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Predation of Scallops by American Plaice and Yellowtail Flounder

by

K. S. Naidu and S. Meron
Fisheries Research Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's, Newfoundland A1C 5X1

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Abstract

American plaice, Hippoglossoides platessoides prey on two scallop species on St. Pierre Bank, viz. sea scallop Placopecten magellanicus and Iceland scallop, Chlamys islandica, particularly the latter. Percent occurrence in stomachs of the two scallop species was 7.0% and 22.4% respectively. No preference is indicated or implied. Approximately 87% of scallops found in plaice stomachs (30-73 cm TL) were Iceland scallops ranging from 10-59 mm in shell height ($\bar{x}$ = 29.7 ± 11.2 mm). Sea scallops ranged from 12-55 mm ($\bar{x}$ = 28.8 ± 11.0 mm). Greater propensity to being bysally attached, combined with a relatively weaker escape response probably make Iceland scallops more vulnerable to fish predation. Up to 34 Iceland scallops were found in a single stomach of a 64 cm (TL) plaice. Maximum number of sea scallops in any one fish (69 cm) was only 19. Female plaice being significantly larger than males had a higher rate of predation (38% vs. 7.5% occurrence in stomachs).

Not surprisingly, yellowtail flounder, Limanda ferruginea with its much smaller mouth gape than plaice, were found to be insignificant predators of scallops. Only one sea scallop (12 mm) was found in a fish measuring 38.0 cm (TL).

Prey size frequencies from plaice stomachs suggest that sea scallops may be vulnerable to fish predation for up to 2.5 yr. The slower growing Iceland scallop, on the other hand, may be preyed upon for up to 5 yr. Yellowtail, by contrast, are at best confined to preying on young-of-the-year scallop spat.

Résumé

La plie canadienne (Hippoglossoides platessoides) qui vit dans les eaux du banc Saint-Pierre se nourrit de deux espèces de pétoncles, à savoir le pétoncle géant (Placopecten magellanicus) et le pétoncle d'Islande (Chlamys islandica), mais surtout de ce dernier. Des études ont révélé que la fréquence d'apparition de ces deux espèces de pétoncles dans l'estomac de la plie était respectivement de 7,0 % et de 22,4 %. Aucune préférence n'est indiquée ou supposée. Environ 87 % des pétoncles trouvés dans l'estomac des plies (30- 73 cm LT) étaient des pétoncles d'Islande dont la hauteur de la coquille variait de 10 à 59 mm ($\bar{x}$ = 29,7 ± 11,2 mm). Dans le cas du pétoncle géant, la hauteur était de 12-55 mm ($\bar{x}$ = 28,8 ± 11,0 mm). Une plus grande tendance à se fixer à l'aide de son byssus et une réaction de fuite plus faible expliquent probablement pourquoi le pétoncle d'Islande est plus vulnérable à la prédation des poissons. On a trouvé jusqu'à 34 pétoncles d'Islande dans l'estomac d'une plie de 64 cm (LT). Le nombre maximal de pétoncles géants dans l'estomac d'un même poisson (69 cm) n'a été que de 19. La taille des plies femelles étant nettement plus grande que celle des mâles, leur taux de prédation était plus élevé (38 % comparativement à 7,5 % d'après le contenu stomacal).

Comme on s'y attendait, la limande à queue jaune (Limanda ferruginea), dont l'ouverture buccale est plus petite que celle de la plie, s'est révélée un prédateur négligeable pour les pétoncles. Un seul pétoncle géant (12 mm) a été trouvé dans l'estomac d'un poisson mesurant 38,0 cm (LT).

La fréquence des tailles des proies dans l'estomac des plies donne à entendre que les pétoncles géants peuvent être vulnérables à la prédation des poissons pendant une période allant jusqu'à 2,5 années. Par contre, le pétoncle d'Islande, dont la croissance est plus lente, peut être vulnérable pendant une période allant jusqu'à 5 années. Contrairement à celle de la plie, l'activité prédatrice de la limande se limite, au mieux, au naissain de pétoncles (jeunes de l'année).

Introduction

Two of the more common demersal finfish species occurring in scallop beds on St. Pierre Bank (NAFO Div. 3P), sometimes incidentally taken in scallop rakes, are the American plaice, Hippoglossoides platessoides, and yellowtail flounder, Limanda ferruginea. While food and feeding in these cohabiting pleuronectids have been investigated in the Newfoundland region (Yanulov 1962; Pitt 1973, 1976; Minet 1973), no published information is available on the specifics of predation on scallops. Minet (1973) noted that molluscs were the second-most important food group for plaice from St. Pierre Bank and Cape Breton shelf. Among the Filibranchia, the Iceland scallop, Chlamys islandica was reported to be the most frequent. Surprisingly, it was not reported in plaice from the Grand Banks (Pitt 1973). Food of eight Northwest Atlantic pleuronectiform species was also investigated by Langton and Bowman (1981). They, too, found Iceland scallops in the American plaice but gave no details on prey size distributions. Predation of sea scallops, Placopecten magellanicus, by yellowtail flounder and American plaice has not previously been reported, even if anecdotal accounts, particularly of predation by plaice, abound. This study characterizes the nature and magnitude of fish predation on sea and Iceland scallops on St. Pierre Bank. Such information may lead to a better understanding of the dynamics of scallop populations in this area as well as other areas where scallops and plaice co-occur.

Materials and Methods

Resource surveys are conducted annually on St. Pierre Bank (Fig. 1) to assess the state of scallop stocks and to provide scientific advice on their management. The material used in this study was collected during these surveys in September 1984, April 1985 and September 1985 on the research vessel GADUS ATLANTICA. Stomachs of fish (plaice and yellowtail, Fig. 2) incidentally taken in scallop dredges were examined either fresh onboard the vessel or subsamples brought back to the laboratory in full-strength ethyl alcohol for later examination. Total length and sex were recorded for each fish sampled. Stage of repletion (full, half full, and empty) was noted. All scallops were retrieved from the digestive tract, separated by species (Fig. 3) and individuals measured to the nearest tenth of a millimeter with a pair of vernier calipers. No attempt was made to identify in detail other organisms contained in the stomachs; rather only principal prey components were enumerated. Laboratory examination of 144 plaice stomachs also allowed whole wet weight determinations of the various prey groups encountered. Percent occurrence by predator and prey size groups was calculated separately for each year and for the two years combined using total numbers of fish examined. In all 431 American plaice and 708 yellowtail flounder were examined.

In situ pH measurements of gastric fluids in plaice stomachs were made using a portable pH meter (type PHM 296) with a glass-calomel electrode. Sea bottom temperatures were determined using expendable bathythermographs (XBTs).

Standard statistical methods, were used to test differences between proportions (Chi-square distributions) and to determine if sample correlation coefficients were significant (Student's t distributions).

