International Council for
the Exploration of the Sea

C.M.1995/M:16
Anacat Committee

POSTSMOLTS OF RANCHED ATLANTIC SALMON (*Salmo salar* L.) IN ICELAND: III. The first food of sea origin

by

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Abstract
Atlantic salmon (*Salmo salar* L.) postsmolts of hatchery origin were sampled during their migration in coastal waters in the bay of Breidafjord, West Iceland in 1993. Fishing was done in areas that were 4 - 30 km from the releasing site in several periods from June to September mostly coinciding with releases of smolts. Following releases, the large majority of the salmon postsmolts (13-36 cm) migrated fast outward to off shore areas, but a small fraction dominated by maturing males, foraged along the shores, inwards into the bay of Breidafjord. The forage status of the salmon postsmolts was low, but the food amount increased with increasing distance from the release site and with increasing time from release. The observed low forage efficiency of salmon postsmolts migrating through the bay is not likely to have any perceptible effects on their survival, or the carrying capacity of the bay, because of the short time spent in the bay. The postsmolts fed mostly on pelagic prey, but benthic prey was also an important food in the littoral areas. The main prey types eaten in the inner areas, were dipteras, decapods (megalopa larvae) and benthic amphipods. In June decapods dominated, but in July and August the postsmolts were mainly preying on flies. When the postsmolts reached outer areas they preyed mainly on decapod larvae, hyperid amphipods, euphausids, and sand eel larvae. The postsmolts consumed prey of width ranging from 0.2 - 4.3 % of their fork lenght.

Key words: Atlantic salmon, postsmolts, food, ranching

Introduction

The ecology of Atlantic salmon postsmolts is of special interest due to indications of high mortalities during early sea life, either by predation on postsmolts (Larson 1984; Valle 1985; Hvidsten & Møkkelgjerd 1987; Hvidsten & Lund 1988; Montevecchi et al. 1988) and/or due to adverse sea condition in the beginning of the feeding migration (Scarnecchia 1984). The forage status of the Atlantic salmon postsmolts have to be studied in relation to their migration behaviour and the abundance of available prey and predators along the migration route. In later years the large scale sea ranching of Atlantic salmon (*Salmo salar* L.) in Iceland has given basis for research on the ecology of the salmon postsmolts. Firstly, the releases of millions of salmon postsmolts from a single release site at different dates gives opportunity to capture postsmolts quite far from the release site in enough numbers with traditional fishing methods without considerable fishing effort and additionally to observe the foraging under different environmental circumstances. Secondly when the large scale releasings started, new questions rose regarding whether these large scale releases were affecting the survival of the postsmolts and of other fishes in the area. This paper is one of a series of four papers derived from research on the ecology of postsmolt salmon in Breidafjord bay W-Iceland (Fig. 1). This sampling was continuation of earlier research done in the infjord area (Hraunsfjord and Kolgrafafjord) in 1989 and 1990 (Sturlaugsson 1994). The aim of this part of the project was to study the forage status of Atlantic salmon postsmolts in the first part of their sea migration. The following questions will be considered: (1) which prey types does the postsmolts prey on in the bay? (2) Is the foraging of the postsmolts in the bay, likely to affect their survival or the carrying capacity in the bay ? (3) Are delayed releases affecting the forage of out migrating postsmolts ? (4) Are the released maturing male postsmolts, foraging from the infjord area into the bay ?

The literature on the diet of Atlantic salmon postsmolts in the North Atlantic is sparse (Anon. 1983; Morgan et al. 1986; Dutil & Coutu 1988; Hvidsten et al. 1992 & 1993; Levings et al. 1994; Sturlaugsson 1994). These studies showed that the salmon is largely eating flies together with benthic and pelagic invertebrates near shore. While in the outer areas pelagic invertebrates together with fish (manly larvae in the beginning) became the dominant food.

Material and methods

Study area

Experimental fishing was carried out in the Breidafjord bay, W- Iceland in 1993 and 1994 (Fig. 1). For details see papers I & II in this series; Thorisson and Sturlaugsson 1995a, Sturlaugsson and Thorisson 1995).

Sampling

The fishing was done before, during and after the releases of salmon postsmolts wich always took place at the beginning of the outgoing tide. The effort was directed towards the area were Kolgrafafjord opens into Breidafjord about 4 km from the releasing site and towards outer areas of Breidafjord, up to 30 km from the releasing site (shortest seaway) both at shore and off shore Fig. 1). For details see paper II in this series (Sturlaugsson and Thorisson 1995).

Measurements and laboratory methods

The fish caught were weighed to the nearest 0.1 g on an electronic balance and forklenght was measured to the nearest millimeter (for details see paper II in this series, Sturlaugsson and Thorisson 1995).

The stomachs (pharynx-pyloric spinchter) from the salmon postsmolts were frozen and subsequently thawed in the laboratory, cut open and fullness estimated as percentage of stomach volume (in 5% intervals). Those stomachs that contained only trace of food (< 0.01 g) were ommited from the volume estimates. Contents of the intestine were examined in order to detect prey types. The total amount of food from stomach was blotted and weighed (wet weight) excluding mucus. The food was weighed on an electronic balance to the nearest 1/100 of a gram.

Prey items were spread out in a shallow dish and visually analyzed under a binocular microscope. The stomach content, was sorted into taxonomic groups and the estimation of the volume of prey groups was carried out using glass cylinders.

To measure the interval of the prey width/fish fork lenght ratio (PFR), the largest and smallest prey were sorted visually out from stomachs and their maximum width measured to the nearest 1/10 of millimeter.

A forage ratio (%) was computed from the ratio of the wet mass of the total food in the stomach to the wet mass of the fish (Table 1).

