

Diurnal variations in the diet of 0 to 3 years old Atlantic salmon *Salmo salar* L. under semiarctic summer conditions in the Alta River, Northern Norway.

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The stomach contents of 0 to 3 year old salmon were investigated throughout a single 20 hour period in each of July, August and September 1981. There was no marked diurnal variation in stomach content of fry, while that of parr indicated nocturnal maxima in all three months. In July and August there was a significant increase from evening to night. In September there was a significant increase from mid night to early morning (0400). The amount of food in the stomachs decreased from July to September during both day and night. There was only a weak correlation between diurnal drift and food content.

Chironomidae and Ephemeroptera were the most important food items by volume in July, and Chironomidae in August. Increasing food content during the night in August was mainly caused by increasing content of Chironomidae larvae.

Ephemeroptera was the most important food item by volume in September. Increasing food content during night in September was mainly caused by Ephemeroptera.

The number of Chironomidae and Ephemeroptera ingested indicates greater feeding activity during the night in July—August by juvenile salmon in Alta River. The other food items showed only small diurnal variations (by number) in all three months.

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INTRODUCTION

Few studies have been made of the diurnal variations of feeding by young *Salmo* spp. in arctic and subarctic regions (Amundsen 1984), and no work has been published on diurnal feeding patterns of young salmon *Salmo salar* (L.) in Norway north of the Arctic circle. Most studies of the diurnal feeding patterns by freshwater fish are based on temporal changes in stomach content (Keast & Welsh 1968, Elliott 1970, Elliott & Persson 1978, Nakashima & Leggett 1978).

The aim of this study was to study diurnal feeding patterns at different times of the season in Alta River, the influence of semiarctic summer conditions and the influence of animal drift. The study was made during July, August and September 1981.

THE STUDY AREA

This study was carried out in Alta River (69° 30'N, 21° 30'E) in the county of Finnmark (Fig. 1). The sampling station lies about 45 km from the mouth

of the river, near the upper limit for salmon. The river follows a narrow, steep sided valley covered with birch. The river shores at the station were stony, partly covered with willow. The locality lies in the middle boreal vegetation zone.

Young salmon were collected in a riffle (Svartfossen) downstream from a deep pool. The bottom substrate was coarse, consisting mainly of stones up to 30 cm in diameter, and with some gravel. The stones were sparsely covered with mosses or algae. The current speed varied between 0.2 and 1.0 m/sec, and the depth at the sampling site varied between 0.1 and 0.6 m.

During July 1981, the water temperature increased from 8.5°C to 14°C, the latter being the maximum of the year. In mid August the water temperature was about 1°C lower. On 17—18 September the temperature was about 8°C (Fig. 2). Differences between morning and evening temperatures did not exceed 1°C.

At this latitude there is midnight sun between 20 May and 27 July, and nights are light for more than three months (May to August), i.e. for a large part of the young salmon growth season which is from

