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Preliminary Estimates of Biomass of Commercially Important Species Eaten by Altantic Cod (*Gadus morhua*) in the Southern Gulf of St. Lawrence, 1992 and 1993.

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ABSTRACT

Stomach content data, estimates of biomass in 5 cm length-classes for fish age-3 and older, and a range of daily ration estimates taken from the literature were used to estimate annual consumption of commercially exploited organisms by Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Stomachs were collected approximately monthly from the commercial fishery during May to November 1993 and from research surveys conducted in July 1992, August 1992, September 1992, July 1993, and September 1993. Detailed examination was done for 1,934 cod stomachs in 1992 and 792 stomachs in 1993. Assuming that 1.5% body weight was the average daily ration and a 200 day feeding period (beginning of May to mid-November), cod ate about 59,000 t of herring (*Clupea harengus*), 59,000 t of capelin (*Mallotus villosus*), 1,100 t of winter flounder (*Pleuronectes americanus*), 700 t of American plaice (*Hippoglosoides platessoides*), 1,900 t of rainbow smelt (*Osmerus mordax*), 900 t of white hake (*Urophycis tenuis*), no Atlantic cod, 1,500 t of mackeral (*Scomber scombrus*), 25,000 t of *Pandalus* shrimp, and 900 t of snow crab (*Chionoecetes opilio*) during 1992. Under the same assumptions, cod ate about 56,000 t of herring, no capelin, 900 t of winter flounder, 1,200 t of American plaice, 3,900 t of rainbow smelt, no white hake, 5,200 t of Atlantic cod, no mackeral, 33,000 t of *Pandalus* shrimp, and 175 t of snow crab during 1993. No lobster (*Homarus americana*) were found in cod stomachs during either year. Clearly cod can be an important source of natural mortality on some of the commercially exploited species in the southern Gulf of St. Lawrence.

RÉSUMÉ

Pour évaluer la consommation annuelle par la morue franche (*Gadus morhua*) des organismes exploités commercialement dans le sud du golfe du Saint-Laurent, on a utilisé des données sur le contenu des estomacs, des évaluations de la biomasse des catégories de longueur de 5 cm pour les poissons âgés de 3 ans ou plus, et une gamme de valeurs estimées de rations quotidiennes provenant de la documentation. Les estomacs ont été recueillis à des intervalles d'environ un mois dans les pêches commerciales pendant la période de mai à novembre 1993, ainsi qu'à l'aide de relevés de recherche effectués en juillet, août et septembre 1992, ainsi qu'en juillet et septembre 1993. On a fait des examens approfondis de 1 934 estomacs de morue en 1992 et de 792 estomacs en 1993. En supposant une ration quotidienne moyenne correspondant à 1,5 % du poids corporel et une période d'alimentation de 200 jours (de mai à la mi-novembre), on peut conclure que la morue a consommé environ 59 000 t de hareng (*Clupea harengus*), 59 000 t de capelan (*Mallotus villosus*), 1 100 t de plie rouge (*Pleuronectes americanus*), 700 t de plie canadienne (*Hippoglosoides platessoides*), 1 900 t d'éperlan arc-en-ciel (*Osmerus mordax*), 900 t de merluche blanche (*urophycis tenuis*), pas de morue franche, 1 500 t de maquereau (*Scomber scombrus*), 25 000 t de crevette *Pandalus* et 900 t de crabe des neiges (*Chionoecetes opilio*) au cours de 1992. Selon les mêmes hypothèses, la morue aurait consommé environ 56 000 t de hareng, pas de capelan, 900 t de plie rouge, 1 200 t de plie canadienne, 3 900 t d'éperlan arc-en-ciel, pas de merluche blanche, 5 200 t de morue franche, pas de maquereau, 33 000 t de crevette *Pandalus* et 175 t de crabe des neiges au cours de 1993. On n'a pas trouvé de homard (*Homarus americana*) dans les estomacs des morues au cours des deux années de l'étude. Il est clair que la morue peut être une cause importante de mortalité naturelle pour certaines espèces exploitées commercialement dans le sud du golfe du Saint-Laurent.

INTRODUCTION

Atlantic cod (*Gadus morhua*) are probably the most abundant (in terms of biomass) demersal fish species in the southern Gulf of St. Lawrence. They eat a very wide range of prey species (Powles 1958; Kohler and Fitzgerald 1969; Waiwood and Majkowski 1984) and can, therefore, be an important source of natural mortality for commercially exploited organisms such as herring (*Clupea harengus*), American plaice (*Hippoglossoides platessoides*), snow crab (*Chionectes opilio*), and northern shrimp (*Pandalus borealis*). Variation in cod abundance, as well as variation in abundance of alternate prey, can affect the annual consumption of these prey by cod. Further, changes in availability of certain prey (as evidenced by interannual variation in diet) may reflect conditions of good or poor growth for southern Gulf of St. Lawrence cod. At present, these indicator organisms have not been identified. A better understanding of predator-prey relations is central to determining ecological interactions between organisms (including man) dependent on the southern Gulf ecosystem, especially with regards to explaining and ultimately predicting changes in abundance and distribution of the commercially exploited organisms.

The southern Gulf of St. Lawrence cod population supported an important fishery with annual catches exceeding 50,000 t from 1979 to 1990. The population declined steadily since about 1988 and the fishery targeting cod was halted 1 September 1993 (Sinclair et al. MS1994). The population was exploited from May to December in the southern Gulf and from mid-November through April or May outside of the Gulf - primarily in Sydney Bight. In contrast with statements by Lett (1978), recent work that measured seasonal energy reserves and quantities of prey eaten indicated that southern Gulf cod feed little from December through April (K. Schwalme, G. A. Chouinard, and J. M. Hanson; unpublished data). The low level of winter feeding means that almost all of the predatory impact of southern Gulf cod occurs while they are within the southern Gulf of St. Lawrence.