Results

Numbers of each fish species examined in 1984 and 1985 and percent occurrence of the two scallop species in each of those years are summarized (Table 1). Predation of scallops by yellowtail was insignificant (incidence of less than 1.0%) with only one 12 mm sea scallop being found. No further analyses were therefore carried out on predation of scallops by yellowtail. Plaice, on the other hand, were commonly found to be feeding on both scallop species during the fall. Considering only the September data, percent size composition of fish examined and mean size of prey per fish length group in each of 1984 and 1985 (Fig. 4) indicate that fish of all size groups sampled, particularly those exceeding 40 cm, readily prey on both scallop species. Scallops were conspicuous by their absence in both yellowtail and plaice in April 1985. A full 22.9% and 21.9% of plaice respectively examined in September 1984 and September 1985 were found to contain Iceland scallops. Incidence of sea scallops for the two corresponding years was 4.7% and 9.4%, respectively.

Examination of numbers and sizes of each scallop species as a function of fish length indicated that larger fish consumed greater numbers and a broader size range of prey (Tables 2 and 3). For the two years combined, number of scallops per fish (with scallops) was positively correlated to fish size (Fig. 5). A plot of the mean numbers of each scallop species versus fish length yielded the following regressions:

$$Y = 0.10x - 2.29 \quad \text{(sea scallops; } r^2 = 0.22,\ p < 0.05\text{)}$$
$$Y = 0.17x - 3.55 \quad \text{(Iceland scallops; } r^2 = 0.38;\ p < 0.05\text{)}$$

Up to 34 Iceland scallops were found in a single stomach of a 64 cm plaice. Maximum number of sea scallops in any one fish (69 cm) was only 19.

Prey size for each species was plotted against fish length for all specimens collected during the two-year study (Fig. 6); this resulted in the following straight-line regressions:

$$Y = 0.2x + 14.2 \quad \text{(sea scallops; } r^2 = 0.03;\ p > 0.05\text{)}$$
$$Y = 0.5x - 1.8 \quad \text{(Iceland scallops; } r^2 = 0.14;\ p < 0.05\text{)}$$

For the two years combined the correlation coefficient was significant ($p < 0.05$) for Iceland scallops, indicating that size of prey taken may be a function of fish size. There was no discernable correlation for sea scallops ($p > 0.05$).

Size composition of the two scallop species in the survey area is summarized in Table 4. Whereas numbers of sea scallops below 40 mm decreased between September 1984 and September 1985 (11.2% vs 0.8%), there was a concommittant increase in the numbers of comparable-sized Iceland scallops (2.1% to 3.4%). Percent occurrence of sea scallops in plaice stomachs, however, increased to 9.4 in 1985 from 4.7 in 1984. Incidence of Iceland scallops remained unchanged during the same period (22.9 vs 21.9 mm in 1984 and 1985 respectively). Mean sizes of sea and Iceland scallops in each of 1984 and

1985 were similar ($p<0.001$) with overall means respectively at 28.8 ± 11.0 mm and 29.7 ± 11.2 mm (Table 5). This suggests factors other than availability may become limiting. Whereas 59% of Iceland scallops recovered from plaice stomachs were equal to or below the observed mean, a full 67% of sea scallops fell short of the overall mean.

Ratio of male to female plaice departed significantly from a 50:50 distribution (x^2 = 133.6; $p < 0.001$). Overall, number of females was two-and-one-half times greater than males. There was a highly significant difference ($p < 0.001$) in the size (total length) of male and female plaice (Table 6), with females on the average being larger. Percent incidence of scallops in females was correspondingly higher (37.7% vs 7.5%). The largest Iceland scallop (59.3 mm) came from a female plaice measuring 69 cm and the largest sea scallop (55.0 mm) also came from a female (65 cm).

Proportions (by numbers) of the two scallop species from any one stomach were highly variable. Of the 74 plaice that had fed on scallops, 51 (68.9%) contained only Iceland scallops. The remaining 23 (31.1%) contained a mixture of both species that ranged from 50 to 88% for Icelandics. Eighty five percent and 90% of scallops from plaice stomachs in each of 1984 and 1985 were of the Iceland variety. Corresponding sea scallop percentages were 15 and 10% (Table 5).

Percent contributions by numbers and weights of principal prey groups (Table 7 and 8) showed that scallops were significant in the diet of plaice. While they were found in some 27.1% (74 out of 274) of the stomachs with food, they contributed up to 55% of the total wet weight of stomach contents. Echinoids (sand dollars and sea urchins) were also frequently encountered. Brittle stars were by far the singlemost important prey group for yellowtail. Suffice to note here that the incidence of brittle stars was much higher than previously reported (e.g. Pitt 1976).

Both acid (24 out of 37) and alkaline (13 out of 37) secretions were found in plaice stomachs (Table 9) with pH values widely ranging from 2.0 to 8.3 ($\bar{x}$ = 6.3 ± 1.8). A comparison of mean pH values among feeding (6.6 ± 1.6) and nonfeeding fish (5.0 ± 1.9) indicated a significant difference ($p < 0.05$) between the two groups, with higher gastric acidity prevailing in nonfeeding fish.

Bottom temperatures varied from a low of -1.06°C in April 1985 to 4.5°C in September 1985 (Table 10). Subzero temperatures were encountered throughout the study area in April 1985. Temperatures for April 1986 were also below zero but higher than the lows recorded for 1985.

Discussion

As has been pointed out already, this study was conducted merely to examine predation of scallops by two common demersal finfish species cohabiting scallop grounds, rather than to repeat the detailed food and feeding studies that have already been carried out (Pitt 1973, 1976; Minet 1973; and Langton and Bowman 1981). It is recognized that in any food and feeding study, it is essential to abruptly stop enzymatic activity within stomachs by quick and thorough fixation. A 5-10% solution of formaldehyde is generally employed. Some digestive action may have continued in the alcohol-preserved stomachs used in this study. This is not considered to be a serious drawback, however, since the primary objective was only to examine the presence of scallops. Even if some enzymatic action had continued, it would not have been sufficient to completely dissolve scallop shells.

Gastric acidity (pH) in plaice has been variously estimated at between 3.85 and 6.45 (e.g. Bayliss 1935). We found pH values below and above this range (2.0-8.3). Our findings contrast with those reported by Bayliss (1935) in that we found pH values to be significantly lower in nonfeeding fish than in those that had been feeding. We are unable to account for the disparate results. Meal size, type of food, state of digestion and residence time of food may each and/or collectively play a role in buffering pH activity. Of significance here is the absence in stomachs of shell fragments. Gastric acidity in plaice does not appear to impair or undermine the chemical integrity of scallop shells. This is in contrast to the porous skeletal structures of sand dollars and sea urchins. The observation that cluckers were found intact in the intestine suggests that plaice egest scallop shells after the soft parts have been digested.