The Ivlev's electivity index (E) (Kolding & Bergstad 1988) was used to estimate postsmolts preference for the available prey types on two sampling dates on selected stations (Table 2). The occurrence (ratio) of prey types were then compared between the stomachs (r) and the environment (p) as follows:

$$E = \frac{r - p}{r + p} \qquad (-1 \leq E \leq 1)$$

If value of E = 1 it indicates strong prey selection
if E = -1 it indicates no selection for given prey type

Both total occurrence of prey in the environment and the occurrence of prey within preyed on size range were used.

For fish that had $\geq$0.01g stomach content, linear regression analysis was used to get the relationship between lenght (cm) of fishes (L) and weight (g) of the food W: $\text{meanW} = aL^{b} * 100$.

Results and discussion

Catch

During the experimental fishing, a total of 663 postsmolts (26.8-565.0g) were caught in 1993 (Fig. 2). Information about composition of the catch (sizes, migration routes etc) are listed in Sturlaugsson and Thorisson 1995.

Consumption

Salmon postsmolts of all sizes (14 -34cm) were eating , although proportion of postsmolts with empty stomachs were high (Fig 3 & Table 1). Information on the digestion rate of salmonids shortly after release (Brodeur & Pearcy 1987; Johnsen & Ugeldal 1988) together with the short interval between visitations of nets, indicate that the food amount observed is representative for the forage status of salmon postsmolts in the sampling area.

The majority of the salmon postsmolts migrated fast towards the open ocean and as expected they had low forage status the first hours of their sea migration (Table 1). The rapid outward migration of these smolts are likely to suppress their feeding. It is also possible that stress could increase the first hours after release with negative effects on the fish forage status. Another possibility is that lack of experience among the postsmolts, regarding feeding on living prey could suppress their feeding (Marcotte & Browman 1986; Fjallstein 1987). Low forage status among wild Atlantic salmon postsmolts in the beginning of their sea migration has been observed in other parts of the Atlantic (Hvidsten et al. (1992 &1993).

The mean FR during the summer of 1993 was on the average very low (Table 1). Outward migrating postsmolts entering the mouth of Kolgrafafjord had on the average 4 times higher FR at the shore (station 3.1) compared to postsmolts caught at same distance from releasing site in the middle of the fjord (station 2.1), see Table 1. FR at the mouth of Kolgrafarfjord (stations 2.1 & 3.1) was low at all sampling dates, decreasing throughout the summer as did the abundance of zooplankton, Table 1 & 2 (for details see Paper I in this series, Thorisson &Sturlaugsson 1995a). This decrease in the FR throughout the summer at the mouth of Kolgrafafjord was reflected in the diet composition of the postsmolts, in terms of volume, whereas the zooplankton was their main food in that area in June and July, but dipteras were dominant prey in August. The amount of food in postsmolts observed at shore located stations increased with increasing time from release.

Comparision of prey proportions in the environment vs. in the postsmolts stomachs, indicated that active prey selection were usual among the postsmolts, but predation on many prey types not found in the zooplankton samples shows that these results must be interpreted cautiously (Table 2).

Tracking of postsmolts at 10. August showed low forage status of salmon postsmolts offshore at the mouth of Kolgarfarfjord (station 2.1) about 2.5 hours after release in dark. Then the FR was low (Table 1) and only 5% of the postsmolts had started eating (maximum number of prey/stomach = 2). After additional 15.5 hours, when the postsmolts had migrated 25 km from the mouth of Kolgrafafjord to station 2.3 in the middle of the bay, their forage status had changed conspicuosly (max. number of prey/stomach = 60) although the FR was still very low (Table 1). Of the postsmolts captured at station 2.3, the majority (70%) had started feeding and they had the highest mean FR observed throughout the summer . This increased fullness of the postsmolts smolts, just half a day after they were nearly all empty at station 2.1, could have been influenced by darkness, but similar forage status at station 2.1 in daylight about half month later (Table 1) does not support that explanation. This observed increase in FR towards outer areas of the Breidafjord bay is likely to be related to higher abundance of preferred prey, along with increased time available for feeding and possibly some difference in the foraging behaviour and/or prey behaviour (vertical distribution). Contrasting to the suggested increase in prey abundance towards outer areas, the abundance of prey observed in the zooplankton samples taken in outer areas did not indicate higher occurrence of prey of preferred size of postsmolts (Table 2), but possibly that is due to the sampling method, as indicated by predation on prey types not found in the zooplankton samples.

Maturing male postsmolts migrated slowly along the shores inward in Breidafjord bay (stations 1.1-1.7) and had relatively high FR compared to the postsmolts caught at the mouth of Kolgrafafjord (stations 2.1 & 3.1), while migrating rapidly towards the open waters of the Bay (Table 1). The distribution of postsmolts migrating inward in Breidaford were closely related to the littoral, and catch at high tide over intertidal areas together with predation on littoral prey suggests that they use partly littoral migration (McKeown 1984) for foraging along shores as was observed among their more stationary counterparts in Hraunsfjord (Sturlaugsson 1994). The shore related foraging among maturing males (Fig. 2) was observed for up to a month after release and up to 30 km away from the releasing sites, suggesting that their foraging are largely and possibly solely restricted to the nearshore areas troughout the summer, until they migrate into freshwater previous to spawning later that summer or the coming autumn.

When feeding postsmolts were analysed separately, the relationship between length of fish and weight of their food were non significant in 1993 for both non mature postsmolts and maturing male postsmolts. The relationship between length of fish and total number of prey/stomach was also non significant.