Waiwood and Majkowski (1984) used an age-based procedure based on Ursin growth theory to estimate consumption of commercially important species by southern Gulf of St. Lawrence cod for May to November 1980. The method that they used is complex and contains a number of assumptions that have since been shown to be questionable. The most critical of these is that inter-annual increase in weight is directly related to food consumption rates. Field experiments, laboratory studies, and advances in bioenergetics modelling all have shown that fish exhibiting a wide range of growth rates can have essentially the same daily ration. Whereas there is a limit to the amount of food that a fish can ingest at a given water temperature, the energy expenditure needed to capture that food and the differences in assimilation efficiencies among prey types can divert a large amount of energy away from growth (Hanson and Leggett 1986; Boisclair and Leggett 1989; Brandt and Hartman 1993; Ney 1993; Boisclair and Sirois 1993; dos Santos et al. 1993). A second assumption the method used by Waiwood and Majkowski (1984) was that weight of southern Gulf cod changed remained constant overwinter whereas recent work has shown that southern Gulf cod lose weight (both from muscle mass and liver reserves) overwinter (K. Schwalme and G. A. Chouinard, Science Branch, Gulf Fisheries Centre, Moncton, N.B. E1C 9B6, unpublished data). This means that estimates of prey consumption based on weight gains from September to September are too low.

To avoid these and other problems, I used a computationally simpler approach to the problem that has fewer assumptions. Cod diets were analyzed and summed for different size-classes, population biomass was calculated for the same size-classes (rather than age-classes), and a range of daily ration levels (obtained from the literature) were used to calculate annual consumption of selected prey items by cod.

Materials and Methods

Cod size-distribution

The cod population was described on the basis of biomass within size-classes rather than age-classes to avoid problems caused by changes in mean size-at-age that has occurred in this population (Hanson and Chouinard 1992) and to minimize effects of variation in year-class strength. Further, diet changes primarily as a function of size in most fish. Length-at-age distributions were obtained from the research surveys for 1991 to 1993. To correct for the tendency of the survey to underestimate abundance of the youngest age-groups, I converted the length-frequencies at age to proportions and multiplied by the beginning of year numbers-at-age obtained from the most recent sequential population analysis (SPA) (Chouinard et al. in press). Because the younger age-groups are incompletely sampled by the survey gear, this corrects the abundances in the total size-distribution. It is unknown, however, whether the length-frequencies for some or all of the incompletely sampled age-groups are biased. Any such bias is likely greatest for the youngest age-groups, ages 0, 1, and perhaps 2, which are not considered in this analysis. The numbers of fish at each cm were then summed across all ages and multiplied by the appropriate weight for that length (from the length-weight relationship from the survey) and the weights grouped into 5 cm intervals (e.g., 0 to 4.9, 5 to 9.9, and 10 to 14.9 cm). The biomass distributions were converted to percentages to permit between-year comparisons independent from changes in abundance.

Cod Diets

Stomach samples were collected from two sources in 1992 and 1993. Samples were collected monthly (or more often) from the commercial fishery during 1992 and those from May to mid-November are included in this study. Samples were more difficult to obtain during 1993 because no fishery directed at cod was permitted after 1 September and there was greatly reduced fishing effort during the period fishing was permitted. Samples were collected in June, July, and August 1993. A suitable sample also was collected as bycatch from the fishery for American Plaice during October 1993. The September sample came only from the September research survey. A sample from the commercial fishery consisted of a minimum of four fish per cm for fish 35 to just over 60 cm long. Additional samples, covering all sizes of fish captured, were collected from research surveys in the western part of the Gulf in July 1992 and 1993 and for the whole Gulf for August 1992 and September 1992 and 1993. A sample from the research survey consisted of at least four fish per cm group for each area sampled. In the case of the August and September surveys, separate collections were made in the eastern and western parts of the southern Gulf of St. Lawrence.

Samples from the commercial fishery consisted of cod collected from the last set done before the ship returned to shore and the fish were kept in crushed ice. This means that some degree of digestion continued until the stomachs were frozen and made prey identification (especially of fish) more difficult. Upon landing, the cod were immediately frozen and returned to the laboratory where fork length (cm), wet weight (to the nearest g), various organ weights, and carcass weights were recorded. Stomachs were removed and stored (frozen) until analysed for prey species identification, numbers, and weights.

Prey identification was usually to order although species identification was attempted whenever possible. For each stomach, all organisms were counted, prey in each taxonomic group weighed, and individual weights (plus lengths for fish) recorded for as many intact organisms as possible. These latter data are not presented in this study. Mucus weights were recorded but were not included as part of total stomach content weight.

Samples collected during research surveys were taken as part of the regular biological sampling routine. In most cases, the fish was frozen a short time after being landed. For some samples, however, space limitation meant that fork length and wet weight (to the nearest 5 g) were measured while on ship and the stomach removed and frozen for storage. For all surveys, however, over half of the fish were returned intact to the laboratory where more accurate weight measurements were recorded. Processing of stomach contents was done as described for the commercial samples.

