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POSTSMOLTS OF RANCHED ATLANTIC SALMON (*Salmo salar* L.) IN ICELAND: I. Environmental conditions

by

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Abstract

About two million Atlantic salmon (*Salmo salar* L.) smolts are released annually from the sea-ranching station Silfurlax Ltd in West Iceland. These large releases made it possible to study the ecology of the postsmolts during the first days of their sea migration. In this first paper in a series of four, environmental conditions are described. In the study area, the uppermost 30 m of the water were well mixed during the whole study period, from April to September. This homogeneity, makes it unlikely that differences in temperature or salinity interfered much with the behaviour of the salmon postsmolts, except possibly close to the releasing site. The limited zooplankton data indicates, that prey of suitable size for the postsmolts was more abundant in May-June than later in the summer.

Introduction

In contrast to the freshwater phases in the life of the Atlantic salmon (*Salmo salar* L.), the sea-migration is poorly documented (Reddin and Short 1991, Jonsson et al. 1993). From the day the smolts reach sea water to their return day one to three years later, little is known of their migrations, food, feeding grounds, competitors and predators. One of the reasons for this is that natural postsmolts are few and far between. The salmon are distributed over hundreds of rivers, and the smolts usually leave each river during a period of about four weeks (Österdahl 1969, Ruggles 1980, Antonsson et al. 1995). The number of smolts leaving a particular river in a given day is therfore small.

In contrast to Pacific salmon species, the sea ranching smolt releases of Atlantic salmon have been rather small until recently (Isaksson 1988), and as the fish disperse even more after release, catching the postsmolts has been extremely difficult. In Iceland, however, one and some years even two sea-ranching stations have been releasing in the order of 1-2 million smolts annually for the last few years. These large releases made the present study on the first days of the sea migration possible.

Sturlaugsson (1994) reports on the only previous study of ranched sea migrating salmon postsmolts in Iceland from 1989-90. Some results from that study will be used here as reference.

The present study area was Kolgrafafjord, where the postsmolts were released, and the bay of Breidafjord, into which Kolgrafafjord opens (Fig. 1a). In addition to the study of the migration and feeding of the salmon postsmolts, potentional competors and predators were collected together with environmental and zooplankton data. The area investigated each year is indicated in Figure 1a. In this first paper in a series of four, environmental and zooplankton data will be presented.

Material and methods

Study area

Breidafjord is a large bay of more than five thousand km² area (Fig. 1a). The bottom depth of the inner part of the bay is mostly shallower than 50 m. The outer part is mostly between 50 and 100 m, except for a canyon near the south coast, that extends into the middle of the bay and is up to 250 m deep. Breidafjord has numerous shallow subsidiary fjords, one of which is the Kolgrafajord to the south. The outer Kolgrafafjord (the area studied) is about 17 km². The shores of Breidafjord and the more exposed parts of the subsidiary fjords consist mostly of rocks or boulders with rich vegetation of benthic algae down to 20-30 m. More sheltered areas have gravel or sand bottoms with more sparse vegetation, and at the heads of the fjords there are often mudflats with little or no vegetation. The tidal currents are strong, due to the high tidal amplitude (up to 5 m), and the intertidal areas are large. Input of freshwater is rather limited in the area.

In late June there is daylight around the clock in the study area, except for a 2-3 hour dusk period from midnight on. In late July there are two hours of darkness (01-03 hours). In late August the dark hours have increased to seven, from about 22 hrs at night to about 05 hrs in the morning.

Sampling of data

During the period from 9 April to 3 September 1993, a grid of 19 fixed stations was sampled seven times for environmental variables (Fig. 1b). At all stations, temperature and salinity profiles were taken down to about 30 m depth, except were bottom depth was less. Secchi-disk readings were made at each station.

Zooplankton was collected at seven selected stations during each cruise (Fig. 1b). The sampling device was a VP2-net with a mesh size of 335 μ, equipped with a flow meter. The net was towed for two minutes at 10 m depth and again for 2 minutes at 5 m depth during the oblique tow from 10 m to the surface at 2.5 knots. The zooplankton samples were preserved in 4 % buffered formalin, and later identified in the laboratory using 10-40 × magnification.