Prey were commonly eaten in low numbers. Total number of prey were 1149 (mean=9.4/stomach SD=28,7 median=2). Likewise the low number of prey types in the stomachs (mean=1.4 SD=0.9) reflects little feeding activity and/or little abundance of suitable prey. Available data on zooplankton densities (see paper I in this series, Thorisson & Sturlaugsson 1995a) in relation to the large size of the postsmolts indicates that lack of prey of suitable size in August compared to June are influencing the forage status of the postsmolts (Table 2).

Prey and prey importance

In areas near shore (0-1500m from tide line), the dominating prey types were terrestrial dipteras and megalopa larvae of the order decapoda (*Hyas* spp and *Pagurus bernhardus*) both in terms of volume and occurence (Fig. 4). Amphipod gammarids, sandeels larvae (*Ammodytidae*) together with Euphausids were also found to be of considerable importance, in terms of volume and also of occurence in the case of gammarids. Adult dipteras has also been reported as important diet of salmon postsmolts in estuary W-Iceland, but the prominent prey items in that area were gammarids (Johannsson et al. 1991).

Off shore in the middle of Breidafjord (station 2.3) 29 km away from the releasing site, the salmon postsmolts did no longer contain flies or prey types from the littoral, as in near shore areas (Fig. 5). Decapods were the main food there both in terms of volume and occurrence. In this area the postsmolts had added hyperids to their menu and were also preying on sandeels (0+) and euphausids that also were important food due to their large size.

The occurrence of prey types (Fig. 6) is largely comparable to their bulk (Fig. 4 & 5), excluding the relatively small copepods (manly calanoida) that had considerable occurence. Isopods and caprellids were consumed at low rates, but caprellid once occured in outward migrating postsmolt over depths at the mouth of Kolgrafafjordur following release. That fish seems therefore to have migrated partially close to the shore in the inner region. The polychaets eaten by salmon postsmolts were *Neires* spp, but they were also found in stomachs of homing adult salmon.

Pre adult stages of the copepod ectoparasite *Lepeoptheirus salmonis* Krøyer was in two instances found as food and were also observed on some postsmolts, one extreme case were a very large postsmolt was covered with 180 *Lepeoptheirus* copepodids.

Maximum prey width of the postsmolts was ranging from 0.2 to 4.3 % of their fork length, largely corresponding the reported intervals of PFR (Wankowski & Thorpe 1979; Sturlaugsson 1994). The most common PFR values were in the interval 1.1-2.3 (decapoda and diptera).

Concluding remarks

Near the shore the postsmolts migrating through the coastal waters of Breidafjord bay preyed near shore mainly on flies and benthic and pelagic crustaceans. But off shore in the middle of the bay they were mainly preying on pelagic crustaceans along with fish larvae. Observed proportions of benthic and pelagic prey together with terrestrial flies is similar to what have been observed among postsmolts in the Norwegian fjords and also in the Gulf of St. Lawrence (Hvidsten et al. 1993; Dutil & Coutu 1988; Hvidsten et al. 1993; Levings et al 1994).

In addition to the typical direct oceanward migration, we also observed salmon postsmolts foraging along shores of the bay, by a minor part of the released postsmolts that mainly consisted of maturing males. In earlier studies such littoral foraging postsmolts had been observed to migrate in the infjords, mainly in Hraunsfjord (Sturlaugsson 1994). The dominating proportion of maturing males in these routes indicates an atypical forage behaviour, but similar migrating behaviour has been observed by large postsmolts (2+) released in a Norwegian fjord (Hansen & Jonsson 1991).

The salmon postsmolts were migrating at the same relatively high speed in the outer off shore areas as in the inner area, but their forage ratio increased towards outer off shore areas, although it was still low. Very low forage ratio and fast migration throughout the bay (also observed in 1994 see Sturlaugsson & Thorisson 1995), rejects the suggestion that salmon postsmolts are influencing the carrying capacity of the fjord and the bay area considerably.

Decreasing forage ratio at nearshore areas throughout the summer reflects the decrease in prey abundance in that area, especially for prey of preferable size (Thorisson & Sturlaugsson 1995a). This difference in prey abundance did not, however, affect the oceanward run of the postsmolts troughout the summer in that area.. Although the difference between periods are not large, this shows that delaying the releases was leading to lower fullness of salmon postsmolts in the beginning of their oceanward run. In addition to that the delaying of postsmolt run also shortens the time available in the ocean within the optimum feeding period, during the summer.

The observed low forage efficiency of salmon postsmolts migrating through the bay is not likely to have any perceptible effects on their survival because of the short time spent in the bay. Secondary influence derived from the fjord and bay area such as infection rates regarding parasites are more likely to affect the survival of the salmon postsmolts (Finstad et al 1994; Grimnes & Jakobsen 1995) than the observed forage or even predation in this coastal area (Thorisson & Sturlaugsson 1995b).

The typical forage behaviour observed among the salmon postsmolts migrating oceanward, indicates that the first feeding areas of large importance on their migration route are out in the ocean.

Acknowledgments

Thanks are due to director Jakob Jakobsson at the Marine Research Institute and director Arni Isaksson at the Institute of Fisheries and Aquaculture Research for their support throughout the project. We also acknowledge the help of the staff at Silfurlax Ltd ranching station and the help of , Mr. Ingi Runar Jonsson and Mr. Sumarlidi Oskarsson at the Institute of Fisheries and

Aquaculture Research. Thanks are also due to anonymous referee for comments on the manuscript. This work was sponsored by funds from the Research Council of Iceland and by the Icelandic Ministry of Fisheries.