Data for 1992 and 1993 were analyzed separately. Because samples were collected monthly from the fishery, which presumably followed the main concentration of cod, and from research surveys that collected samples from the main concentration as well as spatially distant (and less dense) groups of fish, I felt that combining all samples together gave a reasonably representative diet and avoided arbitrary weighting of samples for unknown seasonal and spatial variation. The data were then grouped into 5 cm length-classes (e.g., 0 to 4.9, 5 to 9.9, 10 to 14.9 cm) except that few fish > 70 cm were caught and these were all combined. The weight of all individuals of each prey type were summed within the length-class and were expressed as a percentage of the total prey weight. These values were later multiplied by the biomass of prey consumed annually for that size-class and then summed across size-classes as an estimate of total consumption of the prey item by the cod population.

Although I have samples for fish < 20 cm long from research surveys (ages 0 to 2), the SPA does not provide population estimates for fish younger than age-3, thus the stomach data for younger fish were not used in this analysis. Because no commercially exploited species were eaten by these small fish, this omission does not affect the calculation of cod predation on these organisms.

For many fish prey, it was impossible to identify beyond flatfish (Pleuronectiformes) versus "round" fish (all thers). In describing the diet, these categories were reported as flatfish remains and round fish remains. In calculating cod consumption of fish species, however, I assumed that the species make-up of unidentified fish biomass was identical to that of the prey identified to species. Thus, I partitioned the unidentified fish biomass to other fish species proportional to the relative biomass of the identified fish prey.

No attempt was made to calculate cod daily rations. A wide range of estimates are available in the literature based on a variety of methods and for cod of different sizes living in waters of different temperatures. There are a number of estimates that apply to waters of similar temperature as those experienced by southern Gulf cod. Kerr (1982) reported daily ration values of 1.4 to 1.6% body weight based on bioenergetics models. Daan (1973) reported daily rations of 1.0 to 1.7% for North Sea cod. Finally, Waiwood and Majkowski (1984) reported a daily ration levels of 0.63 to 1.01% of body weight for southern Gulf cod but these are underestimates due to inappropriate assumptions on growth conversion efficiencies and unaccounted for weight losses due to overwinter fasting of southern Gulf cod. Bjornsson (1993) reported maximum consumption of almost 5% body weight daily for fish kept at 10 C in the laboratory. In another laboratory study on gastric evacuation rates, ration levels ranged between 0.4 and 8.4% body weight for fish maintained at temperatures of 1 to 14 C (dos Santos and Jobling 1991). The high ration levels (5 to 8% body weight/day) observed under laboratory conditions and high temperature (10 to 14 C) do not represent conditions experienced by cod in the southern Gulf of St. Lawrence. Rather than select a single value, I calculated consumption at daily ration levels of 1.0, 1.5, 2.0 and 3.0% of body weight. These rations were applied across all size classes. As more information becomes available, it may be possible to weight the estimates reported in this study to represent the allometric relationship between fish size and metabolic rate.

RESULTS AND DISCUSSION

Biomass distributions

Although beginning of year biomass (age-3 and older) declined from about 130,000 t in 1991 to about 81,000 t in 1993, the shape of the biomass distribution showed little between-year difference (Fig. 1). Almost 50% of the biomass was in the 40 to 49.9 cm length-class in all three years and only 3.5 to 5.8% of the biomass occurred in size-classes 60 cm and greater. Although it was not possible to examine seasonal variation in the shape of the biomass distributions, the lack of large differences between years suggests losses from a size-class were balanced by growth and recruitment over the period of this study. The abundance (relative and absolute) of cod > 65 cm long has declined markedly between the mid-1970s and late-1980s (Hanson and Chouinard 1992).

Cod Diet

Stomach content information was available for 1,934 fish in 1992 (Table 1) and 792 fish in 1993 (Table 2). In both cases, the fewest samples were available for the 65 to 69.9 and over 70 cm size-classes; reflecting the small biomass of these size-classes. The general pattern of small fish (< 40 cm) eating mysids, shrimp, and amphipods and larger fish (> 50 cm) primarily eating fish occurred in both years.

The composition of the diet, in terms of invertebrate prey, did not vary much between years (Fig. 2). Mysids were the principal prey (over 35% of the diet) of cod 20 to 35 cm long in both years. Euphausiids were recorded in small amounts in the diet of cod > 35 cm long in 1992 but not in 1993. Crabs did not exceed 10% of the diet of any size-class in either year; toad crab (*Hya araneus*) was the most commonly eaten species. Snow crab did not exceed 1% of the diet of any size-class of cod in either year. This low incidence of snow crab contrasts sharply with the study by Waiwood and Majkowski (1984) where snow crab represented 10 to 20% of the diet of cod > 50 cm long. Shrimp constituted over 20% of the diet of cod 20 to 45 cm long in 1992 and 1993 and dropped to < 10% at 50 to 55 cm (Fig. 2). Although *P. borealis* represented nearly all of the specimens of pandalid shrimp identified to species, no attempt was made to identify to species every specimen of *Pandalus* recovered from cod stomachs, therefore, the grouping *Pandalus* contained an unknown proportion of *P. borealis* and *P. montagui*. *Pandalus* were the principal shrimp prey for cod > 35 cm long whereas *Crangon* and other caridean shrimp (e.g., *Spirontocaris* sp.) were the dominant shrimp prey of cod < 35 cm (Table 1 and Table 2). *Pandalus* tends to be found in deeper water than *Crangon*. The higher occurrence of *Pandalus* in diets of larger cod likely reflects the tendency for larger cod to be found in deeper, cooler, water than small cod (Swain 1993). No lobster (*Homarus americanus*) were eaten by cod in either year although cod stomachs were collected from areas supporting lobster fisheries.

