WILLIAM J. WILTZIUS

Changes in the diet of charr *Salvelinus alpinus* L. after introduction of *Mysis relicta* Lovén in two subalpine reservoirs in Norway

ERIK GARNÅS

Garnås, E. 1986. Changes in the diet of charr *Salvelinus alpinus* L. after introduction of *Mysis relicta* Lovén in two subalpine reservoirs in Norway. *Fauna norv. Ser. A 7,* 17—22.

The mysid crustacean *Mysis relicta* was introduced into two Central Norwegian subalpine reservoirs, Stugusjøen and Gjevilvatn in 1973. Maximum density of *Mysis* was reached 9 to 10 years after the transplanting; densities later diminished to a low level. The introduction of *Mysis* in Stugusjøen has resulted in a large decline in the Cladocera population. From 1978 to 1985, charr diet in the two lakes has usually comprised 20% to 60% *Mysis* during spring and autumn in the two lakes. The amphipod *Pallasea quadrispinosa* was an important part of charr diet in Stugusjøen during spring. There has been a decrease in catch per effort and in mean weight for charr in both lakes during the study period.

Erik Garnås, Fylkeshuset, Haugesgt. 89, N-3000 Drammen, Norway.

INTRODUCTION

Regulation of lakes for hydroelectric purposes generally leads to a decline in the production of littoral benthos (Stube 1958, Grimås 1961, 1962, Nilsson 1961), which with zooplankton are the basic food types required for fish production.

The crustacean *Mysis relicta* Lovén has long been recognized as an important forage for many fish species (Huitfeldt-Kaas 1917). In order to compensate for a reduced, low density of zoobenthos, *Mysis* has therefore been introduced into lakes in both North America and Scandinavia (Fürst 1981, Grossnickle 1982). In general it was thought that *Mysis* would enhance fish production by providing sizable and available energy sources for fish in lakes where food was limiting for fish production (Lasenby, Northcote & Fürst 1986).

In Norway *M. relicta* occurs naturally in only a few lakes below the marine boundary in the southeastern part of the country (Elgmork 1968). *Mysis* has been introduced into 9 Norwegian lakes at different altitudes to serve as a supplementary food source for fish (Mehli 1976). In 1973 *M. relicta* was transplanted into two subalpine reservoirs, Stugusjøen and Gjevilvatn in Central Norway. Some specimens of an other relict crustacean, the amphipod *Pallasea quadrispinosa* Sars, were also introduced (Gunnerød 1977). In the years following the introduction, annual sampling has been carried out, with special emphasis on studying the effects of *Mysis* on the fish diet and production. This paper summarizes some of the results of this study.

STUDY AREA

The lakes Stugusjøen and Gjevilvatn are situated in Central Norway. Stugusjøen (62° 58'N, 11° 50'E) lies at an altitude of 610 m above sea level, and encompasses an area of 6.75 km². The lake was impounded in 1965 and the water level fluctuates 8 m. The maximum depth is about 57 m. The lake is inhabited by charr *Salvelinus alpinus* L., burbot *Lota lota* L. and a small population of brown trout *Salmo trutta* L.. Minnow *Phoxinus phoxinus* L. has recently been introduced.

Gjevilvatn (62° 30'N, 9° 30'E) lies 660 meters above sea level, and has a total area of 21 km². The lake has been regulated for hydroelectric power generation since 1973 and the water level fluctuates by 15 m. The maximum depth is approximately 110 m. This lake contains charr *Salvelinus alpinus* and a sparse population of brown trout *Salmo trutta*.

MATERIAL AND METHODS

Mysis relicta and fish were collected during autumn (August/September) from 1973 to 1984. In 1982, 1984 and 1985 fish was also collected during spring (June). *Mysis* was collected using a beam trawl, as described by Fürst (1965, 1981). The trawl was towed along the bottom at the same station each year and at a low speed for 15 minutes. Each trawl sample started at a depth of 1 m and the trawl was towed away from the shore till a depth of about 20 m. The samples were collected during daylight hours. Five samples were collected from each lake, and *Mysis* in each sample was preserved in 70% ethanol and later counted in the laboratory.

Larger samples were counted by subsampling (see Garnås, Hesthagen & Gunnerød 1980), a procedure deemed sufficiently reliable to estimate the number of *Mysis* in large samples.