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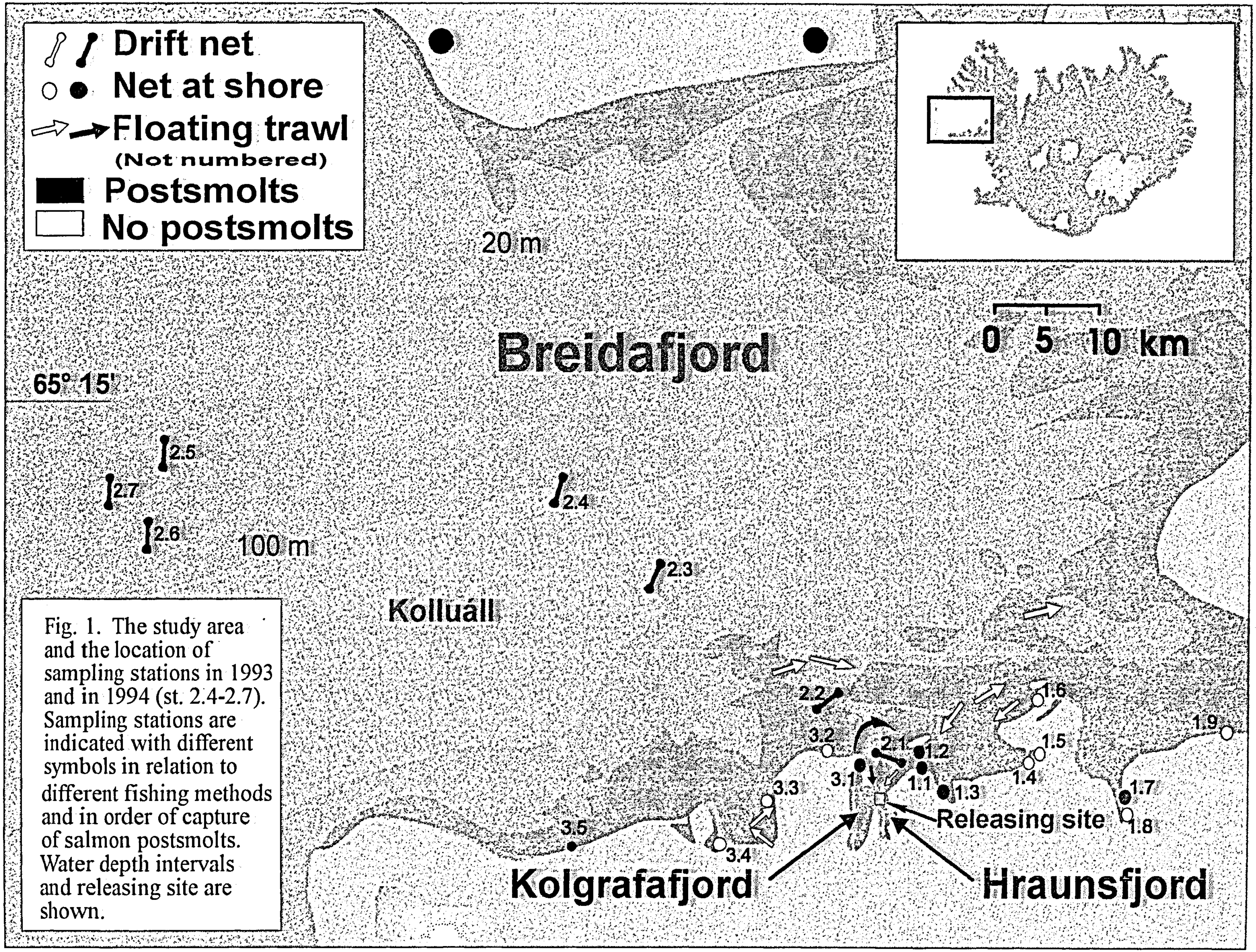

Fig. 1. The study area and the location of sampling stations in 1993 and in 1994 (st. 2.4-2.7). Sampling stations are indicated with different symbols in relation to different fishing methods and in order of capture of salmon postsmolts. Water depth intervals and releasing site are shown.

