LFI-rapp. nr. 13

Norwegian Journal of ZOOLOGY

VOL. 21, NO. 2, JUNE 1973

REPRINT

R. Borgström

The Effect of Increased Water Level Fluctuation upon the Brown Trout Population of Mårvann, a Norwegian Reservoir

UNIVERSITETSFORLAGET

Contribution No. 110, Zoological Museum, University of Oslo

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REIDAR BORGSTRÖM

Borgström, R. 1973. The effect of increased water level fluctuation upon the brown trout population of Mårvann, a Norwegian reservoir. *Norw. J. Zool. 21*, 101–112.

Increased lowering of the water level of Mårvann, a Norwegian high mountain reservoir, during the winter 1969/70 resulted in an especially low water level the following summer. Heavy erosion of the exposed bottom took place and the turbidity increased considerably from 1969 to 1970. During 1971 and 1972 the water level again fluctuated within the previous limits and the turbidity gradually decreased. In the years 1970–72 the yield of trout (*Salmo trutta* L.) in the main reservoir fell almost to zero. This was probably due to increased mortality, caused by an inadequate food supply, and increased emigration of trout to the clear water zones situated out from the main inlets. The reasons for the disappearance of the main food item, *Lepidurus arcticus* (Pallas), are discussed.

Reidar Borgström, Zoological Museum, Sars gt. 1, Oslo 5, Norway.

INTRODUCTION

Huitfeldt-Kaas (1906) stated that lakes filled with considerable quantities of ooze, in particular lakes fed from glaciers, are relatively poor in plankton, and as shown by Murphy (1962) turbidity negatively affects the productivity of an aquatic environment through the control exerted on the effective energy available for photosynthesis. According to Aass (1970) increased turbidity of lakes subject to artificial regulation may lead to serious reductions in fish stocks. This may be caused either by reduction of available food animals, increased fish mortality or an increased emigration of fish from waters which suddenly become ooze-filled. The latter situation was observed in the Hallingdal river (Jensen & Aass 1968).

In 1960 an extended regulation of Mårvann, a Norwegian high mountain reservoir, was carried out. The increased lowering of the lake resulted in increased turbidity, and according to the local fishermen the yield of trout (*Salmo trutta* L.) decreased immediately. The following year the suspended ooze disappeared and the yield of trout improved in subsequent years. During the winter 1969/70 the lake level of Mårvann was lowered even further, and during the summer 1970 the water level still remained unusually low, not reaching the previous lower limit. Melting water, wave action and rivers making new beds in the exposed bottom led to a considerable erosion which resulted in a large increase in water turbidity.

Many authors have described quantitative and qualitative reductions in the bottom fauna caused by water level fluctuations (e.g. Grimås 1961, 1962), and some bottom animals important as food items for fish may disappear or become rare, while others may increase in importance (Nilsson 1961).

It was therefore expected that the increased water level fluctuation of Mårvann in 1969/70 combined with increased turbidity would have serious effects upon the trout population. With reference to this the trout population of Mårvann has been studied, with special emphasis being given to the feeding habits and the condition of the trout.

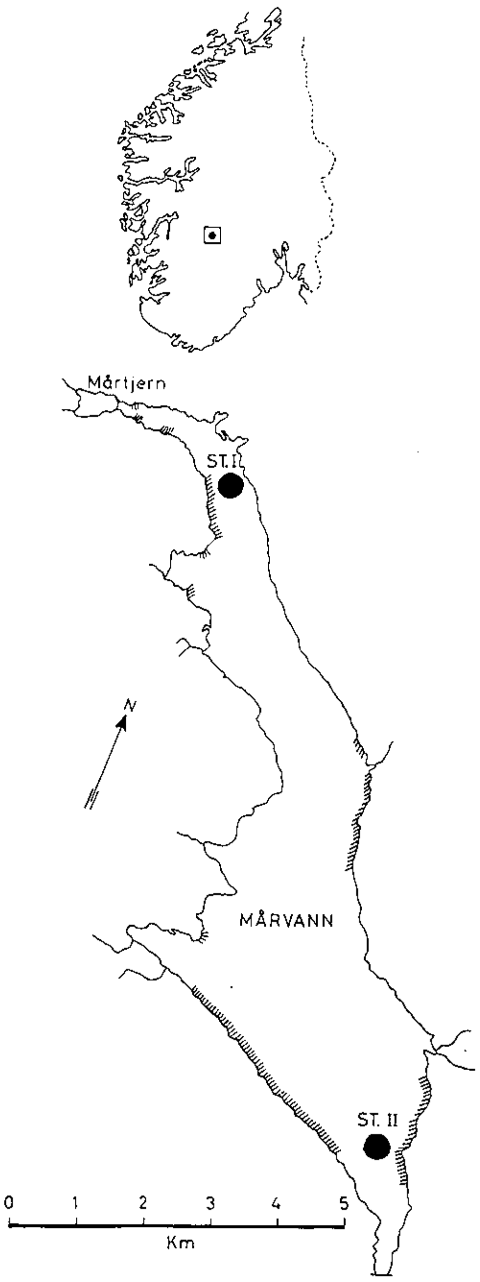

Fig. 1. Location map and map of Mårvann showing the stations where transparency measurements and water samples were taken. The shore lines where netting was performed are indicated by hatching.