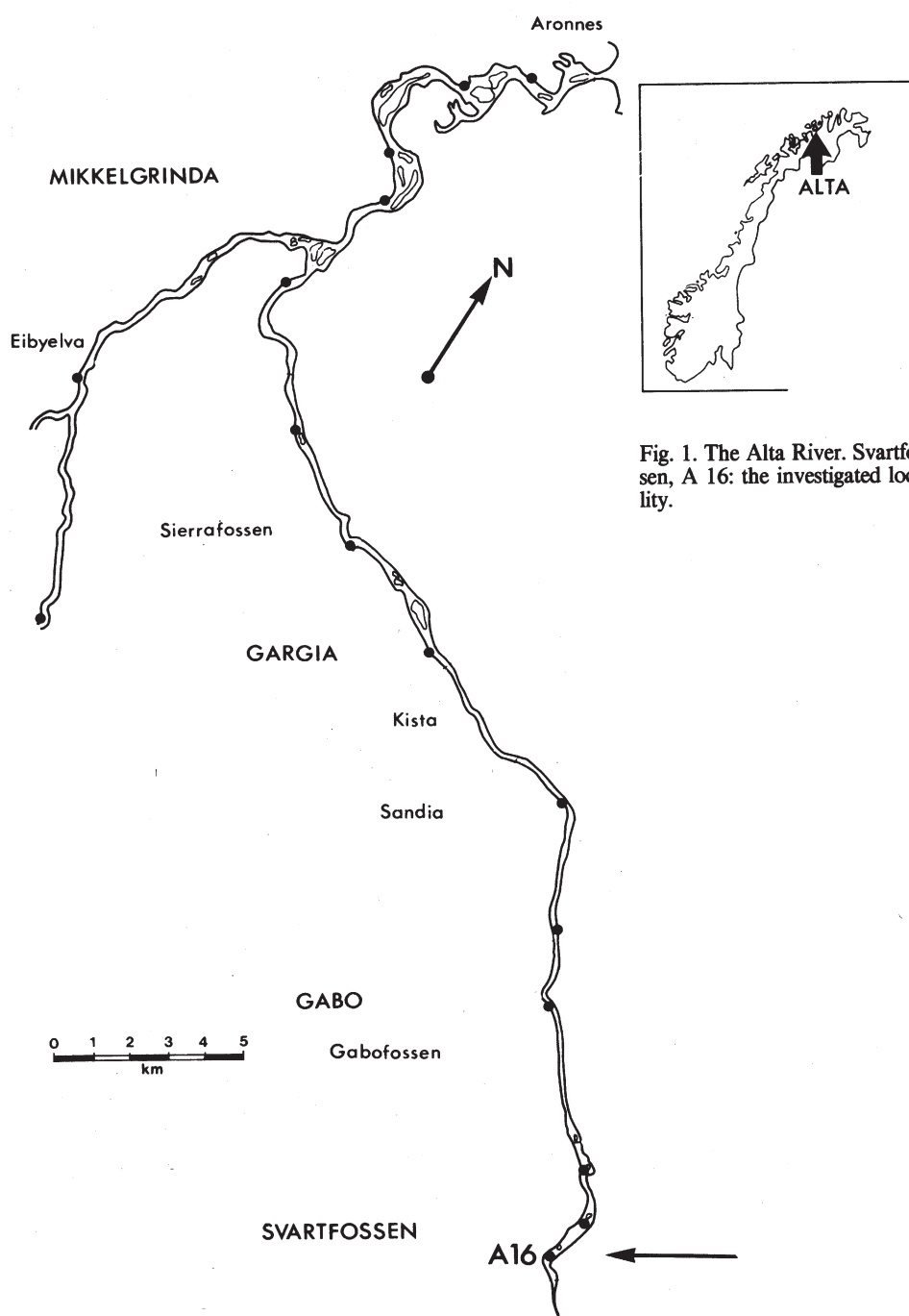


Fig. 1. The Alta River. Svartfossen, A 16: the investigated locality.