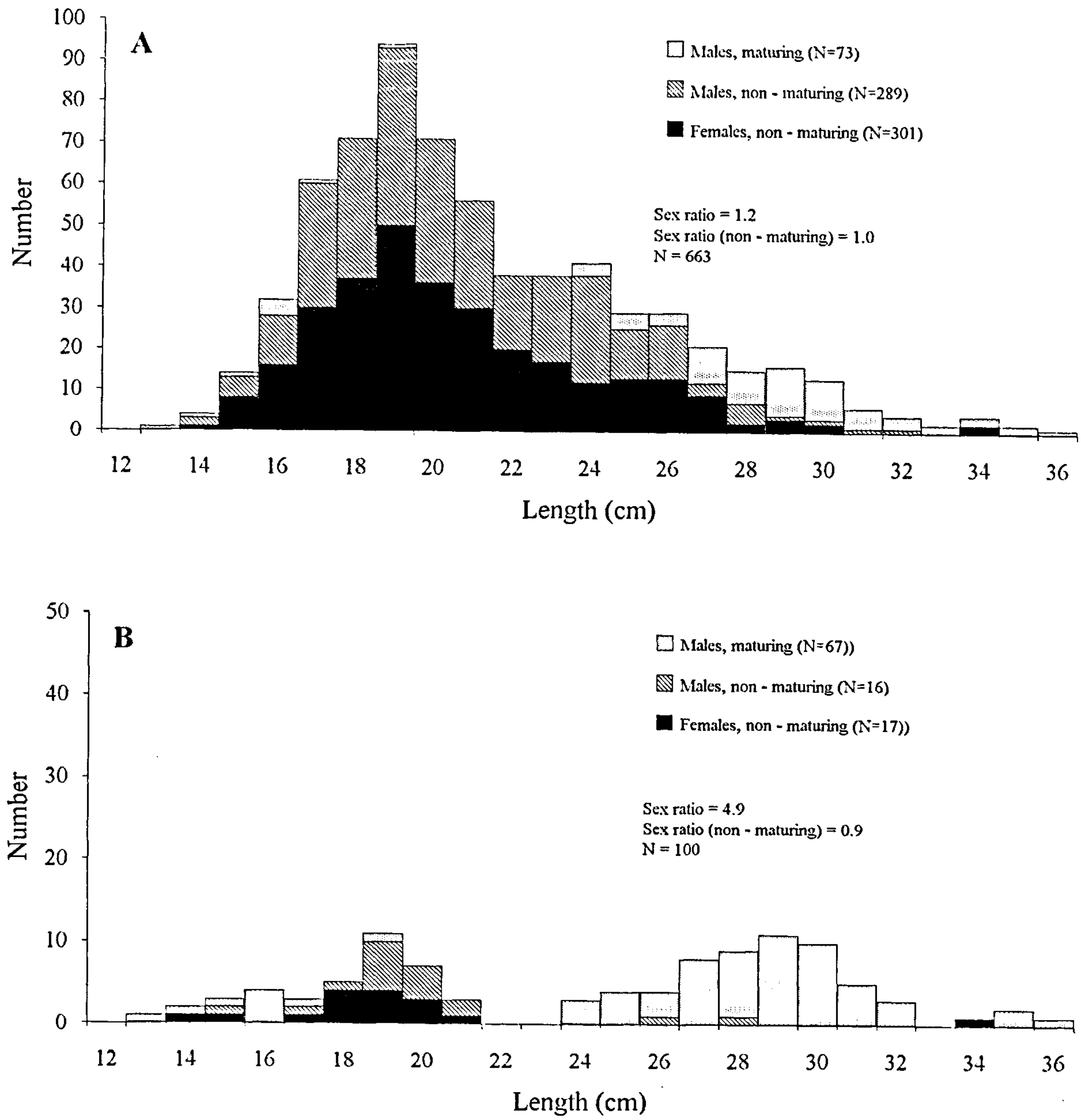

Fig. 2. Length distribution of all salmon postsmolts captured (A) in the bay of Breidafjord (June-August 1993) and thereof inward migrating postsmolts (B), in relation to their sex and maturation. Number of individuals (N) are given for each group and as total, along with sex ratio.