Fish was collected using a net series consisting of 8 nets (mesh 21—52) on the bottom, in the littoral zone. Fish was measured to the nearest mm and weighed to the nearest gram. The stomach from each fish was analysed, and the food items were identified to different taxonomic levels. To express the relative importance of each food category, frequency of occurrence and volume were used (c.f. Hynes 1950).

RESULTS

Density of *Mysis relicta*

Mysis relicta was recorded in low numbers in the trawl samples from both lakes in 1975, two years after stocking. In 1977 the mean number of *Mysis* per trawl sample had increased to about 300 individuals in Stugusjøen, while the mean number in Gjevilvatn was still below 50 per sample (Fig. 1).

Between 1978 and 1980, a nearly exponential increase in the density of *Mysis* occurred in Stugusjøen, with a mean number of 21600 (± 4700 C.i. = 0.95) specimens per sample. In 1981 the density dropped to 7700 (± 4700), however an increase occurred in 1982 when the density rose to 38900 (± 5900). From 1982 to 1984 there was a reduction in the *Mysis* population, and in 1984 4300 (± 1900) specimens were caught per sample.

In Gjevilvatn there was a similar trend in the development of *Mysis*. From 1977 to 1983, there was an increase in the density, with a maximum in 1983 of 22300 (± 6700) per sample. From 1983 to 1984 the density of *Mysis* dropped to 2500 (± 1200) individuals per sample.

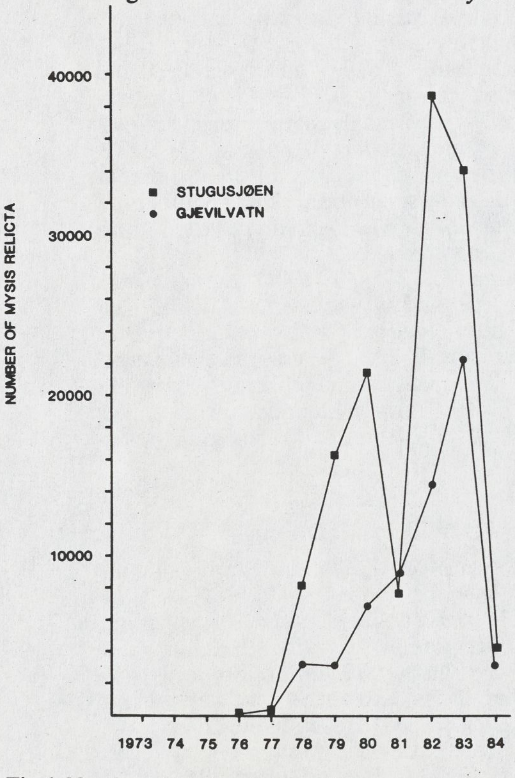

Fig. 1. Number of *Mysis relicta* per 15 min. trawl sample in Stugusjøen and Gjevilvatn from 1973 to 1984 (autumn samples).

Mysis and *Pallasea* as fish food

Mysis was first observed in the stomach contents of charr from Stugusjøen in autumn 1977 (Fig. 2). The diet that year was dominated by zooplankton. *Mysis* made up from 40% to 65% of the stomach volume of charr in the period 1978—1982. In 1983 charr ate almost exclusively *Mysis* (92% frequency).

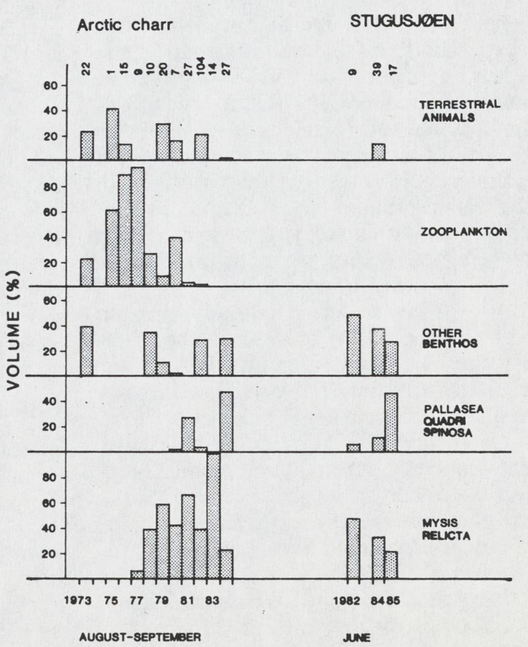

Fig. 2. The food of Arctic charr *Salvelinus alpinus* in Stugusjøen in autumn and spring. The number above the columns represents the number of fish.