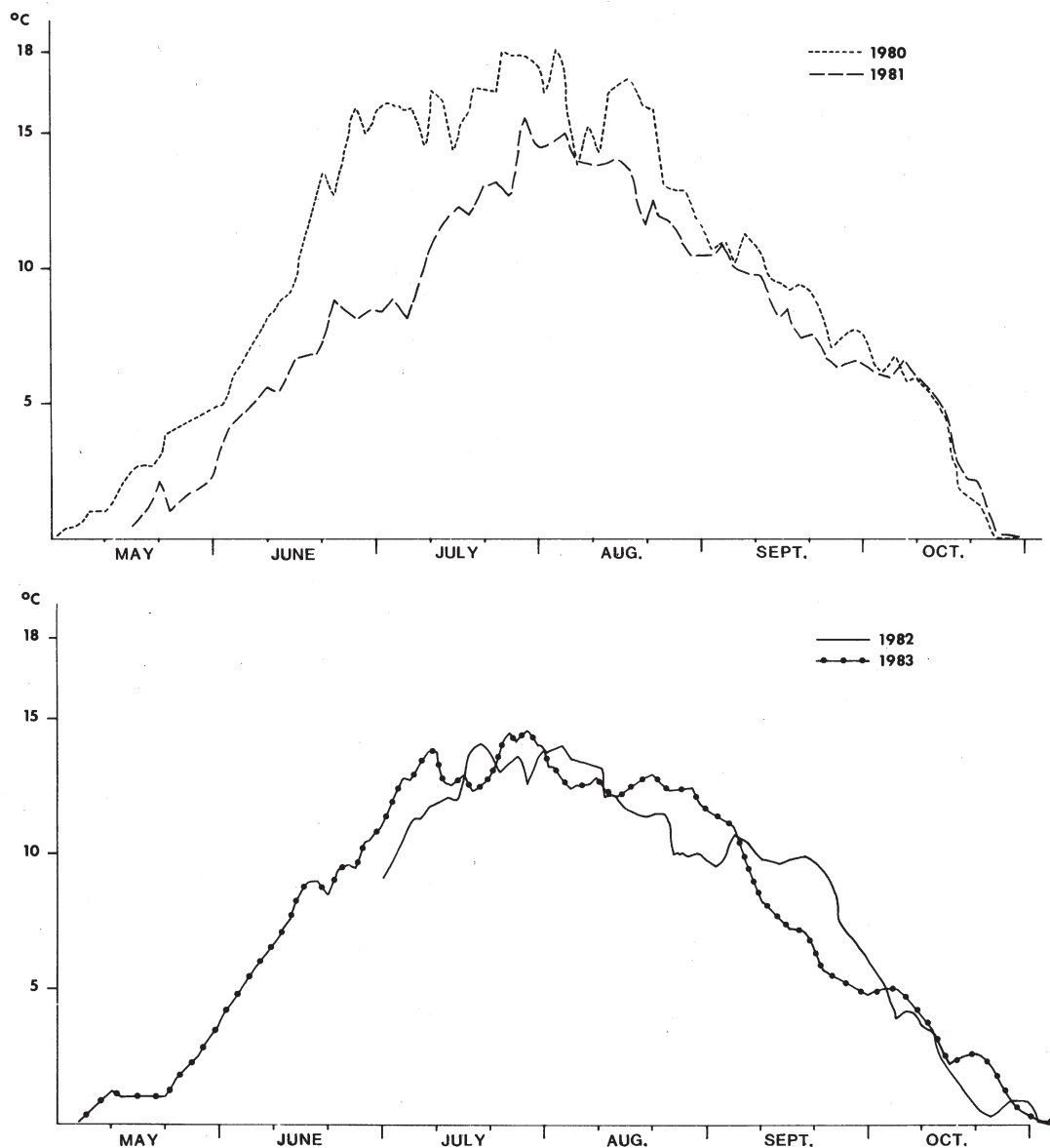


Fig. 2. The water temperature in Alta River, at station Gargia (see Fig. 1) in 1980—1983.

June to September (Heggberget et al. 1984). In July, the mean day length (time between sunrise and sunset) was 23 h. In August it was 18 h with a short period of dusk. On 17—18 September the day was 14 h long with a dark period of ca. 4 hours, and a short dusk and dawn.

During the summer of 1981, the flow of water was high compared with a normal summer. Only in September had the flow fallen to values near normal. The volume of discharge fell from 150 m³/sec.

on 27 July to 110 m³/sec. in August and to 70 m³/sec. on 17 September.

MATERIAL AND METHODS

Up to 40 salmon fry and parr were collected using an electric fishing apparatus for ca. 1/2 hour every four hours during single 20 hour periods in July, August and September 1981. Totally, 448 fishes were collected and analyzed. During the September