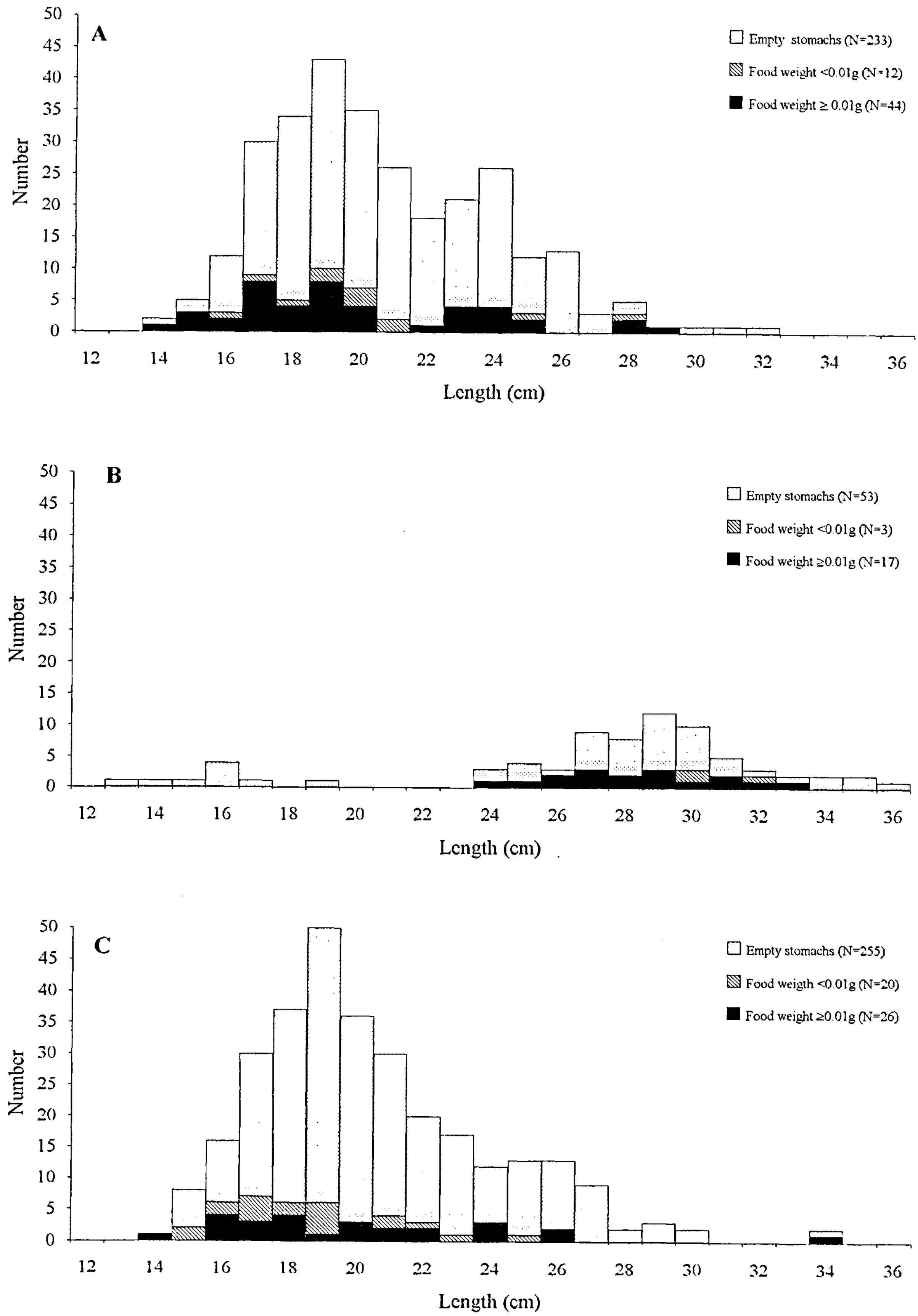

Fig. 3. Length distribution of non-maturing salmon male (A), maturing salmon male (B) and non-maturing salmon female (C) postsmolts captured in the bay of Breidafjord (June - August 1993), in relation to their stomach content.

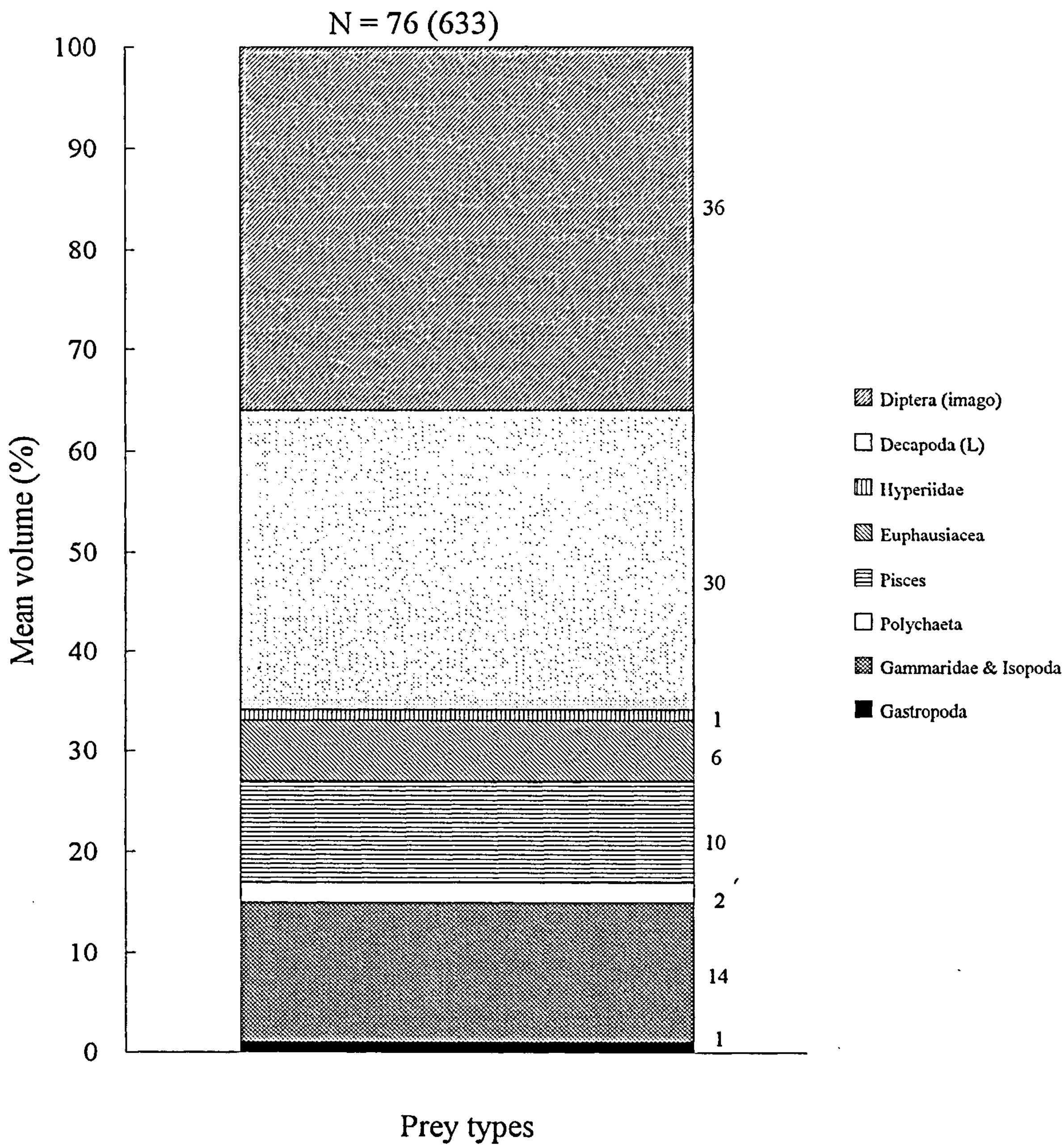

Fig. 4. The mean volume of prey types (%) in predating salmon postsmolts near shore (0-1500 m from tide line) in Breidafjord bay, June - August 1993. Number of feeding postsmolts (food weight ≥ 0.01 g) are given along with number of postsmolts analysed in parenthesis. Volume for each prey type are also given.