Table 1. Frequency (F) of *Mysis relicta* in the stomachs of charr *Salvelinus alpinus* in Stugusjøen and Gjevilvatn from 1977 to 1984. N = Number of fish.

		1977	1978	1979	1980	1981	1982	1983	1984
Stugusjøen	F	11	36	60	14	85	45	92	31
	N	9	11	20	7	27	104	13	26
Gjevilvatn	F	0	20	19	25	16	33	9	40
	N	5	15	16	4	32	178	34	40

In 1984 the importance of *Mysis* was again reduced to about 20% in volume, and 31% in frequency (Table 1).

Mysis was also an important element of the spring diet of charr in Stugusjøen, comprising 20% to 50% of the volume of food in 1982, 1984 and 1985, with frequencies from 30% to 70%.

The amphipod *Pallasea quadrispinosa* was observed in charr stomach contents in 1980. *Pallasea* was especially important in the diet in 1981 and 1984 when it made up 30% to 50% of the stomach volume.

An increase in the volume of *Pallasea* in charr stomachs has been recorded in spring. In 1985 it comprised about 50% in volume of all food, with a frequency of 70%.

Mysis was first observed in the stomachs of charr from Gjevilvatn in 1978. Except the samples from 1980 and 1982, in which *Mysis* made up between 35% and 60% of the total food intake, the volume of *Mysis* in the diet has varied between 10% and 20%, with frequencies from 9% to 40%. In spring *Mysis* was of great importance as food of the charr, constituting 50—60% of the volume (Fig. 3).

Pallasea was first recorded in the stomachs of charr in Gjevilvatn in 1980, when it made up 40% of the food consumed. Later it has only been observed in 1984 and 1985, when *Pallasea* made up less than 5% of the charr's spring diet.

Few burbot were caught in Stugusjøen during the study period (Table 2). *Mysis relicta* was first observed in burbot stomach contents in 1977. In samples of more than ten fish, the frequencies of *Mysis* has varied from 23% to 65%, and the volume from 18% to 43%. Few brown trout were caught in Stugusjøen and Gjevilvatn, and results are therefore not included.

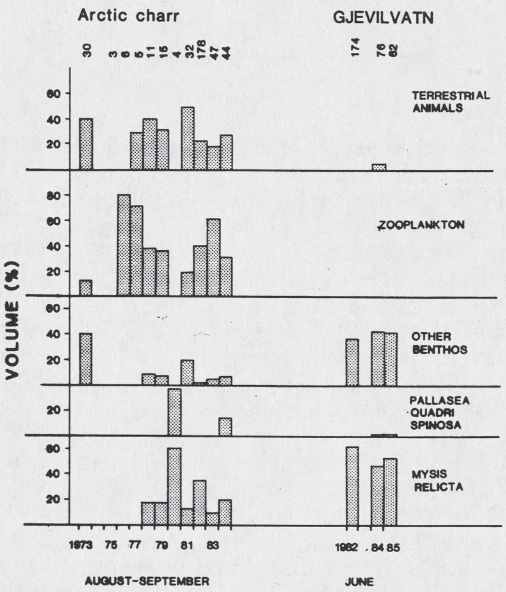

Fig. 3. The food of Arctic charr *Salvelinus alpinus* in Gjevilvatn in autumn and spring. The number above the columns represents the number of fish.

Table 2. Frequency (%) and volume (%) of *Mysis relicta* in the stomachs of burbot *(Lota lota)* in Stugusjøen from 1975 to 1984.