It is apparent that American plaice prey on both sea and Iceland scallops, particularly the latter. No preference is indicated or implied. Plaice appear to be opportunistic feeders. Relative abundance of prey species, including their temporal and spatial variability in size, in relation to the distribution of predators may explain the higher incidence of Iceland scallops. A more likely explanation is the better escape response exhibited by juvenile sea scallops. Morton (1980) considered this species to be amongst the best swimmers in the Family Pectinidae. Iceland scallops appear to be relatively more sedentary and frequently attached to bottom substrates. In laboratory studies, 76% (155 of 205) of Iceland scallops (43-93 mm shell height) were bysally attached, whereas only 7% (8 of 88) of juvenile sea scallops (59-70 mm) were similarly attached under identical conditions (K. S. Naidu, unpublished data). This propensity to being anchored to substrates must render them more vulnerable to predation than sea scallops.

That plaice were found to be feeding on scallops is not altogether surprising. They are well adapted to feeding on bottom-living prey (Van Dobben 1937). Fluchter (1963) examined the functional morphology of the jaw apparatus of plaice and concluded that it was adapted to small food items, especially burrowed molluscs. Both yellowtail flounder and American plaice have terminal open mouths with extensible gapes. Morris (1981) reported a 73% and 141% increase in gape respectively in yellowtail and American plaice. Among the latter, in fish ranging from 10-60 cm (TL), he found gapes varying from 9.0 to 37.7 mm, with a mean at 22.2 mm. Typically, yellowtail had smaller mouth gapes ranging from 10.3 to 20.0 mm with a mean at 14.7 mm. He concluded that flexible, protrusor movement of mouth structures was adapted to the type of bottom prey normally taken. While his measurements indicate that morphologically yellowtail are capable of feeding on only very small scallops, plaice possess the necessary structural adaptations allowing it to capture much larger scallops as is evident in this study. Prey sizes encountered in this study would suggest mouth gapes well in excess of those reported by Morris (1981). In a more recent (May 1986) communication to one of us (K.S.N.), Morris suggests maximum size of prey for a 62 cm (TL) fish to be of the order of 44 mm. Our study showed that some 14% of Iceland scallops and 17% of sea scallops exceeded this critical size for all fish sizes examined. Inspite of changes in availability of the two prey species, mean sizes of scallops in plaice stomachs in 1984 and 1985 were similar, suggestive of size-selective predation, primarily as a result of gape limitation. Small sea scallops were unavailable during the second year as a result of negligible settlement. This may explain the apparent absence of size-specific predation of sea scallops by plaice in the present study.

Our study corroborates the findings by Minet (1973) who concluded that on St. Pierre Bank, Iceland scallops were commonly included in the diet of plaice. The findings reported here contrast with those of Pitt (1973, 1976) who found no evidence of scallops (both species) in the stomachs of either plaice or yellowtail. He based his observations on samples drawn from the Grand Bank of Newfoundland, an area where only Iceland scallops occur (Anon. 1985). Neither Minet (1973) nor Pitt (1973, 1976) recorded the presence in plaice stomachs of sea scallops. The mollusc is found in commercial quantities on St. Pierre Bank but absent from Grand Bank. St. Pierre Bank has been characterized as an area where sea scallop recruitment is irregular (Naidu and Anderson 1984). Obviously both predator and prey species of suitable size must occur over the same space and time for the interaction described here. This combination of circumstances may not have been present when Minet (1973) investigated food and feeding in plaice on St. Pierre Bank. This would account for the reported absence in fish of sea scallops. The absence of Iceland scallops in Pitt's (1973) study, on the other hand, is somewhat more difficult to explain. More recent observations from unrelated exploratory surveys on the Grand Banks show plaice to frequently prey on Iceland scallops (K. S. Naidu, unpublished data).

Scallops were not found in the 101 plaice sampled in April 1985 supporting seasonality in feeding previously reported for this species (Pitt 1973; Minet 1973). During the 1986 spring survey (K. S. Naidu, unpublished data) plaice were again feeding when bottom temperatures ranged narrowly between -0.20°C and -0.24°C suggesting cessation of feeding occurs between -0.24°C and -0.54°C.

What is noteworthy, is the frequency of predation as well as the broad size range of prey (scallops) taken. Female plaice, being larger, are more likely to include scallops in their diet and accounted for most of the predation. Size frequencies of sea scallops retrieved from plaice stomachs suggest that juveniles up to 2.5 years may be vulnerable to predation (Naidu et al. 1983). Similarly the slower growing Iceland scallop (Naidu et al. 1983) may be preyed upon for up to 5 years. By contrast, yellowtail are at best confined to preying on young-of-the-year seed scallops (spat). This would suggest that success of recruitment on St. Pierre Bank, particularly from weak pulses of larval settlement, may in part be affected by the intensity and extent of fish predation on young scallops.

Plaice-scallop interactions clearly play an important role in the dynamics of scallop populations on St. Pierre Bank and probably in other areas with overlapping predator-prey distributions. The reported occurrence of pockets of juvenile sea scallop cluckers, such as those found on Browns Bank (G. Robert, Department of Fisheries and Oceans, Halifax, pers. comm.) may be related to fish (plaice) predation. Plaice is the singlemost important pleuronectid species on the Scotian Shelf. While starfish (Asteras sp.) and whelks (Buccinum sp.) may also prey upon scallops (K. S. Naidu, unpublished data), they are not considered to be significant predators, particularly of sea scallops. The presence of disproportionately large numbers of cluckers relative to live scallops at fully recruited sizes (>80 mm), on the other hand, must be attributed to other factors, including indirect fishing mortality (Naidu et al. 1982).

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Table 1. Percent occurrence of sea and Iceland scallops in yellowtail and American plaice stomachs from St. Pierre Bank.

Date	Species	No. fish examined	No. with scallops (%)	
			Sea	Icelandic
Sept. '84	Yellowtail	269	-	-
Sept. '84	American plaice	170	8 (4.7)	39 (22.9)
Apr. '85	Yellowtail	74	-	-
Apr. '85	American plaice	101	-	-
Sept. '85	Yellowtail	365	1 (<1.0)	-
Sept. '85	American plaice	160	15 (9.4)	35 (21.9)
Totals:	Yellowtail	708	1 (<1.0)	-
	American plaice	431	23 (5.3)	74 (17.2)

Table 2. Size-specific incidence of sea scallops in American plaice from St. Pierre Bank.

