0	3	1.0
44.5	495	67	13.5	2	0	0	1	2	0	0	0	5	1.2
46.5	469	84	17.9	3	1	0	0	1	0	0	0	5	1.3
48.5	405	76	18.8	4	6	0	1	0	1	0	0	12	3.6
50.5	400	61	15.3	6	6	0	0	1	0	0	0	13	3.8
52.5	411	54	13.1	6	3	1	1	1	0	0	0	12	3.4
54.5	394	65	16.5	6	4	0	2	2	0	0	0	14	4.3
56.5	346	63	18.2	6	5	0	1	3		1	0	16	5.7
58.5	250	46	18.4	0	8	0	0	0	0	0	0	8	3.9
60.5	117	20	17.1	0	0	0	0	0	0	1	0	1	1.0
62.5	48	14	29.2	0	1	0	0	0	0	0	0	1	2.9
64.5	24	4	16.7	1	0	0	0	0	0	0	0	1	5.0
66.5	7	1	14.3	...	...	...	...	...	...	...	...	0	...
68.5	1	0	...	...	...	...	...	...	...	...	...	0	...
Sub-total	4712	671	14.2	35	36	1	7	11	1	2	0	93	2.3
Unknown	13	4	30.8	0	1	1	4	0	0	0	1	7	
Total	4725	675	14.3	35	37	2	11	11	1	2	1	100	2.5

Appendix table 2. Landings (t) of Dover sole, by area, quarter year, and year, 1985-92. (Source: PBS Groundfish files).

Area	Qtr	1985	1986	1987	1988	1989	1990	1991	1992	Total	
										(t)	%
4B	I	0.4	0	0.8	0.0	0.0	1.0	0	0.2	2.4	1.4
	II	12.7	3.4	1.8	2.5	1.3	5.5	3.8	6.5	37.5	21.1
	III	17.1	4.8	11.7	7.3	0.1	9.5	6.2	28.5	85.2	48.0
	IV	30.2	3.8	0.4	0.1	0.02	0.5	0.2	17.3	52.5	29.6
	T	60.4	12.0	14.7	9.9	1.4	16.5	10.2	52.5	177.6	100.0
										1.3	
3C	I	9.8	3.1	0	98.6	325.4	633.2	551.4	748.3	2369.8	49.8
	II	8.9	5.8	12.0	172.6	370.5	486.5	246.7	230.7	1533.7	32.2
	III	30.4	35.1	10.5	78.3	41.3	36.9	40.7	152.9	426.1	9.0
	IV	10.3	16.9	2.8	11.8	147.5	60.6	103.5	76.1	429.5	9.0
	T	59.4	60.9	25.3	361.3	884.7	1217.2	942.3	1208.0	4759.1	100.0
										35.6	
3D	I	1.9	1.4	0.0	42.1	210.0	91.2	168.5	144.3	659.4	38.1
	II	11.4	6.7	4.7	56.7	146.6	92.6	97.5	122.9	539.1	31.1
	III	1.3	7.6	5.5	13.8	19.7	27.6	35.1	43.5	154.1	8.9
	IV	1.2	0.3	2.4	30.0	47.9	57.6	157.4	81.7	378.5	21.9
	T	15.8	16.0	12.6	142.6	424.2	269.0	458.5	392.4	1731.1	100.0
										12.9	
5A	I	0.1	5.8	0.05	0.3	0.3	0	0.3	2.3	9.2	3.6
	II	0.7	11.3	13.2	6.9	9.2	7.6	5.6	15.0	69.5	27.3
	III	8.2	13.0	14.1	18.1	18.8	15.0	11.9	19.5	118.6	46.5
	IV	2.7	3.2	8.5	7.7	20.2	2.4	5.4	7.5	57.6	22.6
	T	11.7	33.3	35.9	33.0	48.5	25.0	23.2	44.3	254.9	100.0
										1.9	
5B	I	3.5	1.3	3.7	16.1	17.2	8.1	22.9	23.1	95.9	14.9
	II	5.3	9.7	13.6	29.5	24.0	25.7	41.8	69.2	218.8	34.0
	III	5.9	13.0	16.5	19.3	23.7	25.3	37.9	55.5	197.1	30.6
	IV	1.2	1.0	9.2	16.1	7.1	16.7	34.6	45.5	131.4	20.4
	T	15.9	25.0	43.0	81.0	72.0	75.8	137.2	193.3	643.2	100.0
										4.8	
5C	I	0.4	0.2	0	0.3	0.02	0.0	1.9	0.2	3.1	1.9
	II	3.3	8.5	2.8	4.7	2.2	10.5	1.5	8.0	41.5	25.2
	III	5.3	0	1.4	5.3	8.3	1.5	10.2	10.8	42.8	26.0
	IV	2.2	1.6	23.5	1.1	4.9	3.8	9.1	31.2	77.4	47.0
	T	11.2	10.3	27.7	11.4	15.4	15.8	22.7	50.2	164.8	100.0
										1.2	

Appendix table 2 cont'd. Landings (t) of Dover sole, by area, quarter year, and year, 1985-92. (Source: PBS Groundfish files)

Area	Qtr	1985	1986	1987	1988	1989	1990	1991	1992	Total	
										(t)	%
5D	I	0.1	1.7	0.0	0.9	0.5	0.2	0	0.4	3.8	0.1
	II	11.1	121.8	9.9	64.7	157.1	179.6	102.0	95.6	741.8	18.5
	III	450.5	447.8	215.1	326.2	321.8	322.7	204.7	324.5	2613.3	65.3
	IV	67.7	118.8	102.2	122.9	61.0	27.5	74.9	65.1	640.1	16.0
	T	529.4	690.1	327.2	514.7	540.4	530.0	381.6	485.6	3999.0	100.0
										29.9	
5E	I	85.8	192.9	59.0	64.0	40.9	92.8	58.5	47.3	641.2	39.1
	II	84.7	124.2	85.6	46.6	84.5	110.5	139.0	210.3	885.4	54.0
	III	24.6	6.7	0.8	0.7	0.9	5.2	5.0	4.4	48.3	2.9
	IV	4.4	9.4	2.2	6.6	6.0	10.8	18.7	5.9	64.0	3.9
	T	199.5	333.2	147.6	117.9	132.3	219.3	221.2	267.9	1638.9	100.0
										12.3	
Total		903.3	1180.8	634.0	1271.8	2118.9	2368.6	2196.9	2694.2	13368.6	100.0