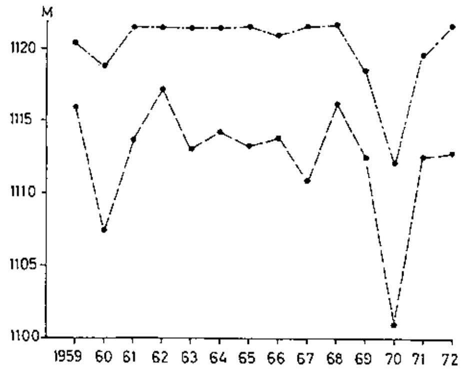

Fig. 2. Highest —·— and lowest ——— annual regulated water level (metres above sea level) in Mårvann during the period 1959–1972.

DESCRIPTION OF MÅRVANN

Mårvann is situated in the south-eastern part of Hardangervidda in the county of Telemark, approximately at 60°8′N, 8°13′E (Fig. 1). The lake was first regulated in 1917. Until 1959 the water level fluctuated between 1,121 and 1,113 metres above sea level, that is, with a maximum vertical amplitude of about 8 metres. The natural lake level was at about 1,115 metres above sea level. At maximum impoundment the reservoir covers an area of 20.2 km².

In 1959 an additional lowering of the lake level was made possible, with a new lower limit at 1,100 metres above sea level. This new limit has, however, never been reached – annual fluctuations with exceptionally low water levels have only occurred twice, in 1959/60 and 1969/70 (Fig. 2).

The bottom area influenced by the previous regulation consists mainly of stone, gravel and sand, except in some small areas where finer sediments may occur. Below the previous lower limit the bottom sediments generally consist of gyttja. At the innermost part of the north-western end of Mårvann the vertical amplitude of the water level is only a few metres due to a natural threshold. As a result this area (Mårtjern) is only connected with the main reservoir at high water levels. During the period 1969-72 this happened in the autumn

Table I. Temperature conditions in Mårvann (St. II)

Depth, metres	11.8.69	27.6.71	28.9.71	Date 20.6.72	2.7.72	11.8.72	30.9.72
0	12.4	5.5	7.9	3.1	7.1	9.8	7.1
2	12.5	–	–	3.0	7.1	9.8	7.1
5	12.0	5.1	7.9	3.0	6.1	9.8	7.1
10	10.9	5.0	7.8	3.0	5.3	9.6	7.1
15	9.8	4.9	7.8	3.0	5.2	8.8	7.1
25	8.8	4.7	7.8	3.0	5.0	7.7	7.1

1972. Mårvann and its catchment area is situated on gneiss-granitic bedrock, which manifests itself in the low electrical conductivity (9.2-15.0 μS/cm), the low calcium content (0.83 mg/l) and the low pH (6.4–6.6) of the lake water (all analysis of surface water in the period August 1969-September 1971). The temperature conditions of the reservoir are given in Table I.

Trout (*S. trutta* L.) is the only fish species present. The outflow from Mårvann empties into Kalhovdfjord Reservoir about 1 km to the south. This impounded lake is situated at an altitude of 1,084 metres and has a maximum vertical amplitude of about 7 metres.

TRANSPARENCY CONDITIONS IN MÅRVANN

The transparency conditions (Secchi disc measurements) of the lake are given in Fig. 3. In August 1969, before the increased lowering of the lake level, the transparency was 9 metres at the southern end (St. II). After the considerable erosion during spring and summer 1970 the turbidity increased and in October the transparency was only 0.3 metres. The turbidity gradually decreased during 1971 and 1972, and in August-September 1972 the transparency was nearly equal to that observed in August 1969.

At its north-western end Mårvann turns westward and at the same time becomes very narrow. This part of the lake, which has its inflow from Mårtjern, is thus little influenced by the wind and wave conditions existing in the main reservoir. Probably due to this, the transparency here was more than 4 metres (Secchi disc at the bottom) in June 1971, while it was only 1 metre at St. I and St. II.

MATERIAL AND METHODS

Only monofilament nylon nets with a depth of 1.2 m and a length of 24 m were used to obtain trout from Mårvann. The same shorelines were fished in each netting period (Fig. 1). Two nets, usually of the same mesh size, were set together in a line from the shore outwards. Only overnight netting was carried out. Tables

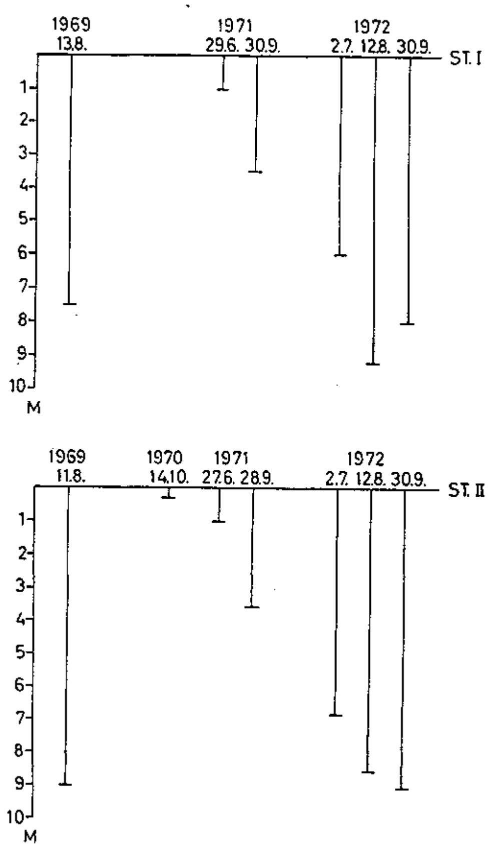

Fig. 3. Transparency conditions (Secchi disc measurements) at St. I and St. II in Mårvann.