Fish length (cm)	No. fish examined			No. with scallops			Mean no. scallop/fish with scallops			Mean shell height ± 1 S.D.			Percent occurrence		
	1984	1985	Combined	1984	1985	Combined	1984	1985	Combined	1984	1985	Combined	1984	1985	Combined
30-33	1	2	3	0	1	1	-	1.0	1.0	-	14.0	14.0	0	50.0	33.3
34-37	8	6	14	0	0	0	-	-	-	-	-	-	0	0	0
38-41	10	17	27	1	0	1	1.0	-	1.0	18.0	-	18.0	10.0	0	3.7
42-45	17	22	39	0	0	0	-	-	-	-	-	-	0	0	0
46-49	25	35	60	0	1	1	-	5.0	5.0	-	25.0± 1.2	25.0± 1.2	0	2.9	1.7
50-53	34	19	53	0	1	1	-	2.0	2.0	-	42.8± 3.9	42.8± 3.9	0	5.3	1.9
54-57	21	22	43	1	2	3	5.0	1.5	2.7	20.2± 6.1	24.0± 3.6	21.6± 5.4	4.8	9.1	7.0
58-61	20	10	30	2	2	4	2.0	2.0	2.0	27.1± 8.5	37.4±10.0	32.2±10.2	10.0	20.0	13.3
62-65	21	20	41	1	7	8	9.0	1.3	2.1	18.1± 5.0	44.8± 7.4	30.6±15.0	4.8	35.0	19.5
66-69	10	4	14	2	1	3	11.5	1.0	8.0	25.5± 4.0	46.0	26.4± 5.7	20.0	25.0	21.4
70-73	3	3	6	1	0	1	3.0	-	3.0	44.0±13.6	-	44.0±13.6	33.3	0	16.7
Totals	170	160	330	8	15	23				24.6± 8.2	36.0±11.7	28.8±11.0	4.7	9.4	7.0

Table 3. Size-specific incidence of Iceland scallops in American plaice from St. Pierre Bank.

Fish length (cm)	No. fish examined			No. with scallops			Mean no. scallop/fish with scallops			Mean shell height ± 1 S.D.			Percent occurrence		
	1984	1985	Combined	1984	1985	Combined	1984	1985	Combined	1984	1985	Combined	1984	1985	Combined
30-33	1	2	3	0	1	1	-	1.0	1.0	-	25.0	25.0	0	50.0	33.3
34-37	8	6	14	0	0	0	-	-	-	-	-	-	0	0	0
38-41	10	17	27	2	0	2	3.0	-	3.0	22.4± 4.1	-	22.4± 4.1	20.0	0	7.4
42-45	17	22	39	3	2	5	4.3	3.0	3.8	18.0± 3.6	16.5± 3.1	17.4± 3.3	17.7	9.1	12.8
46-49	25	35	60	4	4	8	3.8	4.5	4.1	25.5±11.0	24.3± 4.8	24.7± 7.4	16.0	11.4	13.3
50-53	34	19	53	11	2	13	5.6	3.5	5.2	23.8± 9.2	27.8±10.6	24.2± 9.3	32.4	10.5	24.5
54-57	21	22	43	5	5	10	11.6	6.0	9.7	23.5± 7.6	29.2± 9.0	25.8± 8.6	23.8	22.7	23.3
58-61	20	10	30	5	3	8	3.4	8.7	5.4	28.1±10.4	31.2± 6.9	30.0± 8.5	25.0	30.0	26.7
62-65	21	20	41	3	13	16	5.0	7.0	6.6	27.0±11.3	41.1± 7.1	39.1± 9.2	14.3	65.0	39.0
66-69	10	4	14	4	4	8	18.0	4.8	1.1	25.2± 8.7	45.4± 5.4	29.6±11.6	40.0	100.0	57.1
70-73	3	3	6	2	1	3	4.0	9.0	5.7	31.1± 14.0	43.6± 7.1	37.72±12.3	66.7	33.3	50.0
Totals	170	160	330	39	35	74				24.7± 9.1	35.6±10.4	29.7±11.2	22.9	21.9	22.4

Table 4. Size composition of sea and Iceland scallops on St. Pierre Bank (1984-85).

Shell height (mm)	Sea scallops Sept. 1984	Sea scallops April 1985	Sea scallops Sept. 1985	Iceland scallops Sept. 1984	Iceland scallops April 1985	Iceland scallops Sept. 1985
5-9	-	-	-	17	7	0
10-14	-	-	4	28	17	1
15-19	8	3	-	28	41	7
20-24	31	1	17	48	44	48
25-29	180	6	40	101	56	83
30-34	531	29	53	127	152	116
35-39	637	172	82	89	392	237
40-44	317	482	354	145	733	926
45-49	39	751	1245	251	995	2211
50-54	18	461	3525	369	2010	1629
55-59	28	104	4475	589	3765	522
60-64	20	30	2515	1401	6152	423
65-69	6	79	463	2948	8289	784
70-74	21	70	136	4049	9159	1442
75-79	79	65	138	3905	9314	1785
>80	10441	2265	11306	6363	14250	4410
ΣN	12356	4518	24353	20458	55376	14624

Table 5. Prey (scallop) size distributions, means and percent above and below means.

Size group (mm)	Sea scallop			Iceland scallop		
	1984	1985	Combined	1984	1985	Combined
10-14	5	1	6	15	3	18
15-19	7	0	7	59	15	74
20-24	12	3	15	91	21	112
25-29	13	6	19	32	30	62
30-34	5	1	6	18	18	36
35-39	1	3	4	19	31	50
40-44	0	1	1	8	47	55
45-49	0	7	7	6	41	47
50-54	2	2	4	3	8	11
55-59	0	1	1	2	2	4
Totals	45	25	70	253	216	469
Mean ± S.D.	24.6±8.2	36.0±11.7	28.8±11.0	24.7±9.1	35.6±10.4	29.7±11.2
Percent $\leq\bar{x}$	53.3	52.0	67.1	69.6	63.4	57.8
Percent $\geq\bar{x}$	46.7	48.0	32.9	30.4	36.6	42.2

Table 6. Percent incidence of sea and Iceland scallops as a function of sex of plaice.

	Total no. fish	Males ($\bar{x}$ length ± S.D.)	Females ($\bar{x}$ length ± S.D.)	Percent incidence in males			Percent incidence in females		
				Sea	Iceland	Combined	Sea	Iceland	Combined
99 (Sept. '84)	170	50 (48.9±6.2)	120 (54.5±9.2)	2.0	6.0	8.0	5.8	30.0	35.0
114 (Sept. '85)	160	43 (45.1±5.9)	117 (52.9±8.6)	2.3	4.7	7.0	12.0	28.2	40.2
Totals	330	93 (47.1±6.4)	237 (53.5±9.1)	2.2	5.4	7.5	8.9	29.1	38.0

Table 7. Percent contributions by numbers of principal prey groups in plaice and yellowtail stomachs (A = all stomachs and (B) excluding empty stomachs).