Visible radiation was recorded at the Silfurlax ranching station (Fig. 1b) during 14 July to 16 November. The radiation was integrated over one hour intervals and stored on a data logger.

Results

During the study period, the sea temperature increased from about 3 °C in April to about 10 °C in September. The temperature was relatively homogenous in the uppermost 30 m in all surveys (Fig. 2a).

The salinity remained remarkably constant at the deeper stations at about 34.5 ‰ during the whole study period (Fig. 2b). Inside Kolgrafafjord there was more freshwater influence. The salinity there was more variable, mostly between 33.5 and 34.5 ‰. At the release site, the salinity was even lower at times and measured below 33 ‰ in two of the surveys (in June and July).

As expected, visible radiation decreased during the period studied. The total daily radiation was highly variable, and double or half the radiation of the adjacent day was not uncommon (Fig. 3a). As the light intensity influenced the behaviour of the postsmolts, i.e. the vertical distribution (see paper II in this series) the visible radiation for each hour is shown separately for the days 7-11 August 1993, the days of the most intense fishing (Fig. 3b).

The visibility decreased from about 12 m, Secchi depth in April to about 8 m in May at the shallower stations and was between 7 and 9 m for the rest of the study period (Fig. 4). At the deeper stations, the Secchi depth did not decrease below 10 m until late June.

The volume of zooplankton at each station in all cruices is shown in Figure 5. At all stations except the deepest one (St. 19), there were two clear maxima in zooplankton volume. The first maximum was in early May and the second, and larger

Table I. The number of zooplankton animals at stations 6 and 19 in May, June and August 1993. Zooplankton animals as small as *Calanus finmarchicus* St.III or smaller are grouped together as small animals, *C. finmarchicus* St. IV and larger animals are grouped as large animals. (L) stands for larvae. Copepoda (small) are *C. finmarchicus* st III or smaller copepoda and copepoda (large) are *C. finmarchicus* st IV or larger copepoda.

Date:	**1 May**		**21 June**		**10 August**	
Station:	**6**	**19**	**6**	**19**	**6**	**19**
Cirripedia (L)	3,423	238	1,719	6	950	2,995
Cladocera	14	0	3,135	2	7,242	99
Polychaeta (L)	32	6	0	0	0	0
Gastropoda (L)	4	18	177	0	297	253
Copepoda (small)	832	263	8,666	369	7,486	2,726
Total of small animals:	**4,305**	**525**	**13,697**	**377**	**15,975**	**6,073**
Copepoda (large)	26	10	54	209	2	2
Euphausiacea (L)	14	0	5	0	2	0
Decapoda (L)	30	8	2	16	2	2
Fish eggs	0	15	0	0	0	0
Fish larvae	330	172	1	1	1	0
Total of large animals:	**400**	**205**	**62**	**226**	**7**	**4**

one, in late June. Station 19 differed from all the other stations in two respects. Firstly, there was no minimum in zooplankton volume in early June, secondly, very low values were observed during July through September.
Table 1 shows the main categories of the zooplankton in May, June and August. The samples are from the opening of Kolgrafafjord (St. 6), and from the deepest station (St. 19). The larger zooplankton species, presumably of suitable size for the salmon postsmolts (Sturlaugsson 1994), were relatively common during May and June. During the most intense fishing for postsmolts in August, however, there were very few large zooplankton animals and the zooplankton was dominated by small copepods and cladocera (Table 1).

Discussion

Frequent strong winds and large tidal waves keep the waters in Breidafjord relatively well mixed at all times. In the study area, the well mixed waters in the uppermost 30 m, makes it unlikely that differences in temperature or salinity interfered much with the behaviour of the salmon postsmolts except possibly inside Kolgrafafjord proper. On the other hand, the intensity of light interfered with the vertical distribution of the salmon postsmolts (see paper II in this series). Tidal currents, which probably do influence the migration, were not measured.