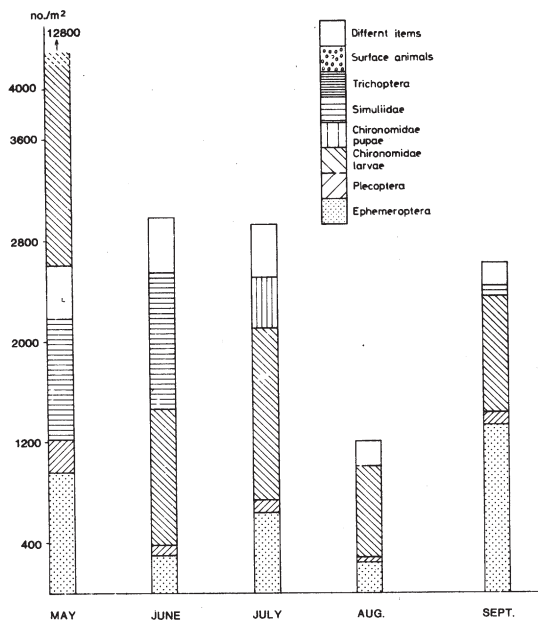


Fig. 3. The density in number/m² and composition of bottom fauna at station A 16 in 1981.

night it was necessary to use head-lights while fishing. The fish were immediately preserved in 96% alcohol. The age of the young salmon was determined by the inspection of otoliths (Heggberget et al. 1984). The abdomens of 2-year old and older fish were opened to ensure complete conservation of the stomach contents. Samples of drifting animals

in the river were collected using a net with mesh size of 250 μ m. One-hour samples of drifting animals were taken during the sampling days. Bottom fauna was collected by a standard travelling kicking method (Pollard 1981) with a net with mesh size of 250 μ m (Fig. 3).

The evening samples were collected between 2000h and 2100h, the night samples between 2400h and 0200h, the morning samples between 0400h and 0800h and the day samples between 1000h and 1600h.

Stomach contents were analyzed both volumetrically and numerically. The volumetric content of food in each stomach ranged from empty (0% food), through filled (100%) to expanded stomach (set to 125% of a filled stomach). The amount of each food item was measured volumetrically and quantified as the percentage of total food content in each stomach. Food items were identified and counted, Ephemeroptera and Plecoptera were identified to genus or species and counted.

The significance of differences was tested using the chi-square test. The differences are significant when $p < 0.05$.

RESULTS

The degree of stomach fullness

The amount of food in the stomachs and the percentages of empty stomachs in all fish caught are shown in Fig. 4. At all sampling times, the coefficient of variation (CV) was about 30% (14–43%) for fry and parr (Fig. 4). The fry usually had most food in their stomachs during the day, but the standard deviation (SD) exceeded the differences between

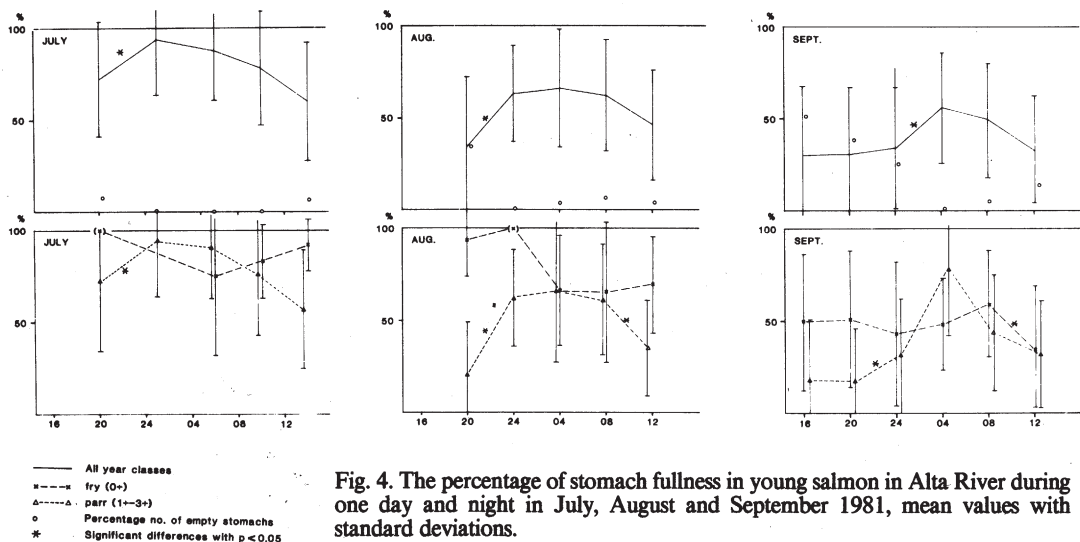


Fig. 4. The percentage of stomach fullness in young salmon in Alta River during one day and night in July, August and September 1981, mean values with standard deviations.