Year	Species	No. of fish examined	Sea scallops	Iceland scallops	Brittle stars	Sea urchins	Sand dollars	Sea cucumbers	Polychaeta	Pagurus	Fish[a]	Gammarid	Unident.	Empty
A. All stomachs:														
1984	Plaice	170	4.7	22.9	5.3	8.2	0.6	-	0.6	0.6	-	-	2.9	17.7
1984	Yellowtail	269	-	-	8.9	-	-	-	1.9	-	-	0.4	17.5	14.9
1985	Plaice	160	9.4	21.9	20.6	13.1	1.9	-	-	3.1	0.6	-	-	16.3
1985	Yellowtail	365	0.3	-	2.7	-	-	0.8	1.1	-	2.2	0.8	3.8	21.4
B. Excluding empty stomachs:														
1984	Plaice	140	5.7	27.9	6.4	10.0	0.7	-	0.7	0.7	-	-	3.6	
1984	Yellowtail	229	-	-	10.5	-	-	-	2.2	-	-	0.4	20.5	
1985	Plaice	134	11.2	26.1	24.6	15.7	2.2	-	-	3.7	0.8	-	-	
1985	Yellowtail	287	0.4	-	3.5	-	-	1.1	1.4	-	2.8	1.1	4.9	

[a]Includes sand launce, capelin and others.

Table 8. Percent contributions by weight of principal prey groups in plaice and yellowtail stomachs.

Year	Species	No. of fish examined	Sea scallops	Iceland scallops	Brittle stars	Sea urchins	Sand dollars	Sea cucumbers	Polychaeta	Pagurus	Fish[a]	Gammarid	Unident.
1984	Plaice	44	13.3	65.3	6.4	13.9	0.5	-	-	0.6	-	-	-
1984	Yellowtail	43	-	-	83.5	-	-	-	3.5	-	-	-	2.9
1985	Plaice	100	5.4	40.9	17.1	20.3	13.3	-	-	3.0	-	-	-
1985	Yellowtail	85	-	-	63.7	-	-	8.9	2.7	-	5.4	1.2	1.2

[a]Includes sand launce, capelin and others.

Table 9. Gastric acidity in American plaice.

Fish length (cm)	pH		
	Feeding	Non-feeding	Mean
38-39	4.5	-	4.5
40-41	2.5	-	2.5
42-43	8.3	-	8.3
44-45	6.9	3.5, 3.5	4.6
46-47	8.1	-	8.1
48-49	6.4	-	6.4
50-51	8.0	7.4	7.7
52-53	6.1	2.0	4.1
54-55	8.2, 7.9	-	8.1
56-57	7.8, 7.9	6.7, 5.4	7.0
58-59	4.1	5.6	4.9
60-61	6.8, 8.2, 6.3	-	7.1
62-63	5.7, 8.3	-	7.0
64-65	2.8, 6.7, 7.7	6.3	5.9
66-67	6.7	-	6.7
68-69	7.3, 6.6, 6.7	-	6.9
70-71	6.9, 7.5	-	7.2
72-73	3.5, 6.7	-	5.1
$\bar{x} \pm$ S.D.	6.58 ± 1.64	5.04 ± 1.87	6.25 ± 1.78
N	29	8	37

Table 10. Bottom temperatures on St. Pierre Bank.

Date	Location	Depth (m)	Temp (°C)
Sept. 18, 1984	46°16.4'N; 56°56.1'W	42	3.50
Sept. 25, 1984	45°32.6'N; 56°07.4'W	48	2.80
Apr. 8, 1985	46°42.0'N; 57°03.3'W	69	-1.06
Apr. 9, 1985	46°43.8'N; 57°06.3'W	61	-0.91
Apr. 10, 1985	46°41.9'N; 57°16.6'W	66	-0.85
Apr. 13, 1985	45°36.2'N; 55°59.5'W	46	-0.54
Apr. 15, 1985	45°39.7'N; 56°07.7'W	47	-0.57
Sept. 18, 1985	46°39.0'N; 56°40.8'W	62	2.0
Sept. 18, 1985	46°36.3'N; 56°36.4'W	52	4.5
Sept. 18, 1985	46°33.8'N; 56°43.1'W	51	3.8
Apr. 4, 1986	45°41.3 N; 56°03.7'W	47	-0.20
Apr. 6, 1986	45°38.9'N; 55°45.0'W	43	-0.24

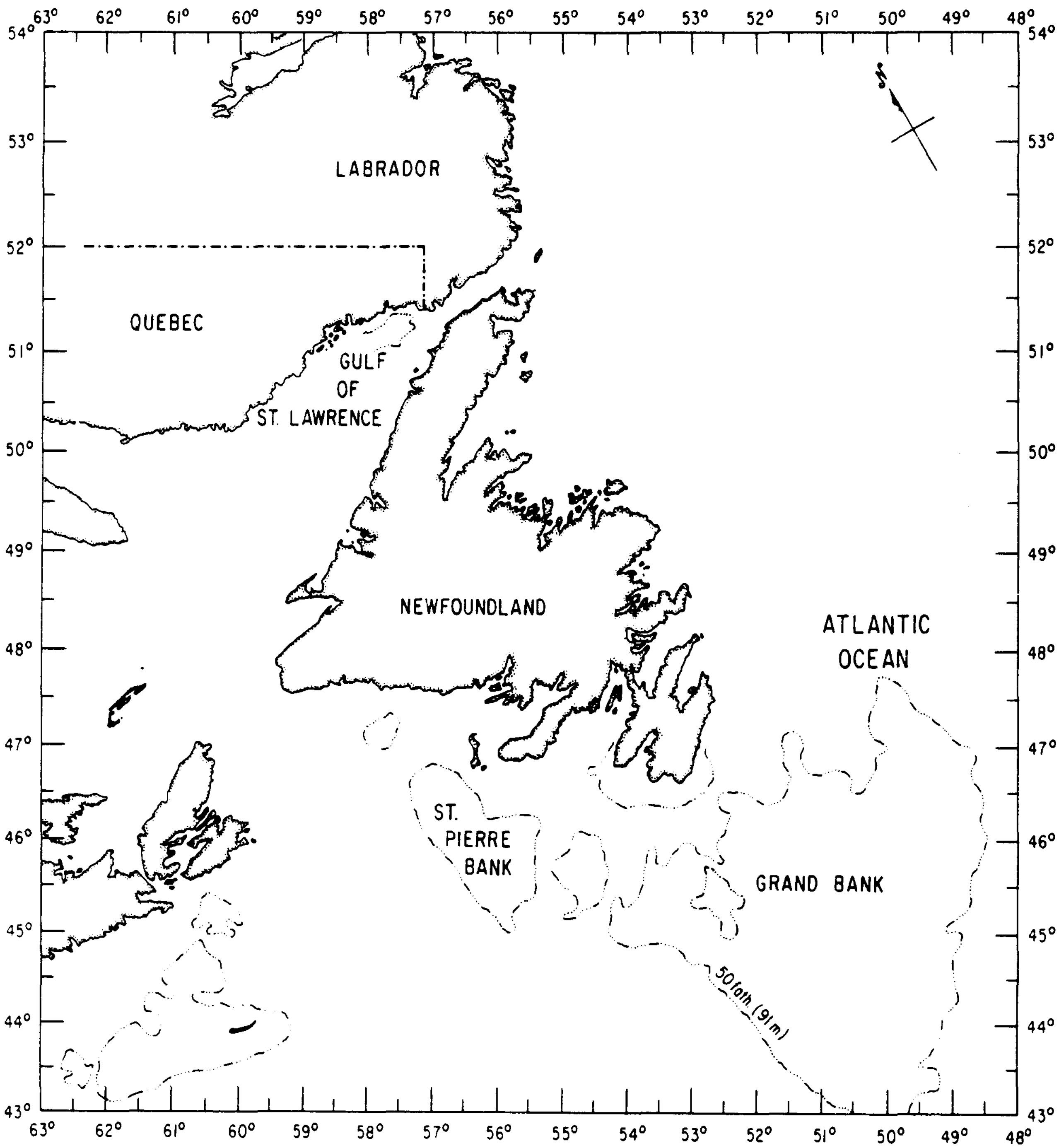

Fig. 1. Locational map showing study area and place names mentioned in the text.