External data on zooplankton volumes to compare with the present results is limited, but low zooplankton values were reported close to West-Iceland in May-June in the annual spring survey conducted by the Marine Research Institute, Reykjavik (Anon. 1993). In the present material there was a minimum in zooplankton volumes at most stations at about the same time (early June).

The limited study on the composition of the present zooplankton samples indicate that more prey of suitable size (Sturlaugsson 1994) is available for the salmon postsmolts in May-June, than later in the summer. This may have influenced the stomach contents of the salmon postsmolts (see paper III in this series).

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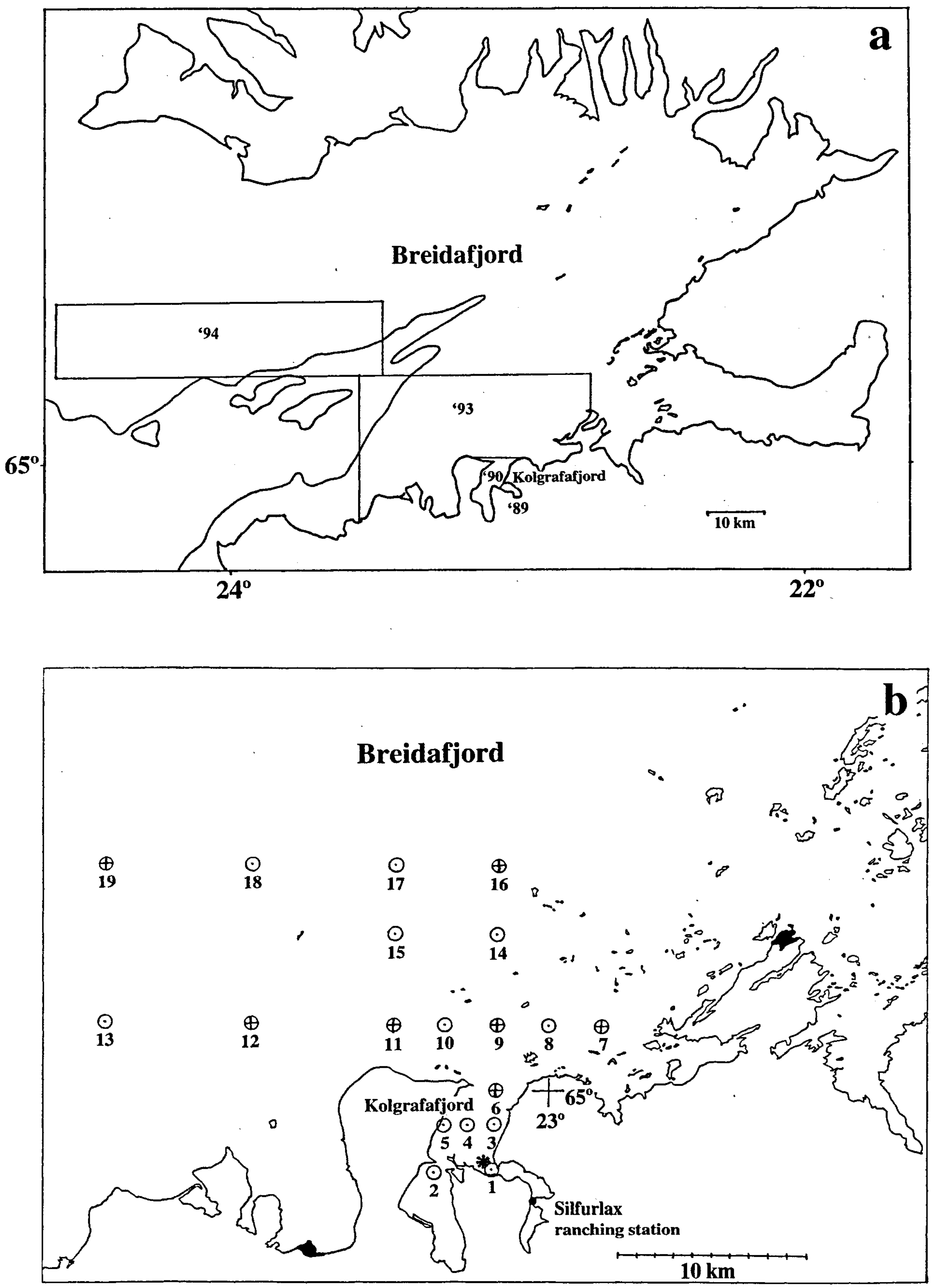


Figure 1. a) Map of Breidafjord West Iceland. The main sampling areas of different years are shown. Each year, some additional sampling was done in the area of the previous year. b) Map of the sampling area 1993. * = release site of salmon postsmolts. 1-19 = sampling stations for environmental data. ⊕ = zooplankton sampling.