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Frequency	0	0	38	33	40	67	38	23	56	56
Volume	0	0	6	30	22	50	15	21	43	18
No of fish	1	7	8	3	5	9	8	13	16	17

Table 3. Average number (N) and total weight (W,g) of charr per net serie (C/E) in Stugusjøen and Gjevilvatn in 1973 and from 1979 to 1984.
$\overline{w}$ = mean weight (g) C.i. = 95% Confidence limit

	Stugusjøen			Gjevilvatn		
	N	W	$\overline{w}$ C.i.	N	W	$\overline{w}$ C.i.
1973	11	5137	467±91.2	15	1815	121±31.0
1979	10	1810	181±37.1	7.5	795	106±16.5
1980	3.5	514	147±55.9	2.0	562	281±78
1981	10.5	1785	170±48.9	16.0	2096	131±15.2
1982	11.6	1960	169±22.4	17.8	2136	120± 9.9
1983	6.5	1216	187±29.9	12.0	1752	146±24.1
1984	6.7	2017	301±72.4	12.5	1238	99±12.4

Charr density

The catches of charr per net series are listed in Table 3. In 1973 the mean weight of charr in Stugusjøen was 467 g. The total catch was 5137 g. In 1979 the mean weight was reduced to 181 g, with a corresponding reduction in catch per net series. The mean weight of charr has increased from 1980 to 1984, while the catch per series and number of fish per series has decreased to 2017 g and 6.7 individuals respectively, which implies a reduction of 40 to 60% in comparison with the results from 1973.

In 1973 the mean weight of the charr in Gjevilvatn was low (121 g), and catch per effort was 1815 g. In 1979 and 1980 small numbers of charr were caught. In 1981 and 1982, however, both the number of fish per series and mean weight were at about the same level as in 1973. Catch per net series was slightly reduced in 1983 and 1984, and the number and weight of fish per net series, as well as the mean weight, were 20% to 30% lower in 1984 than in 1973.

DISCUSSION

After the introduction of *Mysis relicta* into Stugusjøen and Gjevilvatn in 1973, 9 to 10 years elapsed before the population reached maximum density. After reaching this peak, the populations of *Mysis* in both reservoirs seem to be reduced. These results are in accordance with those of Fürst et al. (1984), who stated that a time lapse of 5 to 9 years is required before maximum density of *Mysis* is reached. The increase in density of *Mysis* is accompanied by a corresponding decrease in the density of zooplankton. In Stugusjøen there has been a large decline in the cladoceran population from 1976 to 1980, with a reduction in the cladoceran biomass of nearly 99% (Langeland 1981). From 1980 to 1984 the density of *Cladocera* has remained low (Langeland unpubl.). The reduction of the cladoceran biomass is most likely a result of heavy predation by *Mysis*. The mysids select cladocerans such as *Daphnia* and *Bosmina* in the zooplankton community (Cooper & Goldman 1980, Lasenby & Fürst 1981).

Mysis density was especially high in Stugusjøen in 1982 and the increase was more rapid than in Gjevilvatn. Conditions for *Mysis* were optimal in Stugusjøen during the first years after transplanting, because the lake had a sparse charr population as well as a relatively high zooplankton density (Langeland 1981). In Gjevilvatn there was a dense population of slowly growing charr when *Mysis* was introduced (Jensen 1972). The density of zooplankton was also low, making the conditions for *Mysis* less favourable than in Stugusjøen. Variations in density of *Mysis* in different lakes are well documented by Fürst et al. (1984).

Mysis was observed in the stomach contents of charr from Stugusjøen and Gjevilvatn four to five years after transplanting, and has later been an important source of food for charr in the two reservoirs both during spring and autumn. This is in accordance with the results of Fürst et al. (1978, 1981) and Hanson (1982). *Mysis* has also been reported as important food for charr during winter (Hammer 1980, Fürst 1981).

The results from Stugusjøen, and to some extent those from Gjevilvatn, indicate that the charr have changed from a diet consisting mainly of zooplankton in autumn, to a diet where *Mysis* is a major component. In Stugusjøen, this is closely related to a decrease in the zooplankton density as reported by Langeland (1981). *Mysis relicta* generally has a great impact on the zooplankton community (Richards et al. 1975, Goldman et al. 1979, Kinsten & Olsen 1981). The reduction of zooplankton caused by *Mysis* has thus resulted that the charr feed on *Mysis*. In spring the density of zooplankton is very low in subalpine reservoirs. *Mysis* is therefore an important supplement to the bottom animals which charr usually feed on, and which have reduced density in hydroelectric reservoirs (Grimås 1961).