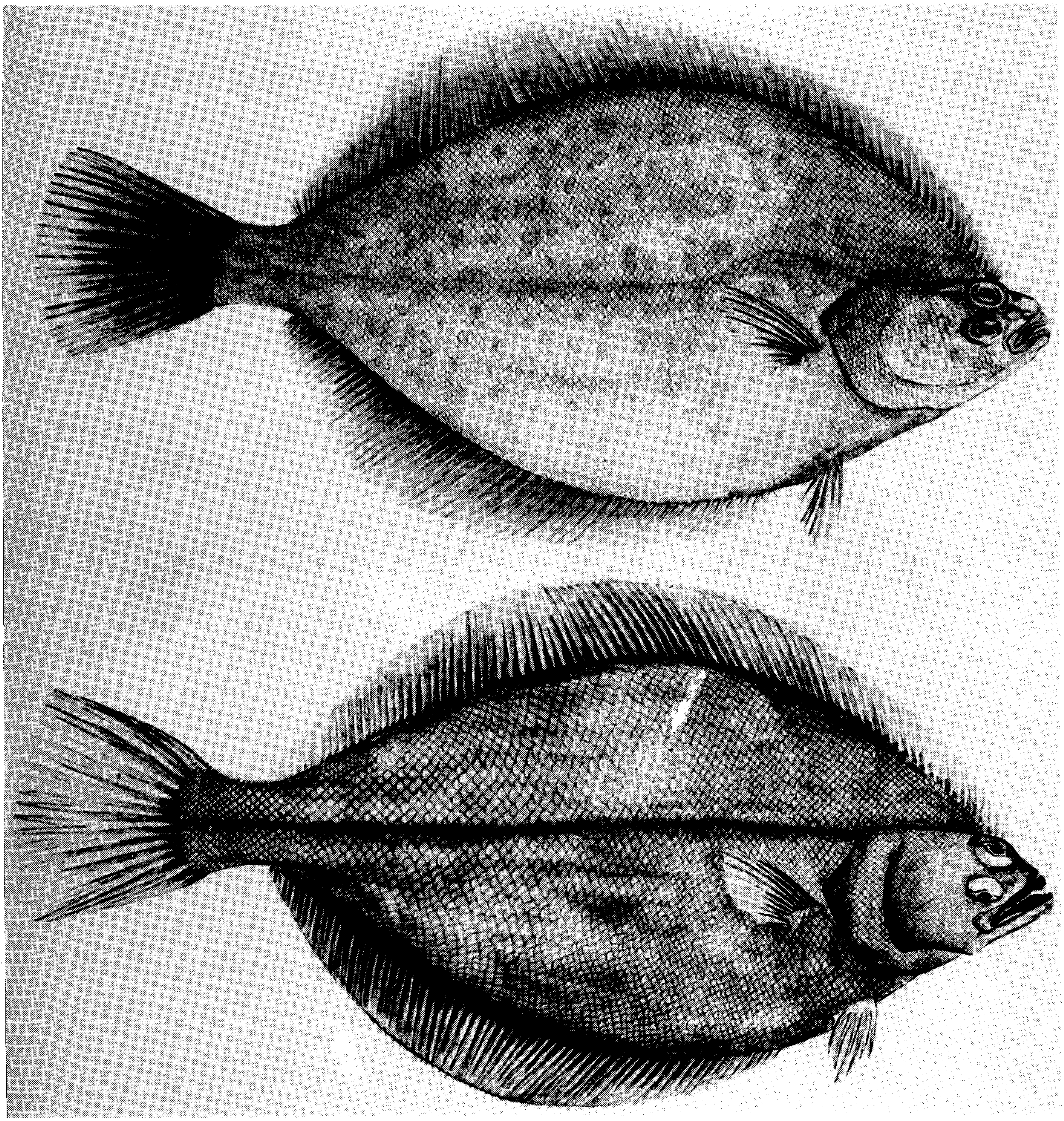

Fig. 2. Predators: Yellowtail flounder (top) and American plaice (from Canadian Fish Products, Atlantic Region, Department of Fisheries and Oceans, Ottawa).