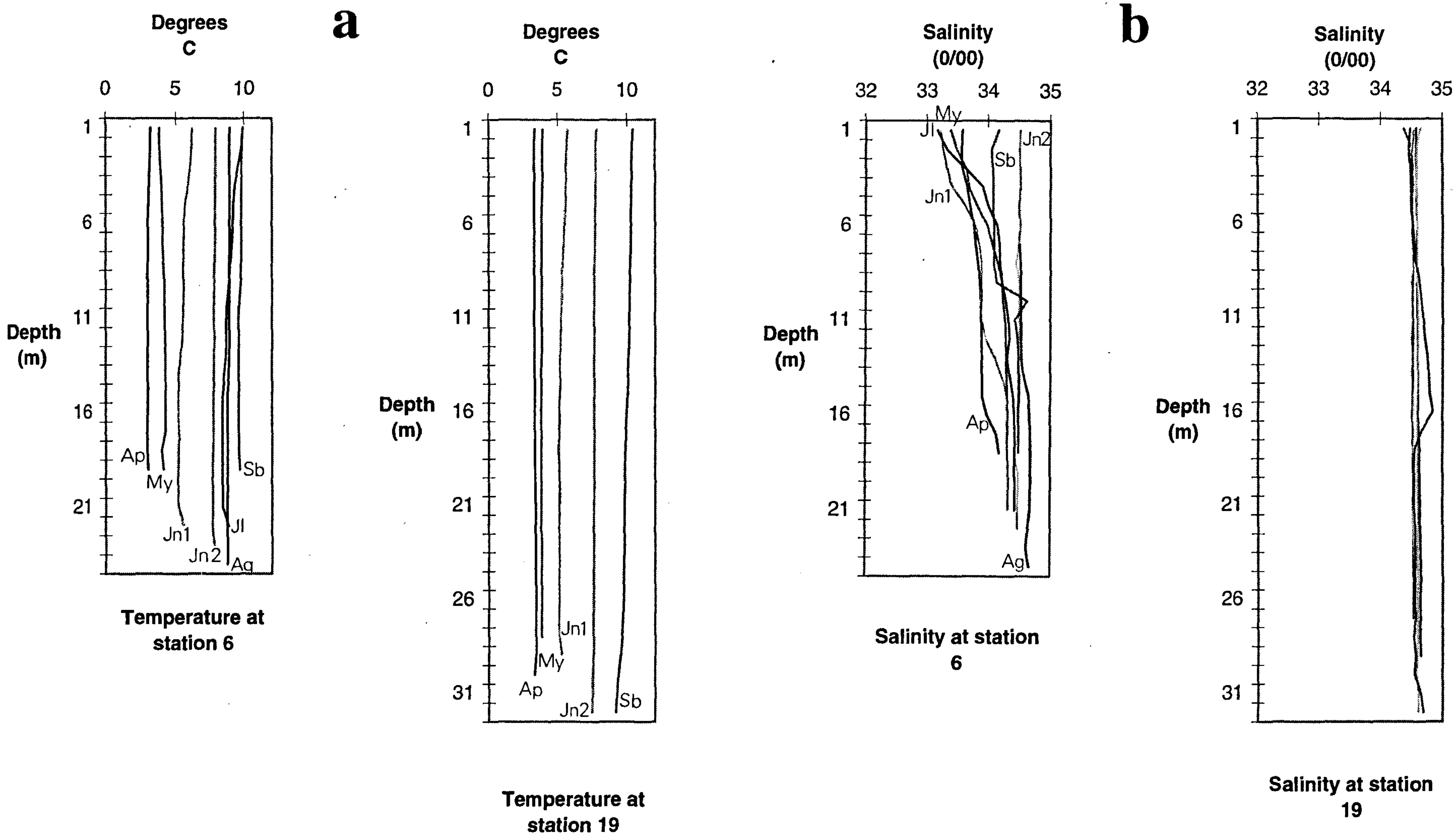