Table II. Number of nettings (net-nights) of each mesh size

Mesh size mm	No. of nettings					
	1969	1971		1972		
	8–16/8	25/6–1/7	28–30/9	1–3/7	8–12/8	28–30/8
20	3	6	3	8	4	6
23	3	8	6	8	4	6
26	3	8	6	8	10	6
32	5	6	3	8	8	6
35	5	8	6	8	8	6
39	23	14	13	8	8	6

II and III give the netting periods and the number of net-nights of each mesh size used in the main reservoir and at the inlet from Mårtjern.

Immediately after trout collection length and weight measurements were taken, and the contents of the oesophagus and stomach removed and preserved in alcohol. The volume of the stomach (oesophagus and stomach) contents was estimated according to Hynes point method (Hynes 1950).

The condition factor, $K = W \times 100/L^3$ (where W = weight of fish in grams and L = total length of fish in cm) was calculated for each fish, and the mean value of different length groups determined. The condition factor (K) will be influenced by the fish's length, sex and stage of maturity, fullness of stomach, etc. (Sömme 1944, Nilsson 1955), but this is taken into account to a certain extent and only fish within limited length groups are compared.

The stage of maturity of the trout was determined according to the classification used by Dahl (1917).

As Kalhovdfjord Reservoir was not subjected to abnormal regulation during 1970-72, stomach contents of trout from this reservoir were also examined as a check. The trout from Kalhovdfjord in 1971 and 1972 and Mårvann in 1970 were caught by local fishermen.

RESULTS

Trout netting

The main fishing equipment used in Mårvann is gill nets with 39 mm as minimum mesh size. According to some of the landowners their total catch in 1969 was about 350 kg, in 1970 about 40 kg, while in 1971 and 1972 the catch was practically zero. In 1971 and 1972 the netting was very limited due to the low catch per effort and the extremely poor condition of the trout.

The author's netting was not extensively

Table III. Number of nettings (net-nights) of each mesh size at the inlet from Mårtjern

Mesh size mm	No. of nettings					
	1969	1971		1972		
	13–14/8	29–30/6	29–30/9	2–3/7	10–11/8	29–30/9
20	1	2	–	–	–	–
23	1	–	1	–	–	–
26	–	–	–	2	2	2
32	2	2	–	1	2	2
35	–	–	1	1	2	2

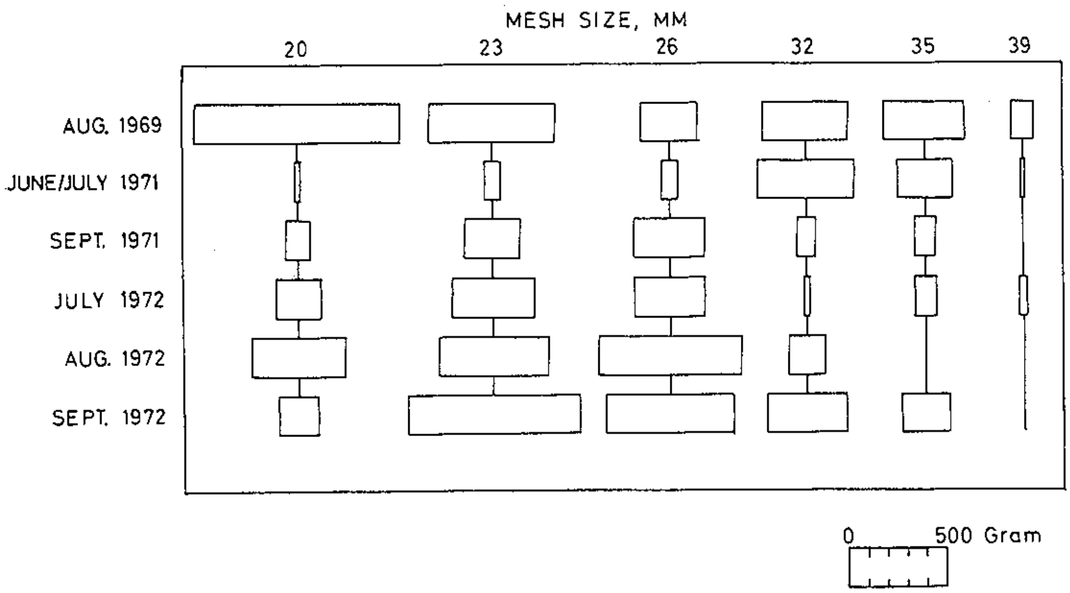

Fig. 4. Average catch in grams per net-night obtained with different mesh sizes in each netting period.

measured in net-nights, but the results indicate a marked decrease in yield per effort (per net-night) from 1969 to 1971 (Fig. 4). During 1972 there was a gradual increase in catch per net-night with finer mesh sizes (Fig. 4).