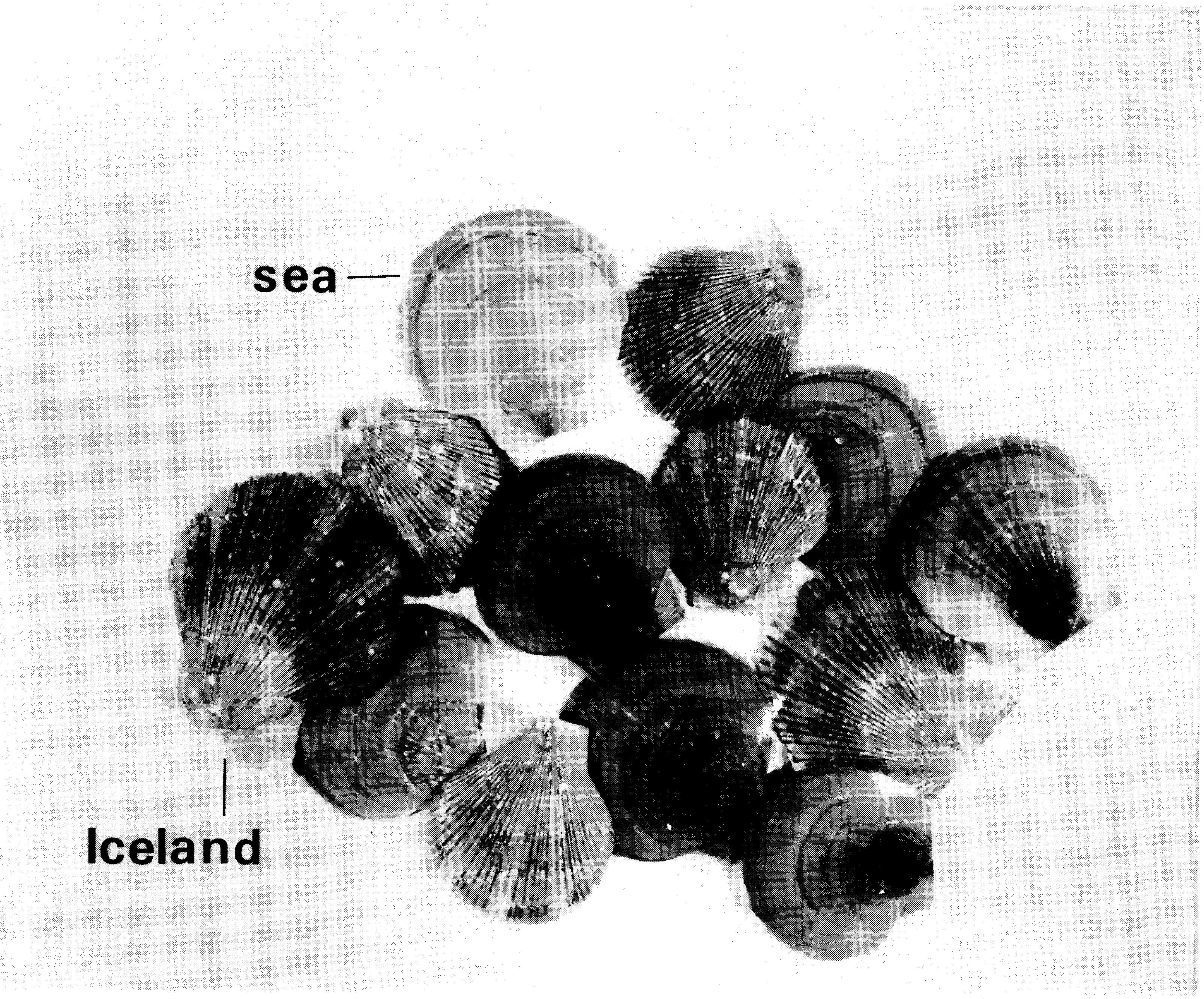

Fig. 3. Prey: sea and Iceland scallop. Largest scallop (Iceland) is 57 mm.

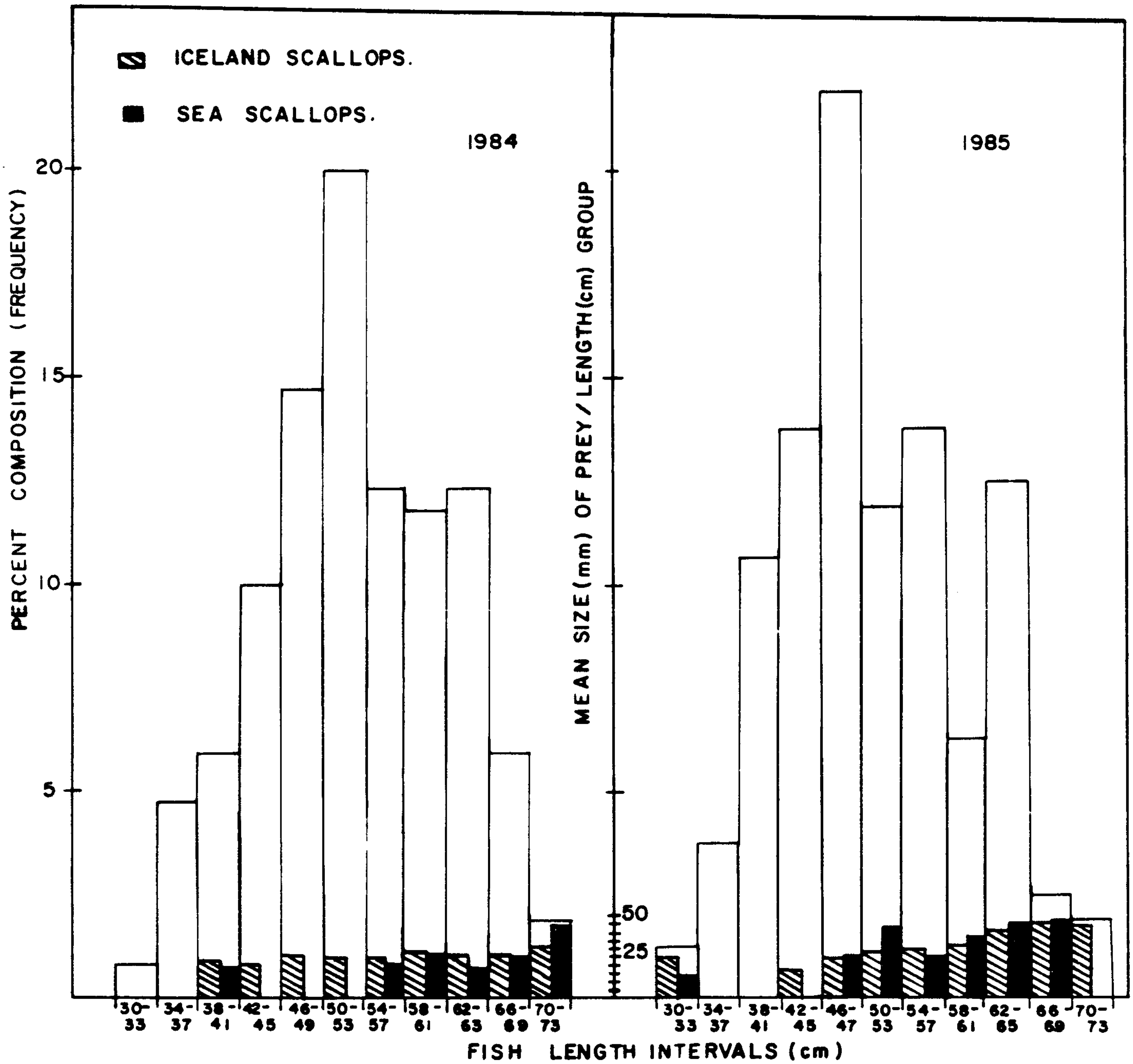

Fig. 4. Length composition of American plaice and prey size per fish length group.