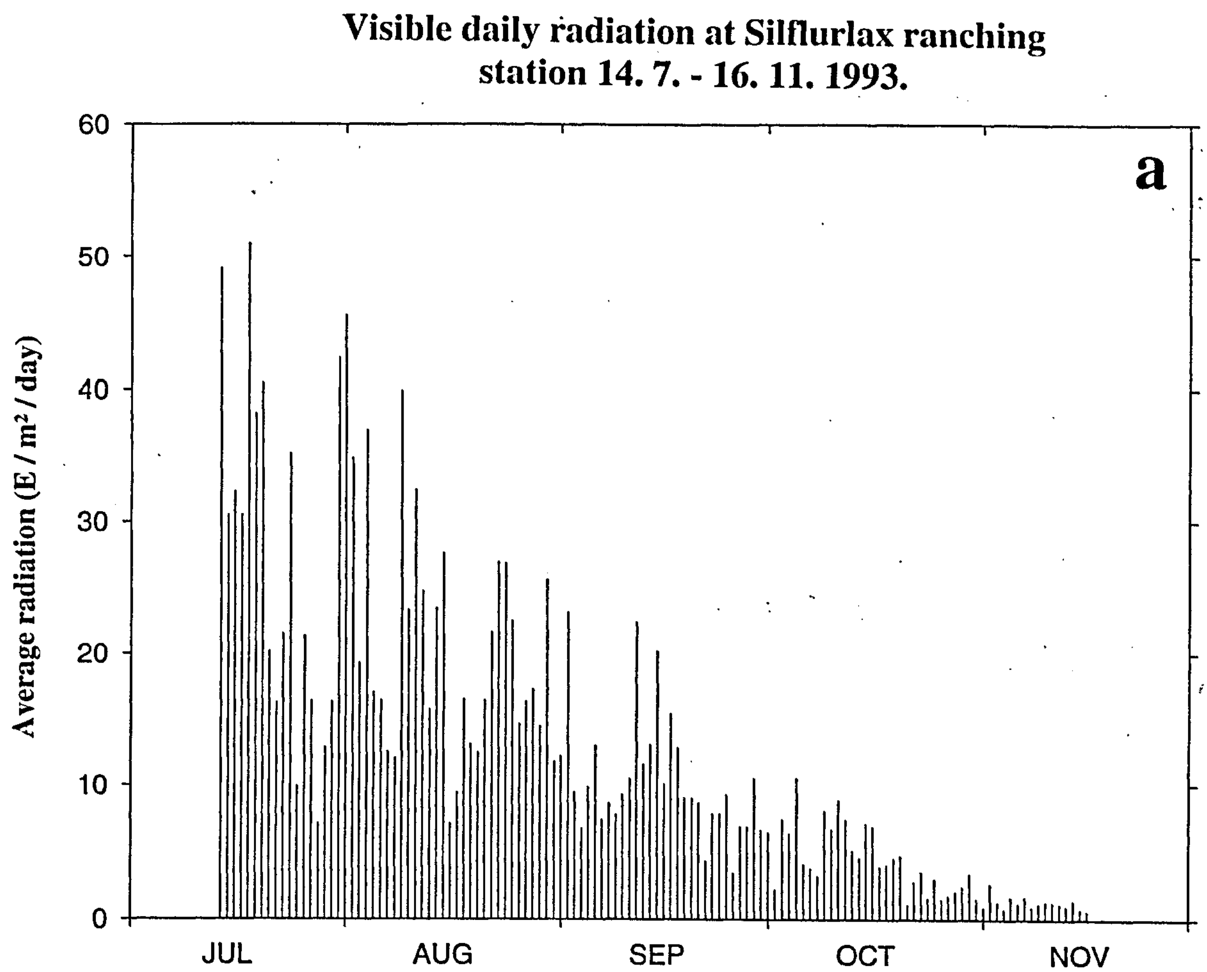