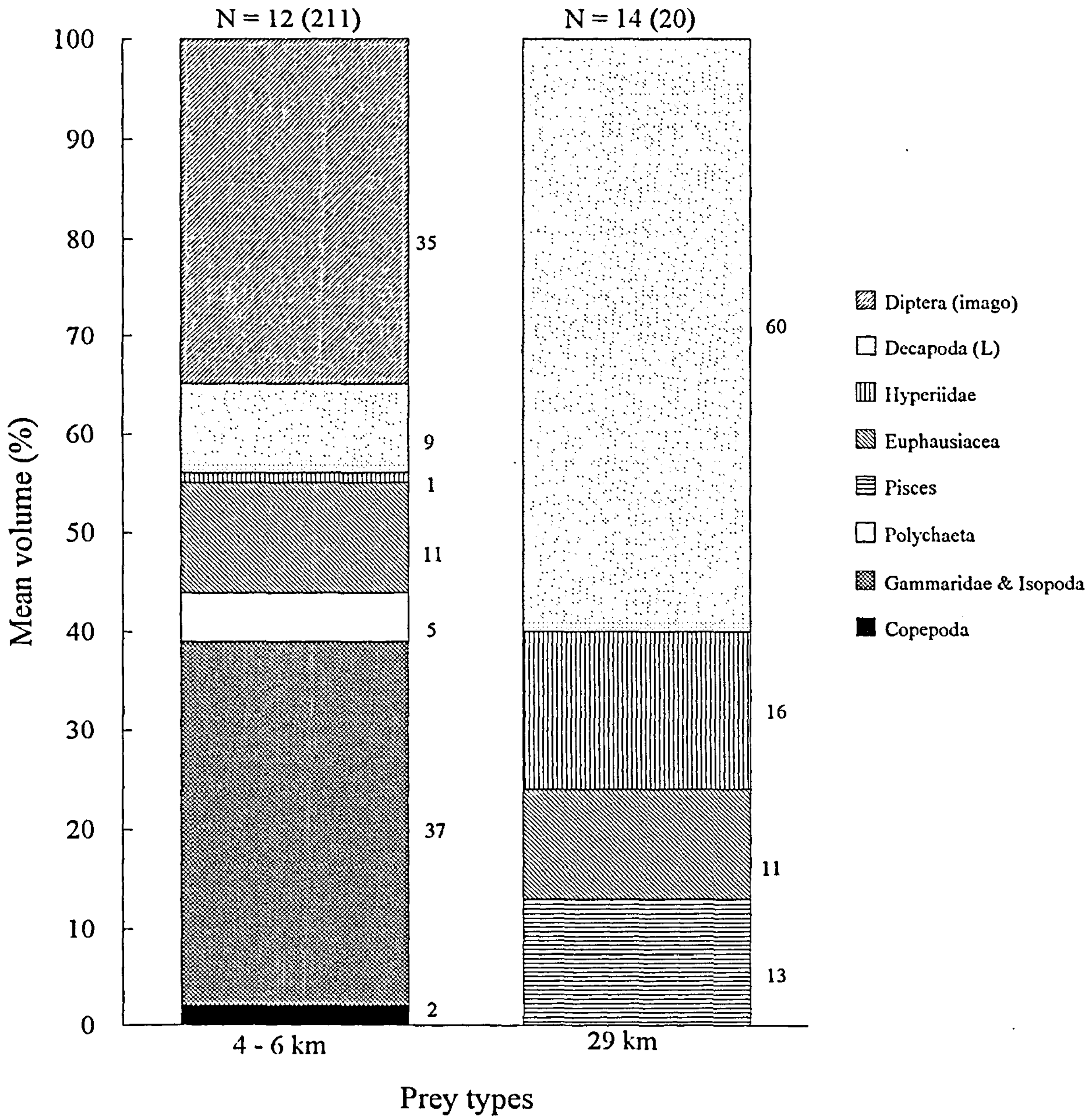

Fig. 5. The mean volume of prey types (%) in predating salmon postsmolts in Breidafjord, 7th - 11th August 1993, at 4-6 km (stations 1.1, 2.1 & 3.1) & 29 km (station 2.3) from release site. Number of feeding postsmolts (food weight ≥ 0.01 g) are given along with number of postsmolts analysed in parenthesis. Volume for each prey type are also given.