Small amounts of fish (< 20% of total stomach contents weight) were found in cod 20 to 30 cm long (Fig. 3). These were primarily capelin (*Mallotus villosus)*, rainbow smelt (*Osmerus mordax)*, and snakeblenny (*Lumpenus lumpretaeformis*) in 1992 and were mostly smelt and snakeblenny in 1993. Roundfish, which includes all species other than Pleuronectiformes, comprised over 90% of the fish eaten. Atlantic herring represented the majority of identified fish prey for cod > 55 cm long in both years. In previous studies, herring were the dominant prey of cod > 50 cm long in some years (Powles 1958; Lacroix and Marcotte 1961; Kohler and Fitzgerald 1969) and not present in others (Waiwood 1981; Waiwood and Majkowski 1984). Capelin represented 10 to 18% of the food eaten by cod 35 to 65 cm long in 1992 (Table 1) but were not identified in the prey during 1993 (Table 2). Water temperatures were very low in 1992 and the distributions of cod and capelin may have overlapped more than usual. The fishery in 1993 did not follow its usual pattern and there may have been little trawling was done in the western part of the Gulf near Gaspé, which is where capelin are most often found. Thus the commercial samples may have missed the cod feeding on capelin. Stomach samples were collected from near Bay of Chaleur, where capelin are frequently caught during research surveys, during the September 1993 survey but these fish had primarily eaten herring. Capelin were not reported in the 1980 study of cod diets in the western Gulf (Waiwood and Majkowski 1984) or the 1958 to 1963 sampling of the western half of the Gulf (Kohler and Fitzgerald 1969) but Powles (1958) found capelin represented about 10% of the diet of cod caught in the Bay of Chaleur region in 1955 and 1956 and Waiwood (1981) reported moderate quantities of capelin in cod caught in research surveys in the southwestern Gulf from 1965 to 1979 but almost none in 1980 and 1959 to 1964. Clearly capelin availability varies between years. Few gadids were eaten in either year.

Flatfish seldom comprised > 5% of the cod diet (Fig. 3). Winter flounder (*Pleuronectes americanus*) and yellowtail flounder (*Pleuronectes ferruginea*) were the dominant flatfish prey. American plaice occurred in very small amounts in 1992 and only once in the diet during 1993. (Table 1 and Table 2). This low incidence of plaice in the diet is similar to earlier published work for fish < 70 cm long (Kohler and Fitzgerald 1969; Waiwood 1981; Waiwood and Majkowski 1984). Only 17 stomachs of fish > 70 cm long were available for diet analysis in this study (none of which ate plaice) because cod of this size are rare in the southern Gulf at this time (Fig. 1) and they were not sampled from the commercial fishery.

Biomass of prey eaten

Because the feeding period (1 May to 17 November) represents 200 days, the 1.0% daily ration equates to an annual prey consumption of twice the cod biomass (Table 3). Ration levels differ by a constant, therefore, the estimates of consumption differ by a constant, the proportions of prey in the diet remain the same. Future work will attempt to examine the seasonal patterns in the cod diets and to calculate quantities consumed for each season where sufficient samples exist. The estimates of biomass of commercially important species eaten by cod in 1992 and 1993 presented here will likely change slightly once the results of the 1994 stock assessment are available. The assessment will provide more accurate estimates of numbers at age-3 for 1993. The changes are likely to be slight, however, because they will only affect the smallest size-classes, which represent a relatively small fraction of the total cod biomass and these small fish also ate the least amount of species of commercial importance. The calculations of biomasses of commercially important prey eaten by southern Gulf cod will be done for 1991 once the analysis of cod diets are completed.

The estimate of total prey consumption in 1993 was about 83,000 t (26%) less than in 1992 (Table 3). This is due to the cod population biomass being 26% lower in 1993 than 1992. Commercially important species composed 46% of the total prey biomass eaten by cod during 1992 and 41% in 1993 (Table 4). In the discussion that follows, I assumed that an average daily ration level of 1.5% body weight best represents the average daily ration.

Atlantic cod in the southern Gulf of St. Lawrence ate about 59,000 t of herring in 1992 compared with 56,000 t in 1993. Many of these herring were juveniles (< 25 cm long) but the actual proportion that were juveniles remains to be calculated. The estimated consuption of capelin was similar to that of herring in 1992 despite capelin never exceeding 25% of the diet of any size-class. This is because herring were primarily eaten by large cod and capelin by small cod but there was a much larger biomass of small cod. No mackeral were found in the cod stomachs examined for 1993 whereas the estimated consumption in 1992 was about 1,500 t. Rainbow smelt represented 1,900 t and 4,000 t of the estimated cod diet in 1992 and 1993, respectively. Cod consumed relatively small amounts of American plaice and winter flounder (< 1,100 t) in both years. No cod were found in cod stomachs collected in 1992 compared with almost 5,200 t in 1993. The cod that were eaten weighed about 500 g each (about 38 cm long) and were eaten by cod > 70 cm long. Given the large size, these cod may represent fish discarded from the commercial fishery, which has a minimum size limit of 41 cm. A small number of juvenile hake, each weighing about 25 g, were eaten in 1992 and represented about 900 t consumed. No small hake were found in the cod stomachs examined in 1993.

The most important commercially exploited invertebrate prey was *Pandalus* shrimp, of which 25,000 t were estimated to have been eaten in 1992 and almost 33,000 t in 1993 (Table 4). Although *Pandalus borealis* was the most commonly observed species identified during stomach content analysis some *P. montague* were also noted. The stomach content samples used in this study were not collected with the express purpose of estimating cod predation on individual prey species and all *Pandalus* were combined into a single category during the stomach content analysis. Only a relatively small numbers of snow crab were recovered from cod stomachs, representing a consumption of 915 t in 1992 and 175 t in 1993. No lobster were found in cod stomachs examined in this study nor have they been reported in any previous study (Powles 1958; Lacroix and Marcotte 1961; Kohler and Fitzgerald 1969; Waiwood 1981; Waiwood and Majkowski 1984) despite the fact that many samples were collected in areas that support lobster fisheries and small lobster were also caught in the same tows as the cod used in this study (pers. obs.).