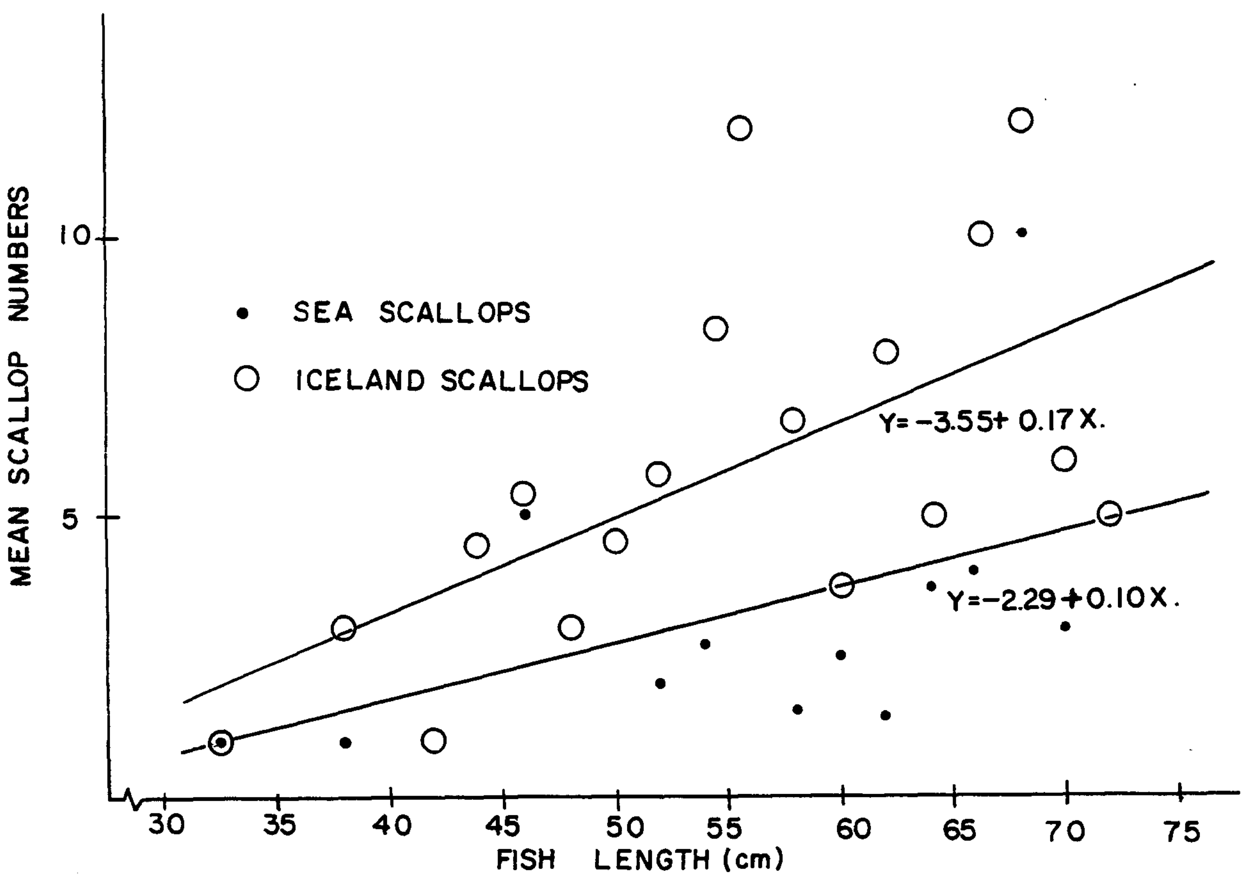

Fig. 5. Mean numbers of sea and Iceland scallops as a function of fish length.

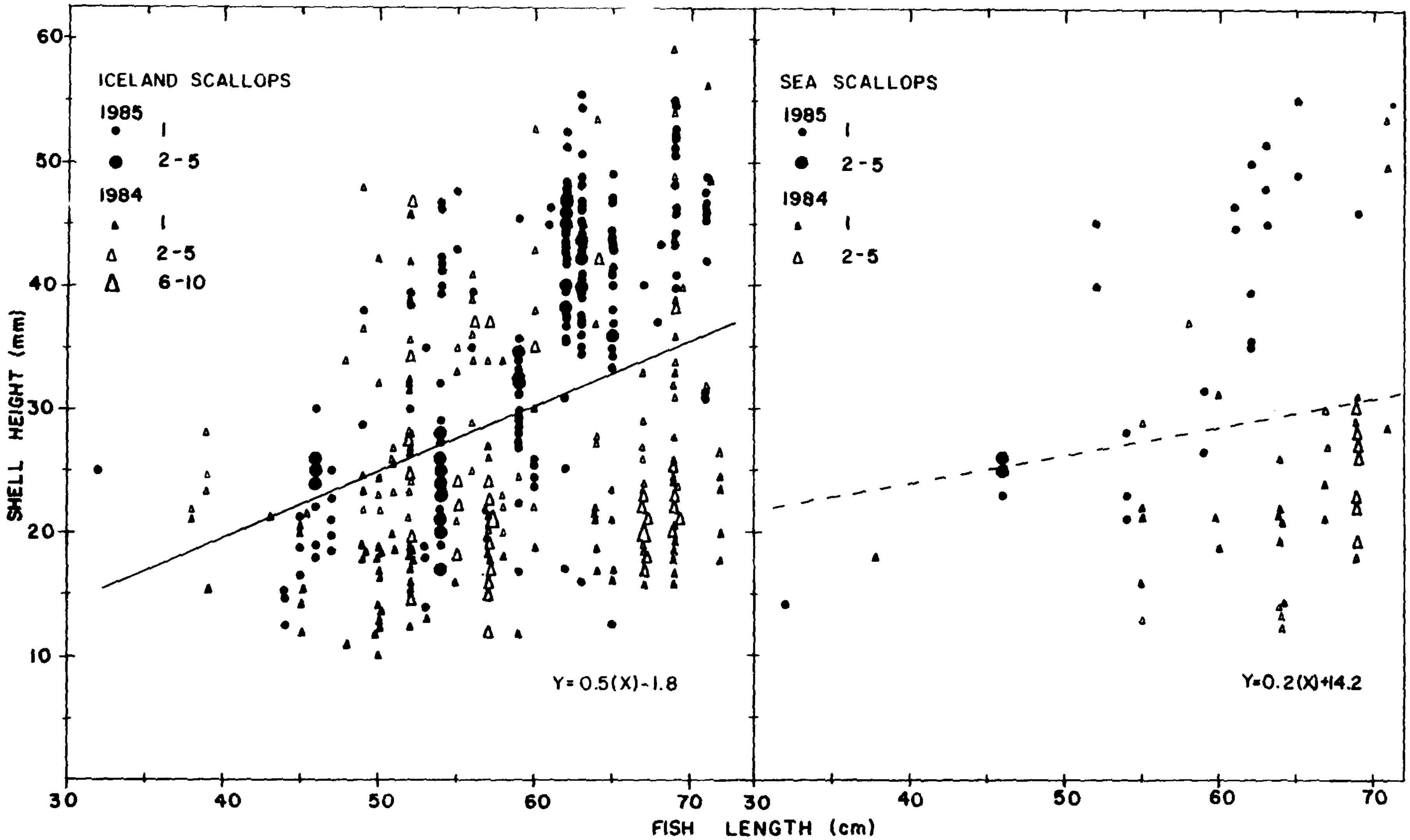

Fig. 6. Prey size (sea and Iceland scallops) as a function of fish length.