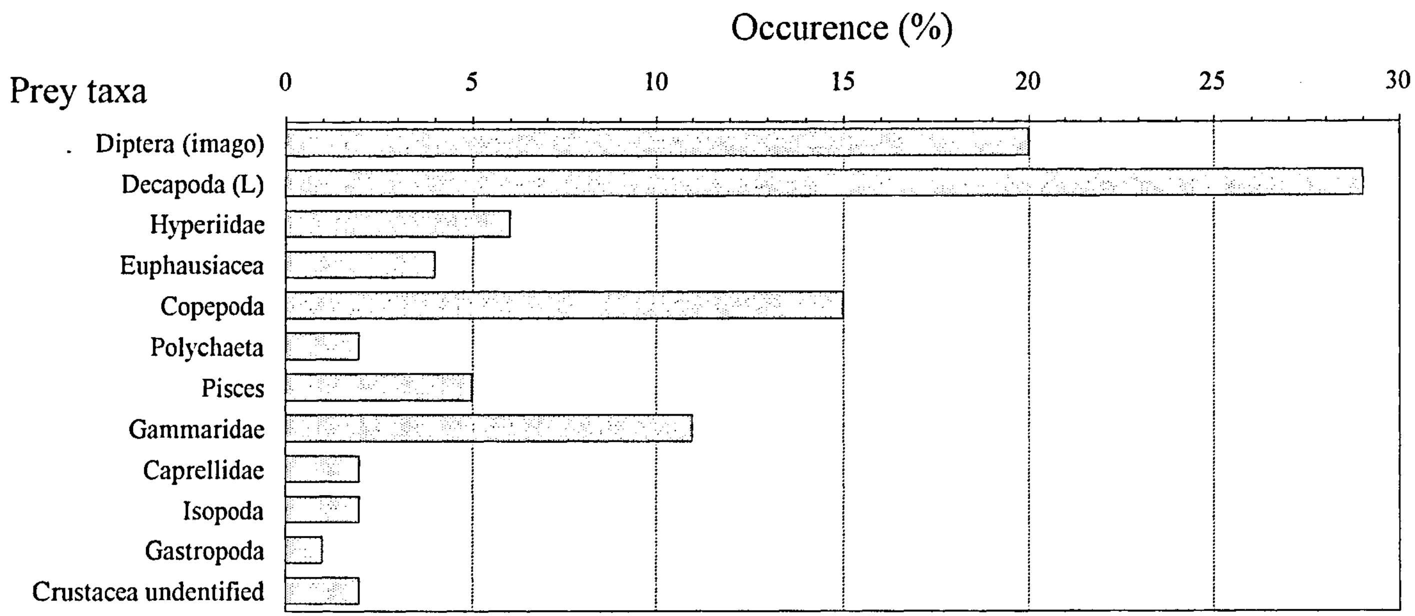

Fig. 6. Prey occurence (%) among predating salmon postsmolts (N=122) in Breidafjord bay, June to August 1993.

Table 1. Comparison of stomach content of salmon postsmolts categories in Breidafjord June to August 1993. Number of feeding fish and empty fish, together with means, medians and maximum values of forage ratio for all fishes and for feeding fishes are given.

Postsmolts categories	Postsmolts number	Forage status; predating vs empty (number (%))			Forage ratio (%)						
		Feeding all	Feeding ≥0.01 g	Empty	All				Food ≥ 0.01 g		
					Mean	SD	Median	Max	Mean	SD	Median
All samples	663	18.4	13.4	81.6	0.019	0.096	0.00*	1.53	0.144	0.226	0.06
All non-maturing males and females	590	16.3	11.4	83.7	0.018	0.098	0.00*	1.53	0.251	0.031	0.06
All maturing males	73	35.6	31.5	64.4	0.032	0.082	0.00*	0.51	0.101	0.120	0.06
Stations 1.1 - 1.7 (Total catch)	100	35.0	31.0	65.0	0.036	0.087	0.00*	0.60	0.116	0.125	0.07
Station 3.1 (Total catch)	200	17.5	11.5	82.5	0.016	0.081	0.00*	0.88	0.137	0.205	0.05
Station 2.1 (Total catch)	322	9.9	5.9	90.1	0.004	0.032	0.00*	0.51	0.072	0.116	0.04
Station 2.1 (22. July)	122	17.2	9.0	82.8	0.005	0.023	0.00*	0.18	0.051	0.059	0.02
Station 2.1 (10. August)	109	4.6	1.8	95.4	0.001	0.008	0.00*	0.07	0.055	0.021	-
Station 2.1 (26. August)	87	5.8	5.8	94.2	0.002	0.009	0.00*	0.05	0.034	0.015	0.04
Station 2.2 (Total catch)	14	7.1	7.1	92.9	0.873	-	-	-	0.873	-	-
Station 2.3 (Total catch)	20	70.0	70.0	30.0	0.115	0.145	0.06	0.49	0.165	0.148	0.10

* = more than half of the stomachs were empty

Table 2. Occurence of prey items in the stomachs of Atlantic salmon potsmolts, compared to the occurence of prey items in the environment. Occurence of prey items in the environment (from Table 1 in Thorisson & Sturlaugsson 1995a) are given as percentage of total number of prey items and additionally the percentage of prey items within the larger prey size group, are given in parenthesis. Ivlev's electivity index is also given for comparision of total occurence and based on the larger prey items, given in parenthesis. Station number and dates of sampling are given. Numbers of feeding fishes (N) are given along with the number of postsmolts analysed in parenthesis. Numbers of prey items in each category (n) are shown.

Prey	Stations 2.1 & 3.1 June 21 N=5 (13)			Station 2.1 August 10 N=5 (109)			Station 2.3 August 10 N=14 (20)		
Size groups & items	Diet n=28 (%)	Environment n=13759 (226) (%)	(E) ($-1 \leq E \leq 1$)	Diet n=6 (%)	Environment n=15982 (7) (%)	(E) ($-1 \leq E \leq 1$)	Diet n=216 (%)	Environment n=6077 (4) (%)	(E) ($-1 \leq E \leq 1$)
Small prey									
Cirripedia (L)		12.5	-1		5.9	-1		49.3	-1
Cladocera		22.8	-1		45.3	-1		1.6	-1
Gastropoda (L)		1.3	-1		1.9	-1		4.2	-1
Copepoda small[1]		63.0	-1		46.8	-1		44.8	-1
Large prey									
Copepoda large[2]	17.9	0.4 (92.5)	0.2 (-0.7)	33.3	+ (28.6)	1 (0.1)	1.4	+ (50.0)	1 (-0.9)
Hyperiidae							13.0		1 (1)
Euphausiacea	3.6		1 (1)				0.9		1 (1)
Euphausiacea (L)		+	-1 (-1)		+ (28.6)	-1 (-1)			
Decapoda (L)	64.3	+ (7.1)	1 (0.8)	33.3	+ (28.6)	1 (0.1)	83.8	+ (50.0)	1 (0.3)
Fish (L)	7.1	+ (0.4)	1 (0.9)		+ (14.2)	-1 (-1)	0.9	+	1 (1)
Diptera (Imago)	7.1		1 (1)	33.3		1 (1)			

(L) = larvae
+ = < 0.1

1 = Calanus finmarchicus III or smaller
2 = Calanus finmarchicus IV or larger