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Table 1. Diet (as percent weight) of Atlantic cod (age-3 and older) in the southern Gulf of St. Lawrence during 1992. Digest represents prey digested too far for any other level of identification. Remains = rem.

	Size Class										
Items	20-24.9	25-29.9	30-34.9	35-39.9	40-44.9	45-49.9	50-54.9	55-59.9	60-64.9	65-69.9	70+
Carideans	25.15	3.07	1.56	0.00	1.68	1.06	1.28	0.36	0.27	0.00	0.00
Crangon	7.23	11.38	0.18	2.01	0.78	1.42	1.76	0.40	0.06	0.00	0.00
Cumaceans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pasiphaeid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pandalus	4.10	7.20	7.37	13.08	12.95	14.52	5.47	0.60	0.08	0.00	0.13
Shrimp rem	0.00	2.33	4.71	5.31	5.48	6.45	2.62	1.75	0.70	0.00	0.00
Euphasiids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mysids	43.08	37.03	36.15	21.85	5.67	6.60	12.54	1.98	0.34	0.00	0.00
Caprellids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hyperiids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gammarids	11.72	15.43	3.09	4.19	2.07	2.18	1.64	0.09	0.08	0.31	0.00
Isopods	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hermit crab	0.00	1.78	0.85	0.27	0.24	0.57	0.24	0.15	0.00	0.00	0.00
Toad crab	1.67	0.00	1.57	1.37	4.32	5.94	6.80	5.13	5.63	5.98	0.58
Snow crab	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.52	0.00	0.00	0.00
Rock crab	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.40	0.00	0.00	0.00
Other crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Crab rem	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Squid	0.00	0.00	0.00	0.00	0.00	0.00	2.07	0.00	0.00	0.00	0.00
Clam rem	0.00	1.12	8.32	17.34	15.72	13.84	3.95	2.57	0.72	1.25	0.64
Propellor clams	0.00	0.00	4.92	4.85	3.05	0.32	0.00	0.00	0.00	0.00	0.00
Surf clams	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scallops	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00
Whelk	0.00	0.00	0.03	1.60	1.38	2.47	0.38	0.00	0.03	0.00	0.09
Tunicate	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00
Annelids	0.00	6.17	0.28	0.00	1.31	0.29	0.19	0.08	0.00	0.00	0.00
Nematodes	0.26	0.00	0.00	0.20	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Aschleminthes	0.00	0.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00
Platyhelminthes	0.54	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polychaetes	0.25	9.43	3.66	4.55	4.34	0.22	1.67	0.60	0.21	1.25	0.22
Sea mouse	0.00	0.00	0.47	0.25	2.72	1.75	1.14	0.60	0.00	0.00	0.00
Sea cucumber	0.00	0.00	0.00	2.69	0.60	1.86	0.95	0.99	0.94	0.00	0.00
Brittle star	0.00	0.00	0.00	0.66	1.24	1.01	0.39	0.00	0.00	0.00	0.00
Round fish rem	3.19	3.87	8.42	8.83	20.59	22.85	24.40	23.69	40.31	37.33	6.04
Flatfish rem	0.00	0.00	0.00	0.00	0.80	1.41	1.42	2.83	0.27	0.00	0.20
Winter flounder	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.80	0.00	0.00
Yellowtail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.41	5.51	0.00	0.00
Plaice	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00
Capelin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smelt	0.00	0.53	7.07	0.00	0.00	0.00	0.01	0.00	0.15	0.00	0.00
Herring rem	0.00	0.00	0.00	3.96	11.20	4.61	20.78	54.55	39.96	53.88	33.95
Herring scales	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cod	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	50.14
Hake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Redfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
S. H. Sculpin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sculpin rem	0.00	0.00	0.00	0.22	0.08	0.07	0.05	0.00	0.00	0.00	0.00
L.H Sculpin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.34	0.00	0.00
Hookear sculpin	0.00	0.00	0.00	1.14	0.20	0.06	0.00	0.00	0.00	0.00	0.00
Snakeblenny	1.52	0.43	0.00	0.00	1.28	4.47	5.31	0.31	0.00	0.00	0.00
Mackeral	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laval's E.P	0.00	0.00	0.00	1.18	0.51	0.61	0.00	0.00	0.00	0.00	0.00
Vahl's E.P	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.34	1.70	0.00	0.00
Radiated shanny	0.00	0.00	0.17	0.00	0.61	0.00	0.36	0.00	0.00	0.00	0.00
Fish stomach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shark intestine	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00
Other fish sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.23	0.29	0.00	0.00
Digest	1.16	0.23	11.17	4.23	0.53	0.23	0.69	0.46	0.37	0.00	8.02
TOTAL WT	56.78	89.67	223.39	610.21	1313.63	1506.17	3080.74	3153.18	2779.93	747.02	2137.53
N	69	48	50	100	130	122	118	76	53	13	13
EMPTY	13	10	6	5	10	10	10	13	7	1	4

Table 2. Diet (as percent weight) of Atlantic cod (age-3 and older) in the southern Gulf of St. Lawrence during 1993. Digest represents prey digested too far for any other level of identification. Remains = rem.