According to the local fishermen the best time for netting is in September. As seen in Fig. 4 no trout were obtained using legal sized nets (mesh size 39 mm) in September 1971, and August and September 1972, while in August 1969, 115 grams per net-night were obtained.

In the clear water zone situated out from the inlet from Mårtjern the situation has been different. In relation to the catch in the main reservoir many more trout were obtained in this area, except in August 1969 and September 1972 (Table IV). Anglers also caught large numbers of legal sized trout (more than 30 cm in length) in the same locality in 1971, while few trout were obtained by angling in the main reservoir.

Food of the trout

The frequency of food items in the stomach contents of the trout is presented in Tables V and VI for length groups 15-24.5 cm and 25-39.5 cm respectively. The volume of the main groups of food items, i.e. *Lepidurus arcticus*, cladocerans and copepods, aquatic insects and terrestrial insects is given in Fig. 5.

The composition of the diet varied considerably during the course of time. In August 1969 *L. arcticus* was very common in length group 25-39.5 cm and predominated in volume. In length group 15-24.5 cm cladocerans, mainly *Eurycercus lamellatus*, constituted the main bulk of the stomach contents.

In September 1970 only trout larger than 25 cm were examined. Terrestrial insects (Diptera) were the only group recorded in stomach analyses.

In June/July 1971 chironomids were the main food item of both length groups. Many aquatic insects, for instance, Plecoptera, Ephemeroptera, Trichoptera and Simuliidae were also represented. The Simuliidae larvae probably belong to the drift fauna coming into Mårvann, as plankton hauls from the surface water in Mårtjern contained live Simuliid larvae. Terrestrial insects also account for an appreciable amount of the stomach contents from this period.

In September 1971 cladocerans and copepods composed more than 50 % of the stomach contents in both length groups of

Table IV. Results of gill netting (average number of trout per net-night) at the inlet from Mårtjern. Numbers in parentheses: average number per net-night in main reservoir

Mesh size mm	1969	1971		1972		
	Aug.	June	Sep.	July	Aug.	Sep.
20	13.0 (15.0)	31.5 (0.3)	(2.0)	(3.4)	(6.8)	(3.0)
23	6.0 (5.0)	(0.8)	13.0 (2.5)	(4.4)	(5.8)	(8.7)
26	(1.7)	(0.4)	(2.3)	17.0 (2.2)	10.5 (3.7)	3.5 (4.8)
32	1.0 (1.4)	6.0 (1.8)	(0.3)	3.0 (0.1)	3.0 (0.8)	2.0 (1.8)
35	(1.2)	(0.9)	2.0 (0.2)	5.0 (0.5)	1.0 (0)	0.5 (0.8)

Table V. Frequency of each food item in stomach contents of trout between 15 and 24.5 cm in length

	Date of capture					
	1969	1971		1972		
	9–16/8	26/6–1/7	28–30/9	1–3/7	8–12/8	29–30/9
Food item	N:70	N:30	N:35	N:15	N:38	N:30
Crustacea:						
Lepidurus arcticus	40.0	–	2.9	–	10.5	10.0
Cladocera	61.4	3.3	51.4	6.7	39.5	70.0
Copepoda	1.4	–	8.6	–	26.3	13.4
Aquatic insects:						
Chironomidae l.	3.0	56.7	48.6	46.7	18.4	30.0
Chironomidae p. im.	7.1	43.3	22.9	80.0	39.5	13.4
Trichoptera l.	20.0	–	2.9	6.7	–	–
Trichoptera p.	–	–	–	–	2.9	–
Trichoptera im.	2.9	–	–	–	–	–
Plecoptera l.	–	13.3	–	20.0	–	–
Plecoptera im.	–	10.0	2.9	6.7	–	–
Ephemeroptera l.	–	20.0	–	–	7.9	–
Dytiscidae l.	2.9	–	–	–	5.3	–
Dytiscidae im.	–	10.0	5.7	–	–	3.3
Tipulidae l.	–	16.7	2.9	–	–	–
Simuliidae l.	–	36.7	–	13.3	–	–
Ceratopogonidae l.	–	–	–	6.7	–	–
Bivalvia:						
Pisidium sp.	1.4	3.3	8.6	–	7.9	–
Terrestrial insects:						
Coleoptera	2.9	6.6	25.7	13.3	7.9	–
Diptera	4.3	20.0	22.9	26.7	23.7	–
Neuroptera	–	–	–	26.7	–	–
Homoptera	1.4	6.6	17.2	26.7	2.6	–
Hymenoptera	1.4	10.0	8.6	20.0	10.5	–
Lepidoptera	2.9	3.3	–	13.3	–	–
Others:	2.9	6.6	–	–	7.9	–

N = number of trout examined: l = larvae: p = pupae: im = imagines.