Pallasea quadrispinosa was observed in low numbers in trawl samples from both Stugusjøen and Gjevilvatn. The amphipod, however, made up 20% to 40% of the charr diet in both lakes in autumn during some of the study years. In spring *Pallasea* has become more important than both *Mysis* and benthos as charr food in Stugusjøen. *Pallasea* was also important as food of charr in Blåsjön and Ajanse (Fürst et al. 1978). Considering the low density of *Pallasea* in the lakes, this prey is probably more attractive to charr than *Mysis*. According to Fürst et al. (1981), *Pallasea* is more suitable than *Mysis* for introduction into regulated lakes, because of less impact on the zooplankton community.

The catch per effort of charr has been reduced more than 60% in Stugusjøen from 1973 to 1984. Despite this reduction in density, the mean weight has also decline 40% to 60%. In Gjevilvatn there was a maximum catch per effort in 1982, but in 1983 and 1984 the catch of charr per net series was reduced with 30% to 40%, and the mean weight decreased 20 g. These results are in accordance with those from Blåsjön and Torrön, where catch of littoral charr was reduced 78% and 49% respectively, mainly as a result of the introduction of *Mysis* (Fürst et al. 1984). In addition to the effect of *Mysis*, the reduction of charr in Stugusjøen and Gjevilvatn may be associated with the impoundment of the lakes. Each winter large littoral areas including previous charr spawning grounds dry up. This has probably resulted in reduced recruitment to the charr population.

The introduction of *Mysis* has led to a change in the diet of burbot in Stugusjøen, from insect larvae, snails and fish (Garnås, Hesthagen and Gunnerød 1980), to mainly *Mysis* and *Pallasea* (Garnås and Gunnerød 1983). A similar change has also been observed in Torrön (Fürst et al. 1981) and Suorva (Hanson 1982). Introduction of *Mysis* is therefore favourable to the burbot population in Stugusjøen representing an attractive food source throughout the year. This has resulted in an increased density of burbot. In Vomsjön the density of burbot increased three fold after introduction of *Mysis* (Fürst et al. 1980).

Introduction of *Mysis relicta* has, as also indicated in this study, a negative impact on the number and mean size of the charr and on the zooplankton community. The density of burbot, which is less attractive as fish resource, may however increase as a result of *Mysis* introduction. Considering these negative effects, transplanting of *Mysis relicta* into hydroelectric reservoirs to establish a new food resource for charr must be avoided (c.f. Lasenby, Northcote & Fürst 1986).

REFERENCES

Cooper, S.D. & Goldman, C.R. 1980. Opossum shrimp *(Mysis relicta)* predation on zooplankton. *Can. J. Fish. Aquat. Sci. 37,* 909—919.

Elgmork, K. 1968. Relikte krepsdyr. Pp. 1123—1125, in K.W. Jensen (ed.): *Sportsfiskerens leksikon, Bind 1, Gyldendal Norsk Forlag, Oslo.*

Fürst, M. 1965. Experiments on the transplantation of *Mysis relicta* Loven into Swedish lakes. *Rep. Inst. Freshw. Res., Drottningholm 46,* 79—89.

Fürst, M. 1981. Results of introduction of new fish food organisms into Swedish lakes. *Rep. Inst. Freshw. Res., Drottningholm 59,* 33—47.

Fürst, M., Boström, V. & Hammar, J. 1978. Effekter av nya fisknäringsdjur i Blåsjön. *Inform. Sötv. Lab. Drottningholm 15,* 1—94.

Fürst, M., Boström, V. & Hammar, J. 1980. Effekter av nya fisknäringsdjur i Vomsjön. *Inform. Sötv. Lab. Drottningholm 3,* 1—42.

Fürst, M., Boström, V. & Hammar, J. 1981. Effekter av nya fisknäringsdjur i Torrön. *Inform. Sötv. Lab. Drottningholm 1,* 1—48.

Fürst, M., Hammar, J., Hill, C., Boström, V. & Kinsten, B. 1984. Effekter av introduktion av *Mysis relicta* i regulerade sjöar i Sverige. *Inform. Sötv. Lab. Drottningholm 1,* 1—84.