	Size Class										
Items	20-24.9	25-29.9	30-34.9	35-39.9	40-44.9	45-49.9	50-54.9	55-59.9	60-64.9	65-69.9	70+
Copepods	0.07	0.03	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carideans	2.91	5.87	2.95	5.88	13.08	3.88	4.44	2.22	1.08	0.00	0.00
Crangon	10.28	7.34	7.80	2.56	1.43	2.46	1.88	0.56	0.64	0.00	0.00
Cumaceans	0.64	0.20	0.12	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Pasiphaeid	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Pandalus	8.78	5.36	7.59	11.77	8.41	4.25	4.34	2.21	3.30	0.38	2.70
Shrimp rem	2.63	3.03	3.41	4.75	4.05	2.25	3.07	0.32	0.85	1.51	11.13
Euphasiids	0.00	0.02	0.00	3.09	3.59	1.84	1.36	3.54	0.88	0.00	0.00
Mysids	51.24	37.11	38.80	11.54	6.05	4.39	2.28	0.52	0.00	0.00	0.00
Caprellids	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hyperiids	0.00	0.00	0.00	0.60	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Gammarids	6.36	5.59	5.80	8.62	4.98	3.44	1.31	0.07	0.03	0.00	0.00
Isopods	0.00	0.05	0.11	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Hermit crab	0.00	0.16	0.61	1.57	0.32	0.18	0.07	0.24	0.00	0.00	0.00
Toad crab	0.00	1.46	0.70	0.77	1.19	2.06	3.11	2.28	1.87	8.83	0.00
Snow crab	0.11	0.00	0.07	0.26	0.00	0.50	0.33	0.93	0.65	0.00	0.00
Rock crab	0.00	0.00	0.66	0.56	0.00	0.44	0.00	0.10	0.00	0.00	0.00
Other crab	0.00	0.00	0.12	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00
Squid	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Clams	0.20	1.41	3.08	5.90	2.61	5.95	6.28	2.14	1.42	0.04	0.00
Propellor clams	0.00	0.53	0.00	0.00	0.23	1.29	1.42	0.07	0.00	0.00	0.00
Surf clams	0.00	0.00	0.00	0.00	0.38	0.24	0.24	0.68	0.00	0.00	0.00
Scallops	0.00	0.00	0.19	1.07	0.00	0.02	0.29	0.00	0.00	0.00	0.00
Whelk	0.00	1.58	0.16	1.08	0.62	0.70	0.11	0.27	0.00	0.00	0.00
Tunicate	0.00	0.00	0.00	0.00	0.00	0.10	0.25	0.05	0.00	0.00	0.00
Annelids	0.00	0.00	0.56	0.26	1.51	1.83	0.72	0.22	0.01	0.00	0.00
Nematodes	0.00	1.51	0.75	0.29	0.18	0.10	0.02	0.00	0.00	0.00	0.00
Aschleminthes	4.02	0.00	0.00	0.00	0.00	0.22	0.21	0.00	0.00	0.00	0.00
Platyhelminthes	0.00	0.00	1.15	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Polycheates	3.96	5.99	2.89	4.55	3.55	3.23	1.74	0.84	0.34	0.00	0.00
Sea mouse	0.00	0.00	0.00	0.00	0.05	0.44	0.43	0.21	0.00	0.00	0.00
Sea cucumber	0.00	0.00	0.00	0.00	0.73	0.37	0.39	0.15	0.00	0.00	0.00
Brittle star	0.55	0.00	0.00	0.32	0.88	0.15	0.05	0.14	0.12	0.00	0.00
Sea anemone	0.00	0.00	0.00	0.00	0.16	0.00	0.15	0.14	0.00	0.00	0.00
Roundfish rem	2.81	4.05	3.82	5.63	11.14	12.91	15.02	24.36	14.71	8.27	44.16
Flatfish rem	0.00	0.78	0.00	0.36	0.27	1.28	0.76	0.41	0.00	4.91	6.73
Winter flounder	2.06	0.00	0.00	0.27	0.00	0.00	1.09	0.51	0.00	0.00	0.00
Yellowtail	0.00	0.00	0.00	0.16	0.19	0.10	0.27	0.32	0.00	0.00	8.01
Plaice	0.00	0.00	0.12	0.17	0.00	0.05	0.00	0.44	0.00	0.00	0.00
Capelin	0.00	6.08	7.36	11.07	15.65	17.27	10.88	17.39	11.51	0.00	0.00
Smelt	0.00	2.51	3.47	0.34	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Herring	0.00	0.00	0.00	2.77	9.66	15.07	27.87	34.18	58.90	76.05	41.10
Herring scales	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hake	0.00	0.00	0.00	0.00	0.02	0.44	0.38	0.70	0.00	0.00	0.00
S.H. Sculpin	0.00	0.00	0.00	1.20	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Sculpin	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00
L.H Sculpin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hookear sculpin	0.00	0.00	0.00	0.00	0.07	0.03	0.01	0.00	0.00	0.00	0.00
Snakeblenny	1.37	1.64	0.75	1.96	2.04	1.51	0.62	0.11	0.33	0.00	0.00
Mackeral	0.00	0.00	0.00	0.00	0.00	1.34	0.91	0.00	0.00	0.00	0.00
Laval's E.P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vahl's E.P	0.00	0.94	0.00	1.36	1.33	0.92	2.02	0.16	0.00	0.00	0.00
Radiated shanny	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish larvae	0.00	0.00	0.00	0.68	0.00	1.23	0.00	0.00	0.00	0.00	0.00
Fish Stomach	0.00	0.00	0.00	0.09	0.02	0.50	0.22	0.00	0.00	0.00	0.00
Shark intestine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other fish sp.	0.00	0.00	0.00	0.00	0.06	0.01	1.31	0.05	0.00	0.00	0.00
Digest	2.03	6.65	6.82	8.51	5.07	6.61	4.12	3.47	3.34	0.00	0.00
TOTAL WT	133.943	516.653	642.268	1574.377	4525.417	7322.865	10434.02	6662.431	2308.511	736.328	285.36
N	88	188	132	161	370	386	344	204	49	8	4
EMPTY	5	14	5	7	28	22	24	37	3	0	1

Table 3. Cod biomass distribution and total food consumption (assumes 200 d feeding) of Atlantic cod in the southern Gulf of St. Lawrence, 1992 and 1993.