Table VI. Frequency of each food item in stomach contents of trout between 25 and 39 cm in length

	Date of capture						
	1969	1970	1971		1972		
	9–16/8	22–30/9	26/6–1/7	28–30/9	1–3/7	8–12/8	29–30/9
Food item	N:30	N:10	N:36	N:21	N:30	N:43	N:33
Crustacea:							
Lepidurus arcticus	63.3	–	–	–	–	18.6	18.2
Gammarus lacustris	–	–	–	–	–	2.3	–
Cladocera	36.7	–	3.3	61.8	–	69.8	78.7
Copepoda	–	–	–	9.5	–	4.7	21.2
Aquatic insects:							
Chironomidae l.	26.7	–	55.6	52.4	46.7	32.6	60.6
Chironomidae p. im.	23.4	–	61.1	23.8	70.0	48.8	3.0
Trichoptera l.	13.3	–	13.9	4.8	6.7	6.9	–
Trichoptera p.	3.3	–	–	–	–	–	–
Trichoptera im.	3.3	–	5.6	–	–	2.3	–
Plecoptera l.	–	–	5.6	–	6.7	2.3	–
Plecoptera im.	–	–	8.4	–	–	2.3	–
Ephemeroptera l.	–	–	8.4	–	3.3	9.3	–
Dytiscidae l.	–	–	–	–	3.3	–	3.0
Dytiscidae im.	–	–	5.6	–	–	2.3	–
Tipulidae l.	–	–	27.8	–	16.7	6.9	–
Simuliidae l.	–	–	13.9	–	6.7	4.7	–
Ceratopogonidae l.	–	–	–	–	13.3	–	3.0
Hirudinea:	–	–	–	–	3.3	–	–
Bivalvia:							
Pisidium sp.	23.4	–	22.2	4.8	3.3	11.6	6.1
Gastropoda:							
Lymnaea sp.	–	–	–	–	3.3	2.3	3.0
Terrestrial insects:							
Coleoptera	–	–	22.2	14.3	26.7	–	6.1
Diptera	13.3	30.0	27.8	33.3	26.7	20.9	33.3
Neuroptera	–	–	2.8	–	26.7	–	–
Homoptera	–	–	16.6	9.5	33.4	4.7	3.0
Hymenoptera	3.3	–	16.6	–	23.3	6.9	–
Lepidoptera	10.0	–	5.6	–	6.7	–	–
Others:	–	–	33.3	23.8	3.3	4.7	9.0

N = number of trout examined: l = larvae: p = pupae: im = imagines.

trout. *L. arcticus* was recorded by a single specimen in this month.

In July 1972 the diet was nearly the same as in June/July 1971, i.e. consisting of aquatic and terrestrial insects.

In August and September 1972 the main food items were cladocerans and copepods, especially *E. lamellatus* and *Heterocope* sp. *L. arcticus* was recorded from about 18 % of trout larger than 25 cm, and from about 10 % of trout in the length group 15-24.5 cm.

In Kalhovdfjord reservoir the same seasonal change in diet seemed to occur as in Mårvann, i.e. predominantly an insect diet in early summer and a crustacean diet in the autumn (Table VII). As seen in the table *L. arcticus* was recorded in trout stomachs both in September 1971 and August 1972.

