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Age, growth and food of the Burbot *Lota lota* in two eutrophic lakes in southeast Norway

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The growth and food of the burbot *Lota lota* was studied in two neighbouring mesoeutrophic lakes in southeast Norway. The burbot grew slower and reached smaller theoretical maximum lengths in Lake Øgderen than in Lake Rødenes ($L\infty$ = 40.5 cm vs 69.5 cm). The diet was also different. In Lake Øgderen the burbot ate mainly ruffe *Acerina cernua,* smelt *Osmerus eperlanus,* and *Mysis relicta.* In Lake Rødenes the burbot also ate large quantities of *Gammaracanthus loricatus* and *Pallasea quadrispinosa.* These two amphipods are suggested to be key food items especially for the younger burbot.

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INTRODUCTION

The burbot *Lota lota* is a major part of the fish community in a number of Norwegian lakes. In spite of this, few investigations on its biology have been carried out (but see Sandlund *et al.* 1984, 1985, Eggan 1990).

The burbot feed mainly on benthic invertebrates and fish, the larger burbot feed almost exclusively on fish (Clemens 1950, McCrimmon & Devitt 1954, Hewson 1955, Baily 1972, Nelichik 1973, Magnin & Fadette 1977, Nilsson 1979, Sandlund et al. 1984, 1985). The abundance and availability of suitable prey fish species will therefore influence the growth rate of the burbot. The growth rate of the top predator pike *Esox lucius* L. has been found to be correlated with prey quality (abundance, size) (Mann 1982, Hart & Connellan 1984, Vøllestad *et al.* 1986). Such a correlation would also be expected to be present in the burbot.

In this study I have examined the growth and feeding of burbot in the eutrophic-mesotrophic Lake Øgderen and Lake Rødenes, and try to ascertain which factors affect burbot growth. This study was part of a comprehensive survey of the fish community in three different lakes in the Halden River System. In the third lake surveyed (Lake Bjørkelangen) the burbot population was very small.

STUDY AREA

Lake Øgderen (surface area 13.3 km^2; maximum depth 35 m) and Lake Rødenes (surface area 15.3 km^2; maximum depth 47 m) are two eutrophic-mesotrophic lakes in southeast Norway (see fig. 1 in Vøllestad 1984). Both lakes receive high inputs of nutrients and particulate material from populated and agricultural areas. In Lake Rødenes algal blooms occur regularly; they occur more rarely in Lake Øgderen. In both lakes there is a slight depletion of oxygen in the deeper parts of the lake (down to 4.2 mg/l in Lake Øgderen and 8.2 mg/l Lake Rødenes) during summer (Østfold County Environmental Administration, unpublished results). The fish fauna in the two lakes is strongly dominated by cyprinids; roach *Rutilus rutilus* constitute over 50% of the fish biomass in both lakes (Vøllestad 1985). The species composition of the prey fish is given in Table 1. I there also summarize the length interval of each species as given by gill-net catches (see later). The fish communities in the two lakes are very similar. The most striking difference is that *Coregonus albula* is absent in Lake Øgderen. Further there was a higher abundance of perch *Perca fluviatilis* in Lake Øgderen compared to Lake Rødenes. There are no data available on the quantity of other prey items such as crustaceans and other benthic invertebrates.

Table 1. Number and length (min—max; mm) of the different fish species caught during experimental gill net fishing in Lake Øgderen and Lake Rødenes during May—October 1982.

	Lake Rødenes			Lake Øgderen		
Species	N	Min	Max	N	Min	Max
Perch Perca fluviatilis	391	80	415	890	80	380
Ruffe Acerina cernua	144	75	165	192	75	150
White bream Blicca bjoerkna	7	-	-	206	80	295
Roach Rutilus rutilus	3095	85	270	2762	85	275
Bleak Alburnus alburnus	603	105	190	199	95	175
Bream Abramis brama	10	-	-	25	95	520
Rudd Scardinius erythrophthalmus	0	-	-	19	-	-
Cisco Coregonus albula	418	100	235	0	-	-
Pike Esox lucius	43	270	870	41	220	910
Smelt Osmerus eperlanus	638	100	295	652	100	260
Burbot Lota lota	148	170	560	90	175	540

MATERIAL AND METHODS

Burbot were collected using gangs of sinking and floating gill nets set at different depth intervals at fixed locations. The nets had mesh sizes between 10.5 and 52 mm bar mesh (mesh increment 4.5—10 mm). The methods are described in detail by Vøllestad (1985). Fishing was performed monthly from May through September/October 1982.