	1992		1993	
Size (cm)	Population Biomass (t)	Biomass eaten at 1.5% daily ration (t)	Population Biomass (t)	Biomass eaten at 1.5% daily ration (t)
20-24.9	314	940	279	837
25-29.9	1,956	5,869	662	1,985
30-34.9	9,840	29,521	8,366	25,098
35-39.9	19,524	58,573	15,291	45,872
40-44.9	25,734	77,202	17,809	53,427
45-49.9	28,310	84,931	19,913	59,739
50-54.9	13,719	41,158	9,888	29,665
55-59.9	5,438	16,314	3,925	11,774
60-64.9	1,316	3,949	1,029	3,087
65-69.9	730	2,191	731	2,191
70-plus	1,724	5,173	2,975	8,936
Total	108,607	325,821	80,867	242,600

Table 4. Consumption (t) of commercially important fish and invertebrate species by Atlantic cod in the southern Gulf of St. Lawrence, 1992 and 1993.

Prey / Ration level	1.0%	1.5%	2.0%	3.0%
		1992		
Atlantic Cod	0	0	0	0
White hake	598	897	1,196	1,794
Atlantic herring	39,588	59,382	79,176	118,764
Mackeral	1,031	1,546	2,062	3,093
American plaice	464	696	928	1,392
Winter flounder	725	1,088	1,450	2,175
Rainbow smelt	1,276	1,914	2,551	3,828
Capelin	39,381	59,072	78,762	118,143
Snow crab	610	915	1,320	1,830
Pandalus shrimp	16,691	25,037	33,383	50,074
Lobster	0	0	0	0
		1993		
Atlantic Cod	3,471	5,206	6,941	10,412
White hake	0	0	0	0
Atlantic herring	37,657	56,486	75,315	112,972
Mackeral	0	0	0	0
American plaice	789	1,182	1,577	2,366
Winter flounder	606	910	1,213	1,819
Rainbow smelt	2,604	3,906	5,209	7,813
Capelin	0	0	0	0
Snow crab	117	174	233	350
Pandalus shrimp	21,764	32,646	45,528	65,292
Lobster	0	0	0	0

Figure 1. Biomass size-distribution of Atlantic cod in the southern Gulf of St. Lawrence, 1991 to 1993.