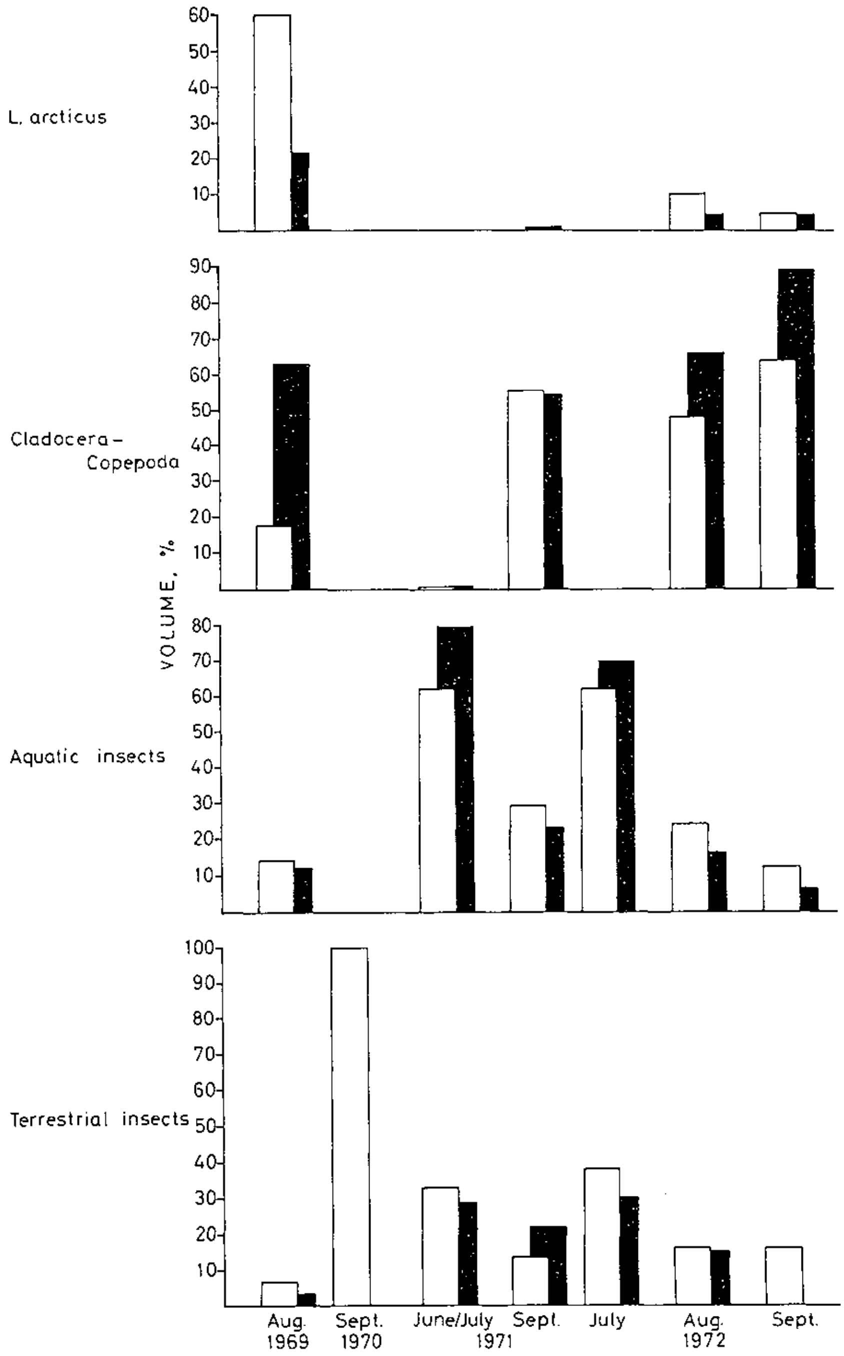

Fig. 5. Volume of *Lepidurus arcticus*, Cladocera/Copepoda, aquatic insects and terrestrial insects as per cent of total volume of stomach contents. Open columns: trout between 25 and 39 cm, black columns: trout between 15 and 25 cm.

Table VII. Kalhovd Reservoir. Frequency of each food item in stomach contents of trout between 32.5 and 43 cm

	1971		1972
Food item	28.6 N:5	28.9 N:10	28.8 N:10
Crustacea:			
Lepidurus arcticus	–	10.0	50.0
Cladocera	–	100.0	70.0
Aquatic insects:			
Chironomidae l.	100.0	10.0	–
Chironomidae p. im.	100.0	50.0	10.0
Trichoptera l.	60.0	10.0	30.0
Trichoptera p.	20.0	–	–
Trichoptera im.	–	–	30.0
Plecoptera l.	20.0	–	–
Plecoptera im.	20.0	–	–
Dytiscidae im.	–	10.0	–
Ceratopogonidae l.	20.0	–	–
Terrestrial insects:			
Diptera	20.0	30.0	30.0
Homoptera	–	20.0	30.0
Hymenoptera	–	–	40.0
Lepidoptera	–	–	20.0
Others:	20.0	20.0	20.0

l = larvae: p = pupae: im = imagines.

Length-weight relationship

It appears from Fig. 6 that the condition factor shows considerable variation, with decreasing values until July 1972 for fish below 20 cm and until September 1971 for larger fish. From then on the condition has shown an increasing trend. The decline in weight in relation to the length of the fish is especially evident for fish larger than 25 cm.

In August-September 1972 the values for fish below 25 cm were nearly at the same level as in August 1969. Larger trout still have much lower K-values than in August 1969. In fact the lowest recorded are from August 1972, where values down to 0.58 were recorded for trout larger than 30 cm.

In Table VIII the K-values have been calculated for immature and mature males and females with lengths from 27 and 36 cm respectively. This is the length interval in which both immature and mature fish occur, below 27 cm mature fish rarely occurred, and fish larger than 36 cm have all been mature.

In each month small differences between males and females belonging to the same category of maturity were observed. Immature females had a higher condition factor than mature ones, while this tendency is not so clear in the males.

Lowest values were recorded in September 1971, and the percentage reduction in K-factor (mean values) from August 1969 to September 1971 is 24.3 for females and 23.0 for males. Irrespective of sex or stage of maturity the K-values showed the same variation from August 1969 to September 1972.

DISCUSSION

As proposed by Nilsson (1960) fish may possibly switch over from one type of food to another which at that particular time gives the

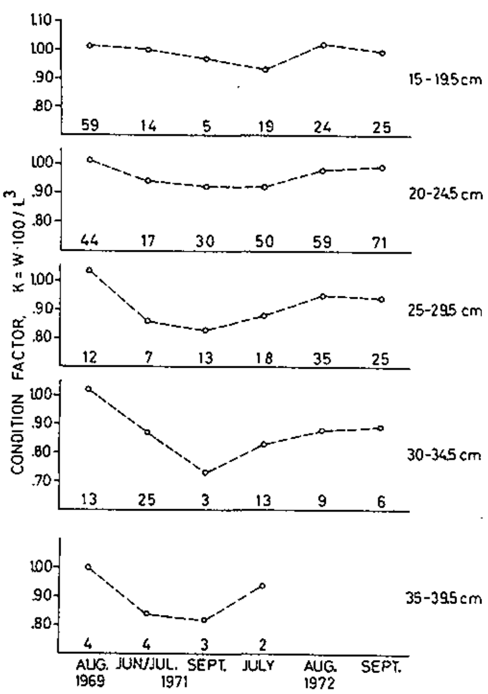

Fig. 6. The mean condition factor of trout in different length groups during the period August 1969 to September 1972. Numbers above horizontal line: Number of trout examined.