Each fish was measured (natural tip length (Ricker 1975; 0.5 cm)), sacculus otoliths were removed for age determination (Martin 1941), and stomach contents were stored frozen for later examination. Stomach contents were identified using a stereoscopic microscope, and the relative importance of each prey item assessed volumetrically (Windell & Bowen 1978). Fish and crustaceans were identified to species, zoobenthos to order or family.

RESULTS

The burbot was mainly caught in benthic nets. A small number of burbot were caught in the pelagic nets, indicating that the burbot at times may venture into the pelagic habitat. Almost all burbot were caught deeper than 10 m. A total of 138 burbot was caught in Lake Rødenes, whereas 90 burbot were caught in Lake Øgderen. The catch per unit of effort did not differ significantly between lakes (*t*-test: $P>0.05$).

Burbot were caught in all mesh sizes used, the best mesh sizes being 29 mm in Lake Øgderen and 39 mm in Lake Rødenes. Few burbot were caught in the small-meshed nets, indicating that the small burbot use habitats not available to the fishing gear. No burbot was caught in the nets with the largest meshes in Lake Øgderen, whereas these nets caught a fair number of fish in Lake Rødenes.

The burbot in Lake Øgderen measured between 17—49 cm, whereas the burbot in

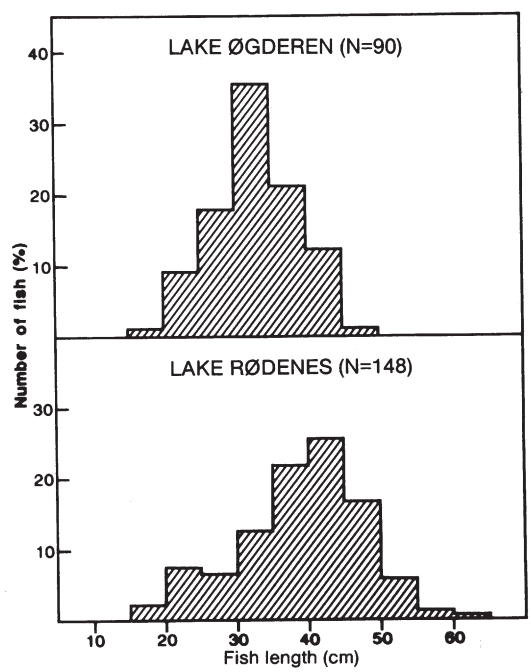

Fig. 1. Length distribution of burbot caught in Lake Rødenes and Lake Øgderen.

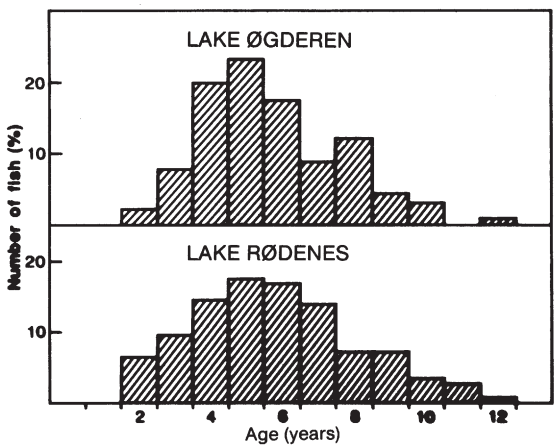

Fig. 2. Age distribution of burbot caught in Lake Rødenes and Lake Øgderen.

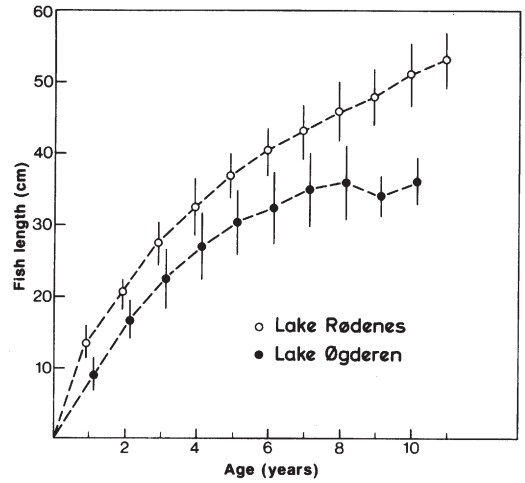

Fig. 3. Back-calculated mean length at age for burbot caught in Lake Rødenes and Lake Øgderen. Mean and standard deviation is given.

Lake Rødenes measured between 17—61 cm (Fig. 1) (X^2-test; test of differences in length distribution; $P<0.001$). Few burbot from Lake Øgderen exceeded 40 cm in length whereas a large part of the catch in Lake Rødenes was larger than this.