Table 1. The mean values for all year classes of stomach fullness in July to September. $p=*$, significant differences with $p<0.05$.

Month	July	Aug	Sept
n	151	173	205
Vol. %	79	54	37
S.D	32	34	34
p		*	*

day and night. The stomach fullness in parr (1+—3+) was greatest during the night, and significant differences were registered in all three months in spite of a CV of ca. 30% (Fig. 4). The mean values for all year classes were similar to the mean values for parr (1+—3+).

The maxima in food content seemed to last longer in July and August (2400h—0900h) than in September. The number of empty stomachs was low (maximum 7%) in July. In the August evening it was 35%, and reached a maximum of 50% in September. The curves for empty stomachs were inverse to the fullness curves in August and September (Fig. 4). The stomachs contained less food in August than in July, still less in September (Table 1).

Stomach content

Volumetric values

In July and September, Ephemeroptera were the most important food items by volume for fry, and Chironomidae larvae were most important in August. No marked differences between day and night could be registered, partly due to low number of some year classes caught. The composition of food in parr (1+—3+) was more or less like the mean values for all year classes. The mean values for all year classes show that in July, Chironomidae and Ephemeroptera were the most important food items (Fig. 5). The increase during the night in July was mainly caused by increase in Chironomidae larvae.

For all fish caught in August, Chironomidae larvae were the most important food type, while Ephemeroptera were less important than in July. The increase in stomach content from 2000h to 0400h was almost wholly due to an ingestion of Chironomidae larvae. Unidentified food items increased from early night to morning, possibly as a result of digestion without food intake.

For all fish caught in September, ca. 50% of the food were Ephemeroptera. A higher degree of sto-

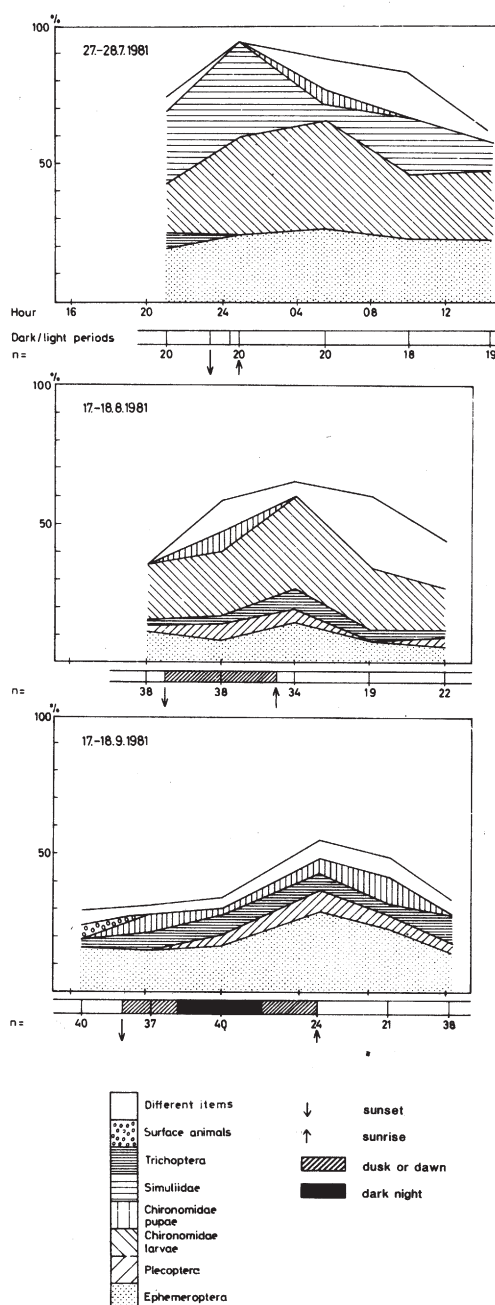


Fig. 5. The percentage composition of stomach content in young salmon in Alta River during one day and night in July, August and September 1981, mean values of all year classes.