Table VIII. The condition factors ($K = W \times 100/L^3$) of male and female trout with lengths from 27 to 36 cm respectively. Number of fish in parentheses.

	Aug. 1969		Sept. 1971		Aug. 1972		Sept. 1972	
Stage of maturity	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
I–II	1.06 (6)	0.99 (4)	0.82 (3)	0.80 (4)	0.93 (3)	0.96 (8)	0.92 (6)	0.88 (4)
III–V and VII/II–V	1.00 (5)	1.01 (6)	0.77 (7)	0.74 (3)	0.89 (9)	0.87 (3)	0.88 (6)	0.93 (6)
Mean value	1.03 (11)	1.00 (10)	0.78 (10)	0.77 (7)	0.90 (12)	0.94 (11)	0.90 (12)	0.91 (10)

optimal reward for the energy expended. Seasonal variations in the food of the trout are therefore possibly caused by the seasonal changes and the seasonal variation in the fauna of the lakes (Berg 1951). Such seasonal variation in the food of trout was also observed in Mårvann before the extended regulation (Rosseland pers. comm.). Although *L. arcticus* according to Sömme (1944) may show annual fluctuations, all previous studies in Mårvann, in August 1929 (Dahl 1932), in August 1930 (Huitfeldt-Kaas 1935), in August 1956 and 1957 (Rosseland pers. comm.), in August/September 1964 (Aass 1969) and the present study in August 1969, point to *L. arcticus* as the predominant food item in these months. When *L. arcticus* practically disappeared from the diet of trout in September 1970 and 1971, this could have been attributable to reduced numbers. This seems particularly reasonable as *L. arcticus* seemed to be common in nearby Kalhovdfjord in both 1971 and 1972. The decline in Mårvann may probably be related to the increased lowering of the lake level and/ or to the increased turbidity.

In other reservoirs egg-carrying females of *L. arcticus* occur with greatest abundance in shallow water down to about 5 metres, but they are recorded at depths down to about 30 metres (Borgström 1970, Borgström unpublished data). The bathymetrical distribution of *L. arcticus* in Mårvann before 1970 is not known, but if the distribution in 1969 corresponded to that found in other reservoirs, a reduced number of eggs would have had the opportunity to hatch in 1970, due to the low water level that year.

A reduced primary production caused by increased turbidity may also have been an important limiting factor for *L. arcticus,* because the first larval stages, being planktonic, probably feed on plankton, and the first bottom-dwelling stage seems to feed to a large extent on diatoms (Borgström, unpublished data).

Dahl (1932) found *L. arcticus* already well established in Pålsbufjord reservoir in 1928 after the lake was first lowered during the winter 1927. He explained this establishment as caused by an influx of larvae from above-lying lakes in which *L. arcticus* was common. The apparent increase of *L. arcticus* in Mårvann in 1972 may also have been contributed to by a supply of larvae from above-lying lakes, including Mårtjern. Larvae of *L. arcticus* were for instance found in Mårtjern in June 1972, but not in the main reservoir.

There was no release of water from Mårvann between 10 May 1970 and 4 May 1971, and thus no trout could leave the reservoir through the outlet during the period with the maximum turbidity of lake water. Such an emigration of fish was observed in Strandefjorden in Hallingdal when the turbidity of the lake increased (Jensen & Aass 1968). According to Aass (1973) the turbidity may actually kill the fish or drive them away. The decrease in the yield of trout in Mårvann in 1970-72 may therefore be related to increased natural mortality, increased emigrations to the inlets or a decreased immigration of fish.

If the trout try to avoid water which suddenly becomes turbid, they would be forced to emigrate to rivers or river outlets with less turbid water. The decrease of the fish stock in the main reservoir and the increased concentration of fish in the north-western end, may support this assumption. However, this does not totally explain the decline in the main reservoir.

Seasonal variations in the condition of brown trout are commonly observed, and are probably due to changing temperatures and amount and composition of available food (Nilsson 1955, Hunt & Jones 1972). Sömme (1944) also states that brown trout from lakes on Hardangervidda which have spawned in the autumn will often be considerably reduced in weight the following spring, but this reduction will normally be regained within a fortnight during the summer. According to Schmidt-Nielsen (1940) annual changes in condition value may occur as a result of changed fishing pressure. The extremely low condition values recorded in brown trout from Mårvann in 1971 and 1972 is, however, not fully explained by such normal seasonal or annual variations. Reimers (1957) found that during a period of 120 days starting from 1 July, 82 % of 50 starved brown trout died. Their mean condition factor was between 0.49 and 0.55. He found that starved trout generally died when the condition factor fell below 0.55-0.60. As K-values down to 0.58 were recorded for trout larger than 30 cm from Mårvann, this may indicate that a fraction of the population died due to starvation. The lack of *L. arcticus* may have been the main reason for an inadequate food supply. Although the trout had eaten other food items, especially cladocerans and copepods, these small crustaceans will according to Nilsson (1955) be less nutritive than larger food items, and fish which depend upon them as a principal food item will drop in condition. The change in diet for smaller trout from 1969 to 1971/72 was less pronounced than for larger fish, and only a small reduction in condition was recorded. This is in accordance with the above assumption.