Garnås, E. & Gunnerød, T.B. 1983. Fiskeribiologiske undersøkelser i 1980—1982 i tre sjøer med utsatt *Mysis relicta* i Sør-Trøndelag. *Rep. DVF Reguleringsunders. 12,* 1—56.

Garnås, E., Hesthagen, T. & Gunnerød, T.B. 1980. Fiskeribiologiske undersøkelser fra 1973—1979 i tre sjøer med utsatt *Mysis relicta* i Sør-Trøndelag. *Rep. DVF Reguleringsunders. 11,* 1—31.

Goldman, Ch.R., Morgan, M.D., Threlkeld, S. & Angeli, N. 1979. A population dynamics analysis of cladoceran disappearance from Lake Tahoe, California, Nevada. *Limnol. Oceanogr. 24,* 289—297.

Grimås, U. 1961. The bottom fauna of natural and impounded lakes in northern Sweden (Ankarvattnet and Blåsjön). *Rep. Inst. Freshw. Res., Drottningholm 42,* 183—237.

Grimås, U. 1962. The effect of increased water level fluctuations upon the bottom fauna in Lake Blåsjön, Northern Sweden. *Rep. Inst. Freshw. Res., Drottningholm 44,* 14—41.

Grossnickle, N.E. 1982. Feeding habits of *Mysis relicta* —an overview. *Hydrobiologia 93,* 101—107.

Gunnerød, T.B. 1977. Utsetting av *Mysis relicta* i Selbusjøen og Stugusjøen i Neavassdraget og i Gjevilvatn (Driva) i Oppdal. *Rep. DVF Reguleringsunders. 1,* 1—21.

Hammar, J. 1980. Ecology and taxonomy of Arctic charr in lake reservoirs in Sweden. *Proc. First ISACF*

workshop on Arctic charr. ISACF Inform. Ser. (1). Inst. Freshw. Res., Drottningholm, 10—28.
Hanson, M. 1982. Effekter av nya fisknäringsdjur i Suorva. *Inform. Sötv. Lab. Drottningholm 3,* 1—28.
Huitfeldt-Kaas, H. 1917. Mjøsens fisker og fiskerier. *DKNVS Skr. 2,* 1—257.
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,* 35—58.
Jensen, J. 1972. Fiskeribiologiske undersøkelser i Gjevilvatn Ångårdsvatn og Dalsvatn før reguleringen av vatnene. *Rep. DKNVS Mus. 4,* 1—21.
Kinsten, B. & Olsen, P. 1981. Impact of *Mysis relicta* Lovén introduction on the plankton of two mountain lakes, Sweden. *Rep. Inst. Freshw. Res., Drottningholm 59,* 64—74.
Langeland, A. 1981. Decreased zooplankton density in two Norwegian lakes caused by predation of recently introduced *Mysis relicta. Verh. int. Ver. Limnol. 21,* 926—937.
Lasenby, D.C. & Fürst, M. 1981. Feeding of *Mysis relicta* Lovén on macrozooplankton. *Rep. Inst. Freshw. Res., Drottningholm 59,* 75—80.
Lasenby, D.C., Northcote, T.G. & Fürst, M. 1986. Theory, practice, and effects of *Mysis relicta* introductions to North American and Scandinavian lakes. *Can. J. Fish. Aquat. Sci. 43,* 1277—1284.
Mehli, S.Aa. 1976. Utsetting av næringsdyr i regulerte innsjøer. Pp. 59—67 in A. Weiseth (ed.) *Årbok 1975/76. Trondheim og Omland Fiskeadministrasjon.*
Nilsson, N.A. 1961. The effect of water-level fluctuations on the feeding habits of trout and charr in the lakes Blåsjön and Jormsjön, North Sweden. *Rep. Inst. Freshw. Res., Drottningholm 42,* 238—261.
Richards, R.C., Goldman, C.R., Frantz, T.C. & Wickwire, R. 1975. Where have all the *Daphnia* gone? The decline of a major cladoceran in Lake Tahoe, California-Nevada. *Verh. int. Ver. Limnol. 19,* 835—842.
Stube, M. 1958. The fauna of a regulated lake. *Rep. Inst. Freshw. Res., Drottningholm 39,* 162—224.