The burbot in both lakes were between 2 and 12 years of age (Fig. 2); the age distributions were not statistically different (χ^2-test: $P>0.05$). Age groups 4, 5 and 6 were most abundant in the catches in both lakes.

The back-calculated growth of male and female burbot did not differ (both lakes: $P>0.05$), therefore the data for both sexes were pooled. The mean back-calculated length at age for burbot from Lake Rødenes was significantly larger than the mean back-calculated length at age for burbot from Lake Øgderen (Fig. 3; t-tests, $P<0.05$). The difference in growth rate was especially pronounced the first year. While the burbot in Lake Rødenes had a high growth rate throughout

Table 2. Seasonal variation (volume percent) of the diet of burbot in Lake Rødenes and Lake Øgderen in 1983.

	LAKE RØDENES					LAKE ØGDEREN				
Food item	M	J	J	A	S/O	M	J	J	A	S/O
Gammaracanthus loricatus	6.0	9.0	4.4	15.7	3.0	0	0	0	0	0
Pallasea quadrispinosa	3.6	11.8	10.6	17.5	36.9	0	0.4	0	3.5	0
Mysis relicta	9.3	0.3	1.1	1.7	11.1	33.0	10.0	24.4	64.2	35.5
Chaoborus flavicans	2.4	6.7	44.4	23.0	0.1	0	5.0	0	0.4	0
Other benthos	1.4	1.8	0.6	2.7	1.2	0	0.4	0.6	1.0	0
Ruffe	29.5	30.5	0	17.0	10.5	67.0	31.7	50.0	23.1	30.0
Smelt	17.2	0	0	14.0	26.5	0	44.2	12.5	7.7	22.2
Bleak	0	0	0	0	0	0	8.3	0	0	0
Perch	5.1	0	0	0	0	0	0	0	0	0
Burbot	5.1	0	0	0	0	0	0	0	0	0
Roach	0	8.3	9.7	0	0	0	0	0	0	0
Cisco	0	8.3	0	0	0	0	0	0	0	0
Fish remains	20.4	25.0	29.2	8.4	11.9	0	0	12.5	0	8.8
Number of fish	21	16	9	21	18	3	12	8	13	9

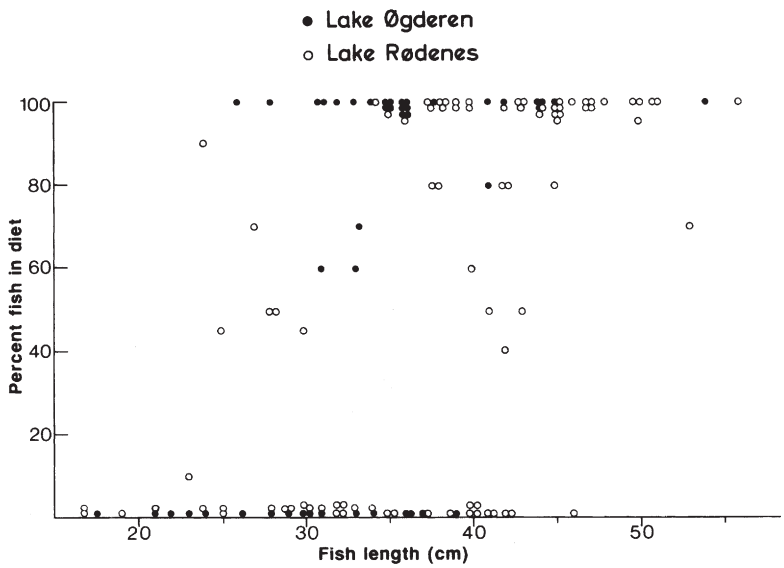

Fig. 4. Percentage (volume) of fish in the diet of individual burbot of different size from Lake Rødenes and Lake Øgderen.

its life span, the burbot in Lake Øgderen rarely exceeded lengths of 35 cm. A Walford-plot indicates highly different theoretical maximum lengths (Lake Rødenes: 69.5 cm; Lake Øgderen: 40.5 cm).

The burbot in both lakes was highly piscivorous (mean volume percentage of fish in the diet was 63.7% in Lake Øgderen and 55.3% in Lake Rødenes), feeding mainly on ruffe *Acerina cernua* and smelt *Osmerus eperianus* (Table 2). The month to month variation was large, some of this variation being due to the low sample size in particular months. In Lake Øgderen the burbot ate large numbers of *Mysis relicta* in July, August and September/October. The diet of the burbot in Lake Rødenes was more diverse. Fish species such as perch *Perca fluviatilis,* roach and burbot were eaten in May, June and July. In July and August larvae and pupae of *Chaoborus flavicans* were the most common food items. The amphipods *Pallasea quadrispinosa* and *Gammaracanthus loricatus* were important on all sampling dates.