Figure 2. a) Temperature profiles at stations 6 and 19 at different sampling dates in 1993. b) Salinity profiles for the same stations. Due to the close similarity of the profiles at station 19 individual labelling was not possible. Ap = 9 April, My = 1 May, Jn1 = 2 June, Jn2 = 21 June, Jl = 13 July, Ag = 15 August and Sb = 3 September.



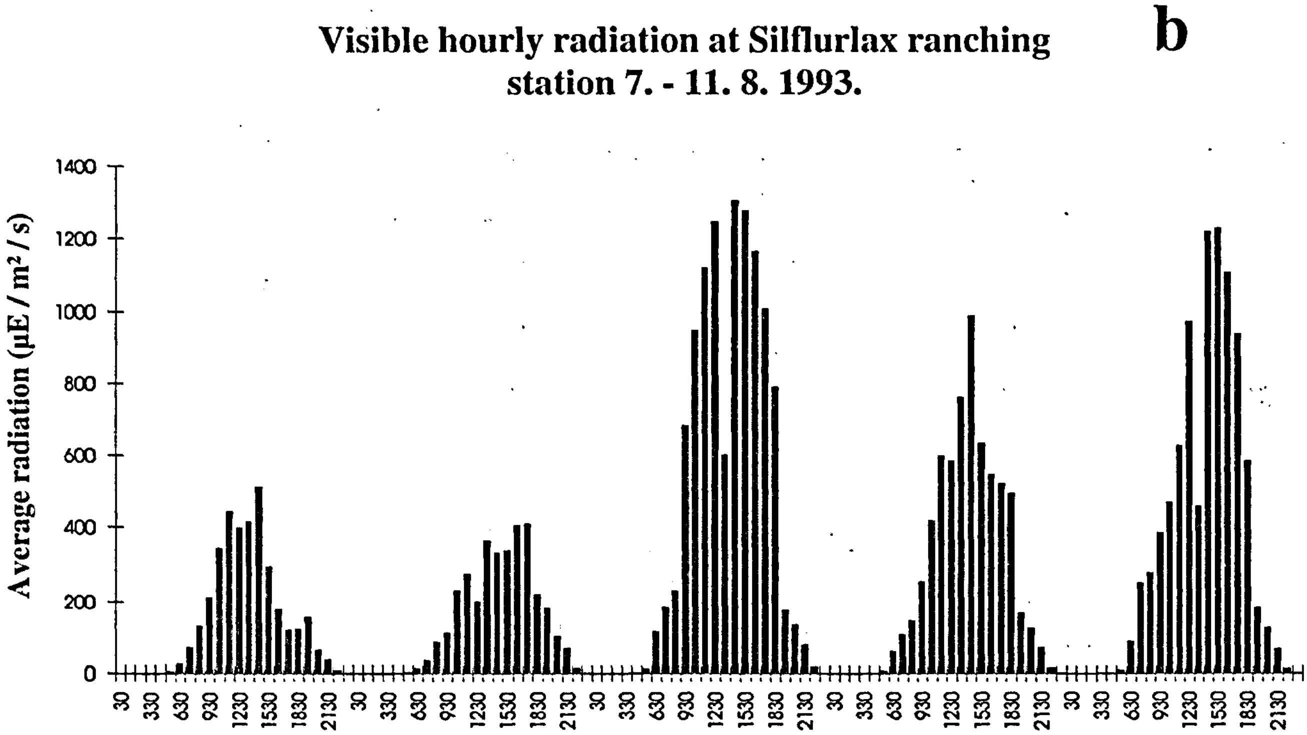


Figure 3. a) Visible radiation at the Silfurlax ranching station 14 July through 16 November 1993. b) Hourly radiation during 7-11 August.