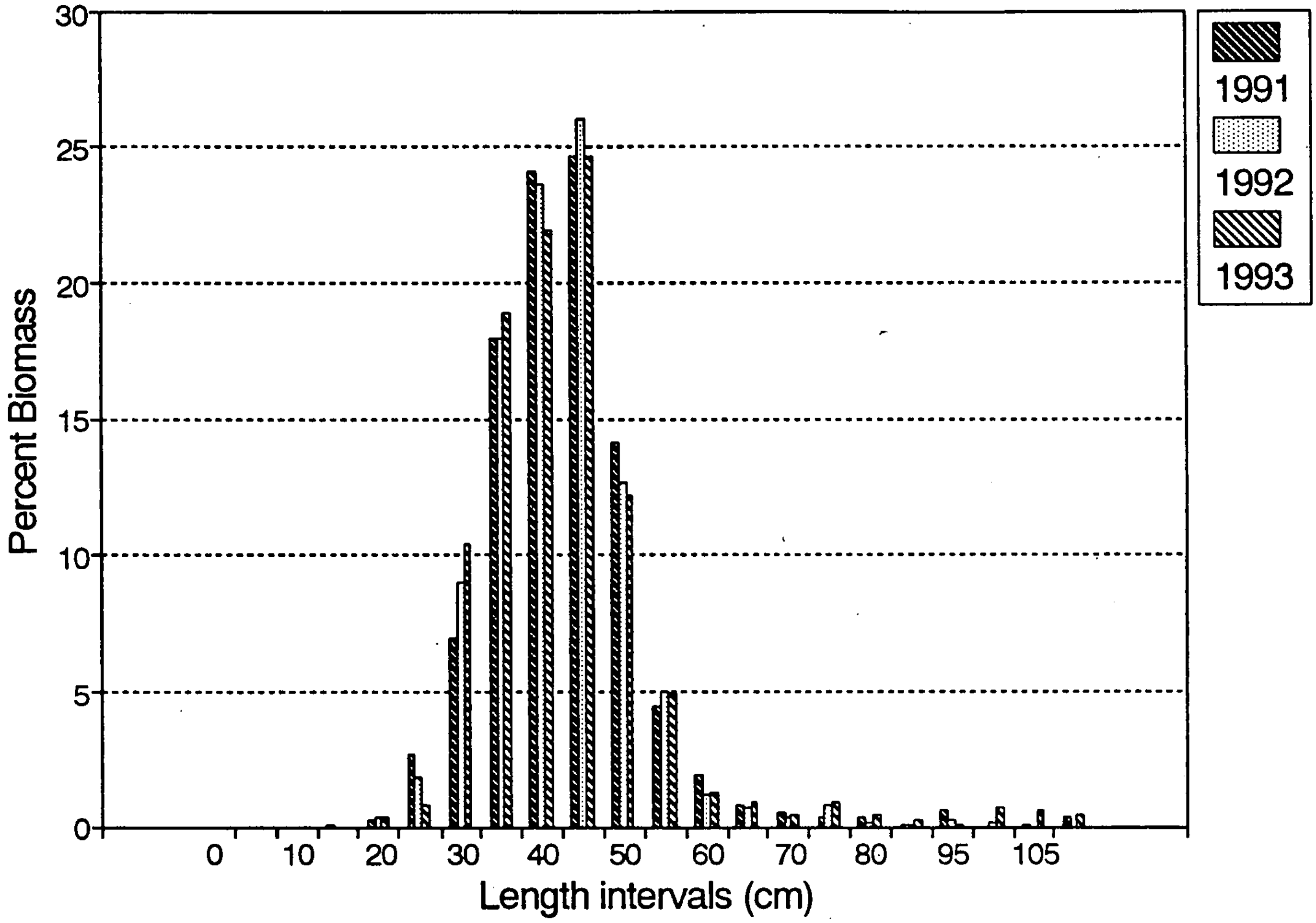

Figure 2. Percent contribution of shrimp, mysids, and crabs to the diet of Atlantic cod in the southern Gulf of St. Lawrence, 1992 and 1993.

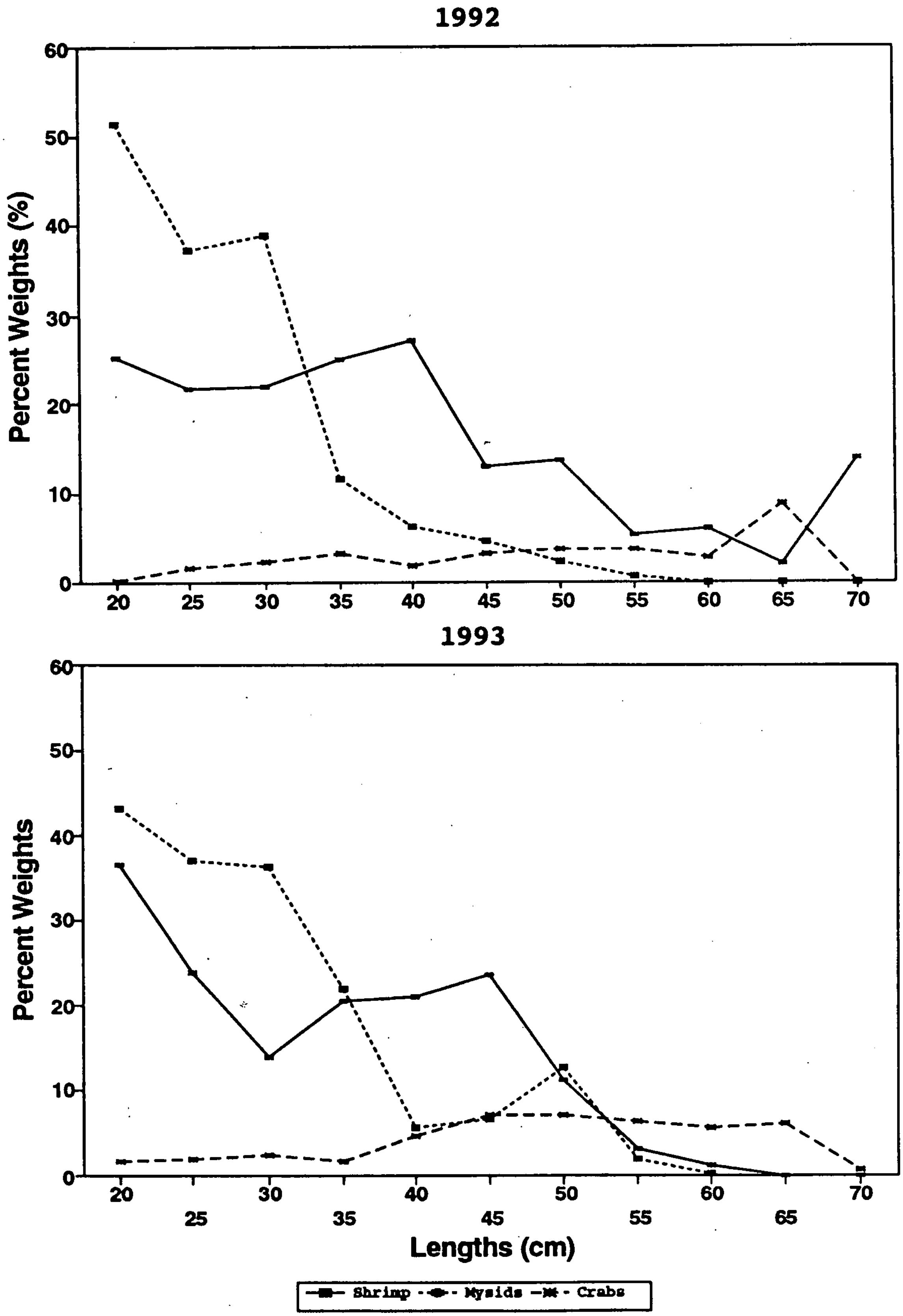

Figure 3. Percent contribution of flatfish, round fish (includes herring), and herring to the diet of Atlantic cod in the southern Gulf of St. Lawrence, 1992 and 1993.