To obtain a better utilization of the stored water in many of the earlier regulated high mountain lakes without construction of new dams, increased lowerings will probably be carried out, as has occurred in Mårvann. Attention should however be paid to the negative effects such regulation may have upon the fauna of these reservoirs. To avoid similar damage to that which occurred in Mårvann, the lake level should not be lowered more than to allow for complete filling to the previous low water level the next spring, thus at least preventing extensive erosion and increased turbidity.

ACKNOWLEDGEMENTS

I am indebted to Professor Rolf Vik for his advice throughout this study and for reading the manuscript, to Kai Myhr for his assistance in field and laboratory work and to Dr. John E. Brittain for his help with the English. I would also like to thank Steinar Myhr, Arne Ewald, employees of Öst-Telemarkens Bruks-eierforening, and the landowners of Mårvann and Kalhovd reservoirs, for their help in the field work.

The investigation was made possible by financial support from Öst-Telemarkens Bruks-eierforening, Konsesjonsavgiftsfondet (Det Kgl. Industridepartement) and Reguleringsforeningenes Landssammenslutning.

REFERENCES

Aass, P. 1969. Crustacea, especially *Lepidurus arcticus* Pallas, as brown trout food in Norwegian mountain reservoirs. *Rep. Inst. Freshw. Res. Drottningholm 49*, 183–201.

Aass, P. 1970. Virkning av reguleringer på fiskebestander. *Kraft og Miljø 1*, 23–34.

Aass, P. 1973. Some effects of lake impoundments on salmonids in Norwegian hydroelectric reservoirs. *Acta Univ. Upsalensis Diss. Sci. 234*, 1–14.

Berg, M. 1951. Om kosthaldet hos auren i Espedalsvatnet og Sjusjøen. *Nytt Mag. Naturvid. 88*, 165–205.

Borgström, R. 1970. Skjoldkreps, *Lepidurus arcticus*, i Stolsvannsmagasinet i Hallingdal. *Fauna 23*, 12–20.

Dahl, K. 1917. *Studier og forsøk over ørret og ørretvand.* Kristiania. 107 pp.

Dahl, K. 1932. Influence of water storage on food conditions of trout in Lake Paalsbufjord. *Skr. norske Vidensk.-Akad. Mat. Naturv. Kl. 1931 (4)*, 1–53.

Grimås, U. 1961. The bottom fauna of natural and impounded lakes in northern Sweden (Ankar-

vattnet and Blåsjøn). *Rep. Inst. Freshw. Res. Drottningholm 42*, 183–237.
Grimås, U. 1962. The effect of increased water level fluctuation upon the bottom fauna in Lake Blåsjön, northern Sweden. *Rep. Inst. Freshw. Res. Drottningholm 44*, 14–41.
Huitfeldt-Kaas, H. 1906. *Planktonundersøgelser i norske vande.* Christiania (Nationaltrykkeriet). 197 pp.
Huitfeldt-Kaas, H. 1935. *Der Einfluss der Gewässerregelungen auf den Fischbestand in Binnenseen.* Oslo (Nationaltrykkeriet). 105 pp.
Hunt, P. C. & Jones, J. W. 1972. The food of brown trout in Llyn Alaw, Anglesey, North Wales. *J. Fish. Biol. 4*, 333–352.
Hynes, H. B. N. 1950. The food of fresh-water sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. *J. Anim. Ecol. 19*, 36–58.
Jensen, K. W. & Aass, P. 1968. Utbygging og regulering av Uste-Hallingdalsvassdraget. II. Virkninger på fisket i Strandafjorden – Nes. 14 pp. (Mimeographed in Norwegian.)
Murphy, G. I. 1962. Effect of mixing depth and turbidity on the productivity of freshwater impoundments. *Am. Fish. Soc. Trans. 91 (1)*, 69–76.
Nilsson, N. A. 1955. Studies of the feeding habits of trout and char in North Swedish lakes. *Rep. Inst. Freshw. Res. Drottningholm 36*, 163–225.
Nilsson, N. A. 1960. Seasonal fluctuations in the food segregation of trout, char and whitefish in 14 North-Swedish lakes. *Rep. Inst. Freshw. Res. Drottningholm 41*, 185–205.
Nilsson, N. A. 1961. The effect of water-level fluctuations on the feeding habits of trout and char in the lakes Blåsjön and Jormsjön, North Sweden. *Rep. Inst. Freshw. Res. Drottningholm 42*, 238–261.
Reimers, N. 1957. Some aspects of the relation between stream foods and trout survival. *Calif. Fish and Game 43*, 43–69.
Schmidt-Nielsen, K. 1940. Comparative studies on the food competition between the brown trout and the char. *K. norske Vidensk. Selsk. Skr. 1939 (4)*, 1–45.
Sömme, I. D. 1944. *Ørretboka.* Oslo (Jacob Dybwads forlag). 591 pp.

Received 30 March 1973
Published June 1973