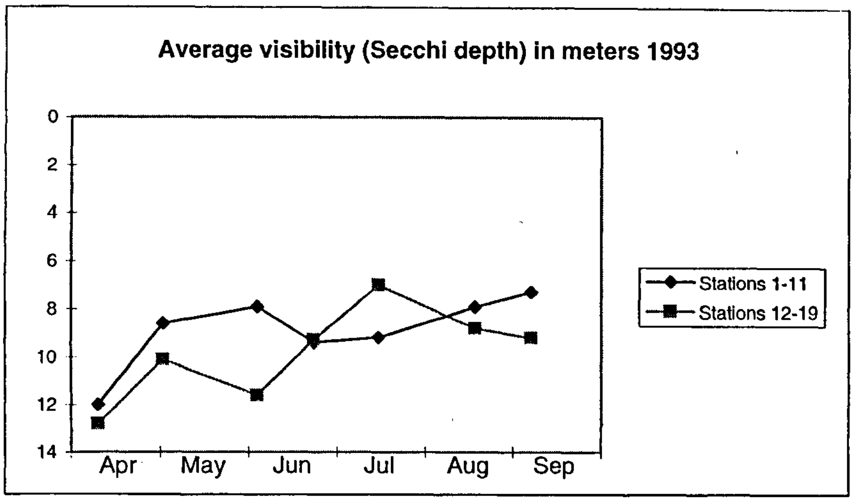
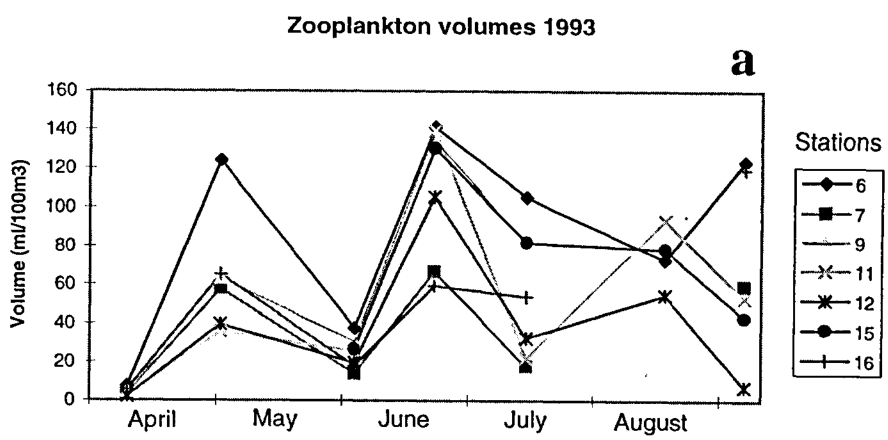


Figure 4. Secchi depth in meters during the study period in 1993. Averages of shallower stations and deeper stations are shown separately.



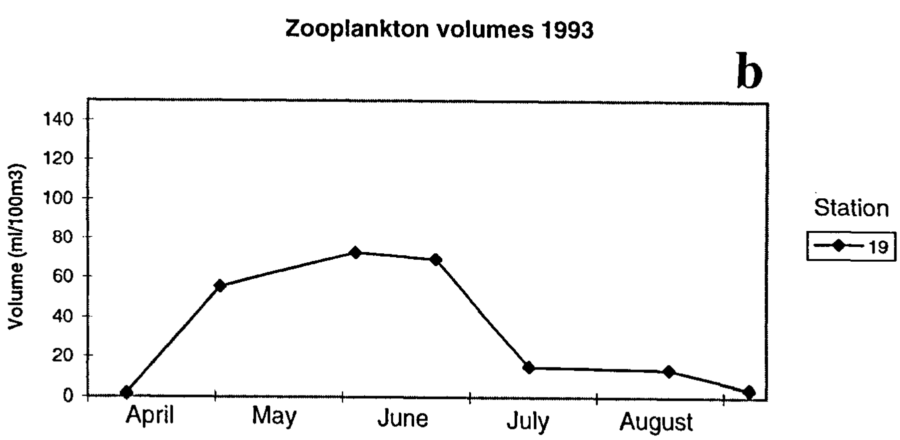


Figure 5. Zooplankton volumes (ml/100m³) at each station at different sampling dates. Station 19 is shown separately in b).