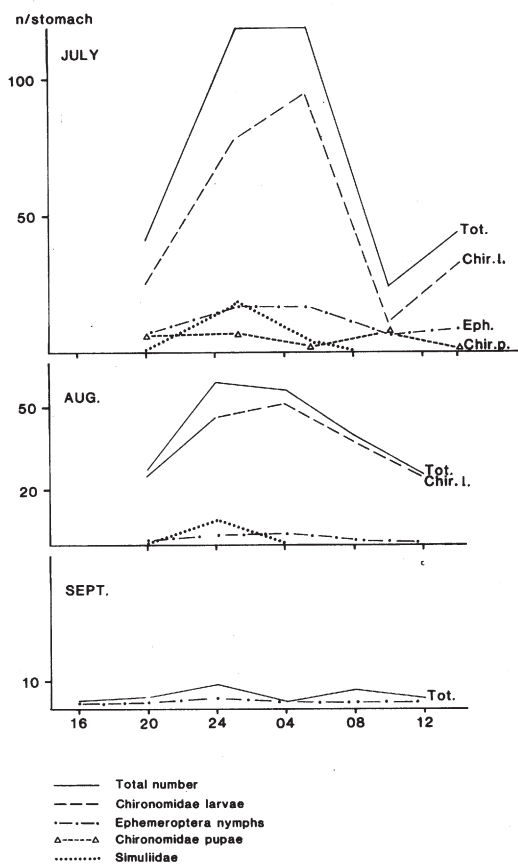


Fig. 6. The number of food items/stomach in young salmon in Alta River during one day and night in July, August and September 1981, mean values of all year classes.

mach fill during the night was caused by larger amount of Ephemeroptera. The variation in stomach content was mainly caused by variations in the amount of Ephemeroptera.

Numerical values

Chironomidae larvae were the most numerous food item in July and August, and Ephemeroptera larvae were most numerous in September. The number of food items eaten fell drastically from July to September (Fig. 6). The number of Chironomidae and Ephemeroptera ingested was significantly higher during the night than during the day in July and August ($p < 0.05$). These differences were greatest in July. *Baetis* spp. (mostly *Baetis rhodani* (Pictet)) were the dominating Ephemeroptera species in July—August. The differences in number/stomach

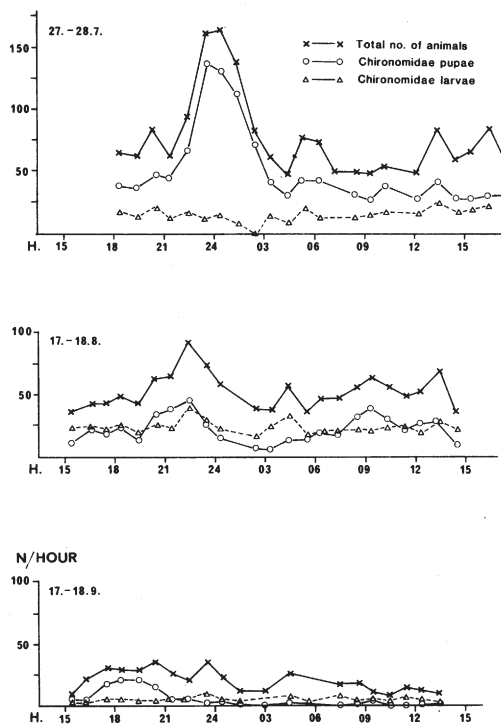


Fig. 7. The number of drifting animals/hour during one day and night in July, August and September 1981.

from day to night in September were, in most cases, not significant.

Other food items were usually found in low numbers per stomach.

Relation to animal drift

The invertebrate drift in the Alta River consisted mainly of small chironomid larvae, pupae and imagoes, and small Ephemeroptera nymphs (Fig. 7). There was a great increase in numbers of drifting chironomid pupae and imagoes between 2200h and 0200h, but only a weak increase in their frequencies in the stomachs. In August, there was also an increase in drifting chironomid pupae around midnight, and these were almost solely found in the stomachs at midnight.