The food of the individual burbot consisted of either fish or invertebrates (Fig. 4). The burbot started feeding on fish at lengths of 22—26 cm, feeding mainly on fish after reaching lengths of 35 cm. The burbot in Lake Rødenes was larger than the burbot in Lake Øgderen when the shift in diet from invertebrates to fish occurred, and more burbot from Lakes Rødenes were found to have both fish and invertebrates in the stomach.

DISCUSSION

The growth rate of the burbot in Lake Øgderen was much slower than the growth rate of the burbot in Lake Rødenes. The Lake Øgderen burbot also grow much slower than burbot from most other localities studied (Lawler 1963, Baily 1972, Scott & Crossman 1973, Nelichik 1973, Eloranta 1982, Sandlund *et al.* 1984, 1985; but see also Holcik & Nagy 1987). The slow growth of the Lake Øgderen burbot may be due to a number of different causes.

Hartman (1977) maintained that the growth of burbot is positively correlated with lake size. Since Lake Øgderen and Lake Rødenes are of nearly the same size this suggestion can not explain the observed differences in growth rate between the two lakes.

In temperate regions low temperatures may seriously constrain the growth of fish (Gerking 1972, Svärdson & Molin 1973). Lake Rødenes and Lake Øgderen, being close neighbours, experience the same weather conditions and have comparable size and depths. Thus temperature regime is an unlikely candidate for explaining the observed growth differences. Available physico-chemical data indicate that there are no significant differences in *e.g.* the length of the stagnation period or the depth of the thermocline. Another factor which might influence growth is oxygen: both lakes are meso- to eutrophic, and may suffer problems with oxygen deple-

tion in the profundal zone both during summer and winter. So far no serious problems have been observed in either lake, although a slightly reduced oxygen saturation level is recorded during summer. The depletion is most pronounced in Lake Øgderen, and may thus influence growth negatively in this lake. But it is not probably that this oxygen depletion is the main factor affecting the growth of the Lake Øgderen burbot.

Differences in prey abundance, prey availability or prey quality may explain these differences. The burbot in Lake Øgderen feed heavily on *Mysis relicta,* especially in autumn. The burbot in Lake Rødenes rarely feed on *M. relicta,* buth rather on the amphipod *Pallasea quadrispinosa.* In Lake Rødenes also *Gammaracanthus loricatus* and especially *Chaoborus flavicans* (both pupae and larvae) were important as food. Ruffe was the fish species most often eaten in Lake Øgderen, it was more rare in burbot stomachs in Lake Rødenes. The burbot may be an important predator on ruffe (Svärdson 1976), but Sandlund *et al.*. (1985) argue that ruffe often may be able to avoid predation from burbot. Thus the cost of capturing ruffe may be high. The burbot in Lake Øgderen feed on the specialized benthivorous ruffe and the semipelagic *M. relicta.* The burbot in Lake Rødenes feed on the large benthic crustaceans *P. quadrispinosa* and *G. loricatus* and also the large *C. flavicans.* The availability of these food items probably assures that the small and medium sized burbot have access to suitable prey. The burbot in Lake Øgderen feed on less easily accessible prey, reducing the growth rate especially in the young age groups.

To conclude, the different growth rates of the burbot in Lake Rødenes and Lake Øgderen cannot be explained by variation in lake morphometry or physico-chemistry (possibly oxygen levels may negatively affect the Lake Øgderen burbot). The most probable explanation for these large differences is the presence of large quantities of amphipods in Lake Rødenes, these being a suitable and profitable prey for mainly small and medium sized burbot.

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SAMMENDRAG

Vekst og diett av lake i to næringsrike vann i Sørøst-Norge

Artikkelen gir resultatene av en undersøkelse av vekst og diett av Lake *Lota lota* i de næringsrike innsjøene Øgderen og Rødenessjøen i Østfold. Fiskene vokste langsommere og ble mindre store i Øgderen (L = 40,5 cm mot 69,5 i Rødenessjøen). I Øgderen var næringen mest Hork *Acerina cernua.* Krøkle *Osmerus eperlanus* og pungreker *Mysis relicta.* I Rødenessjøen åt lake i tillegg store mengder av tangloppe-artene *Gammarocanthus loricatus* og *Pallasea quadrispinosa;* disse artene er antagelig av stor næringsmessig verdi, især for de yngre årsklassene av Lake.

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