In September no relationship between stomach content and animal drift could be demonstrated.

DISCUSSION

In most of the samples, the food contents varied greatly, resulting in a coefficient of variation around 30% (Fig. 4). Such large individual variations in

stomach content have been registered in other fish species (Keast & Welsh 1968, Jenkins & Green 1976) and make it difficult to register general diurnal trends. It is also possible that different age classes have different diurnal feeding activity. The results from Alta River indicate that fry and parr differed somewhat, the latter having clearer nocturnal maxima. Different feeding behaviour has previously been registered in younger and older trout (Bachman 1984).

Two important factors affect the feeding pattern, light and temperature (Brett & Higgs 1970, Elliott & Persson 1978, Windell 1978). The difference in water temperature between August and September was 6°C. In Alta River, the parr starts feeding in May at near 0°C (in May 1981 the stomach fullness was 40–90% (Huru 1984)), suggesting that even at low water temperatures, salmon fry and parr feed when food is available (Lillehammer 1973). The total amount of food ingested fell from July to September during both the day and night. At the same time, the water temperature fell 6 degrees, and animal drift was greatly reduced. In this period, the density of bottom fauna was lowest in August (Fig. 3). All these factors can affect the ingestion rate and feeding activity. The changes from August to September can be an effect of lower water temperature.

But the amount of food ingested also fell from July to August, without a concurrent lowering of water temperature. This can be an effect of lower density of bottom fauna in August, and that small Chironomidae predominated.

Several salmonid species have diurnal feeding rhythms (Elliott 1970, Doble & Eggers 1978, Godin 1981), while others are active both during day and to a lesser degree, the night (Hoar 1942, Kalleberg 1958, Elliott 1967, Jenkins 1969, Mundie 1971, Bisson 1978). Kalleberg (1958) observed that during light nights the feeding activity continued during night. Both the degree of stomach fullness and the number of food items eaten by parr (Figs. 4, 6) indicate a higher feeding activity during the light nights than during the day in July and August. In September, a maximum during the night was only registered in stomach fullness, but not in the number of food items eaten. Thus, a supposed maximum in feeding activity during night in September seems to be speculative. During the September night, fish could be caught in a slow flowing part of the river, but not during the day. This might be a behavioral movement for feeding. The stomach fullness and the number of food items eaten by fry showed no diurnal variations, indicating that the fry in Alta river feed continuously during both day and night.

However, changes in light condition seem to

affect the number of empty stomachs (Fig. 4). A decreasing number of empty stomachs during the September evening-night indicates a somewhat higher feeding activity during night.

Investigations of fish species at high water temperatures under arctic summer conditions showed either a maximum in food content at daytime, or an irregular diurnal pattern (three-spine stickleback) due to satiation/evacuation (Girsa 1975). On the other hand there were no diurnal variations in food intake in a dense population of lake living Arctic charr in Northern Norway (Amundsen 1984).

Several authors have found a good correlation between diurnal changes in animal drift and the diet (Macioleks & Needham 1952, Elliott 1967, 1970, Metz 1974), while Chaston (1969), Mundie (1969, 1971), and Bisson (1976, 1978) found only poor correlation between feeding rates, prey and invertebrate drift. Rainbow trout fry *Salmo gairdneri* Richardson, feeding during day in a large river below a lake, attacked drifting organisms far more frequently than substrate-associated organisms (Irvine & Northcote 1982).

My study showed only a weak correlation between drift and diet. Alta River is a big, relatively fast running river. In such a river, a great part of the drifting organisms will not be available to the juvenile salmon. Young salmon in Alta River seem to feed more off the bottom than drift. The higher number of food items/stomach during the night (Fig. 6) is more a result of higher feeding activity than changes in available food.

Both the volumetric content of food and the number of food items eaten by parr in July–August indicate a higher feeding activity during night. During most of the feeding season, the nights are light enough to enable feeding. This gives the fish the possibility to choose the feeding time and feeding rhythm, on condition that there is sufficient food.

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