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Population size and structure of crucian carp (*Carassius carassius* (L.)) in two small, natural ponds in Eastern Finland

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Two small (<2 ha), natural and seasonally anoxic ponds in eastern Finland were emptied of fish. The only fish species present was crucian carp, with population densities of 29 300 ind./ha in one pond (Hermanninlampi) and 3000 ind./ha in the other (Kuikkalampi). The corresponding values for biomass were 87 kg/ha and 10 kg/ha. The production of crucian carp in Hermanninlampi was estimated as 93 kg/ha/year, yielding a P/B ratio of 1.1. The fish in both ponds were very small, with thôse shorter than 10 cm dominating. The growth of fish differed between the ponds; the increase in length during their first summer was 3–4 cm in both but subsequent growth was slower in the smaller pond (Kuikkalampi). The growth of fish introduced into the empty Hermanninlampi was much faster in the first summer than that of the original stock. In Hermanninlampi sexual maturity was reached in 3–4 years and the total number of eggs in a 10-cm-long female was approx. 600 and in a 20-cm female approx. 7000. A height index and Fulton's coefficient of condition are calculated for several populations and causes of variation are discussed.

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1. Introduction

The crucian carp is a common cyprinid fish in southern and central Finland but is appreciated by fishermen only as a bait. It avoids running water but inhabits all kinds of stagnant water — even the smallest freshwater ponds and Baltic Sea bays with low salinity. Generally, in large and productive water bodies with multispecies fish communities the population densities of crucian carp are low but individual fish can grow large, even up to several kilograms (e.g. Hamrin 1979), whereas in some small waters the densities can be extremely high but the fish small (e.g. Nikolskiy & Shubnikova 1980) — especially in the common case where the crucian is the only fish species present.

The physiology of this species has some unique features resulting in the ability to tolerate months of total anoxia, which is a common phenomenon below ice in thousands of small ponds (Blažka 1958, 1960, Nagel & Brittain 1977, Holopainen & Hyvärinen 1985). With significant help from young and old bait-fishers this species has then been able to invade innumerable small water-bodies in Finland and to permanently conquer a seasonally productive habitat type which is uninhabitable by other fish species.

In an attempt to gain an understanding of the life of this species a series of physiological and ecological studies was commenced (Holopainen & Hyvärinen 1985, Hyvärinen et al. 1985, Holopainen et al. 1985). In this paper we present the results of studies on population size and structure in crucian carp in two seasonally anoxic natural ponds. One of these was poisoned with rotenone in order to remove the entire population for analysis and to provide an empty basin for planned field experiments and the subsequent monitoring of growth in the introduced population.

2. Study sites

The two natural ponds studied are situated about 3 km from each other and 9 km from the town of Joensuu (62°41′N, 29°41′E). The climate in this region of Finland is continental, the long term mean air temperature being -10.5°C in January and +16.7°C in July. The duration of ice cover in large lakes is approx. 175 days (from late November to mid-May) but can be even longer in sheltered ponds.

Hermanninlampi is a small (1.5 ha) and shallow (max. depth 1.6 m) pond (Fig. 1) which was part of the large Lake Höytiäinen until 1859 when suddenly, due to human activities, the water broke out at a new outlet and the lake water level dropped by 9.5 m. The pond was formed in a forested depression some 500 metres from the southern end of the present lake and now has two basins connected by a narrow passage but without any outlet from either basin. The catastrophic drop in the lake water level left a 5-cm sand layer at the bottom of the pond which is now covered by a thin (approx. 10 mm) layer of soft mud (Hyvärinen & Alhonen 1970). The water is brown and slightly acid (Table 1); for temperature and oxygen dynamics see Fig. 2.

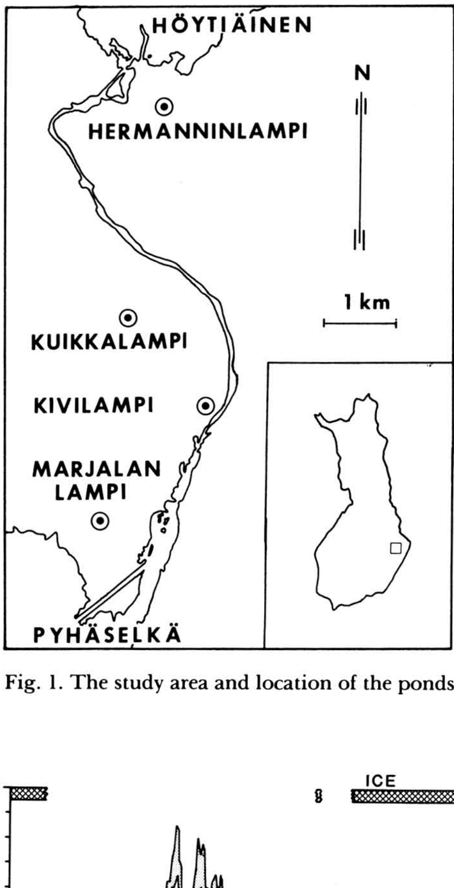

Fig. 1. The study area and location of the ponds.

Marshy vegetation has overgrown the shoreline, with *Carex* and *Sphagnum* dominating, while a dense stand of *Potamogeton natans* now covers a part of the pond surface area. The zooplankton is dominated by Cladocera (*Bosmina, Diaphanosoma*), together with Cyclopoida and the rotifer *Asplanchna* sp. Other invertebrates are mainly insects (Ephemeroptera, Odonata, Chironomidae) and oligochaetes. Molluscs are absent. The vertebrate fauna consists of the crucian carp, common frog, newt and muskrat.

In 1948 (and perhaps at other times) some crucian carps originating from Kuikkalampi, the other pond in our study, and later some other species like perch and even whitefish, were introduced into the pond. Crucian carp is, however, the only fish species able to overwinter and thrive in this pond.

Kuikkalampi is the smaller (0.2 ha) but deeper (max. 3.0 m) of the two ponds. It is situated in a kettle hole depression and also lacks an outlet. The open water is surrounded by a narrow belt of floating vegetation (mainly *Sphagnum*). According to local people the pond has been inhabited by crucian carp for at least the last 50 years and used for washing clothes, swimming, etc., and at times for the watering of pigs, too. Human activities could explain the high phosphorus and nitrogen content of the water (Table 1). The water is dark brown and acid with a high chemical oxygen demand.

Hammaslahti waste water pond. Additional fish for growth comparisons were caught by traps from the waste water pond of a copper mine (Outokumpu Oy) some 20 km south-east of Joensuu. The pond has an area of approx. 1 ha and pH 7.5, specific conductance 125 mS/m, tot. hardness 45°dH, Mn 2.0 mg/l and SO_4 800 mg/l. In previous years the local angling society has attempted to remove crucian carps from the pond by fishing, but without success.

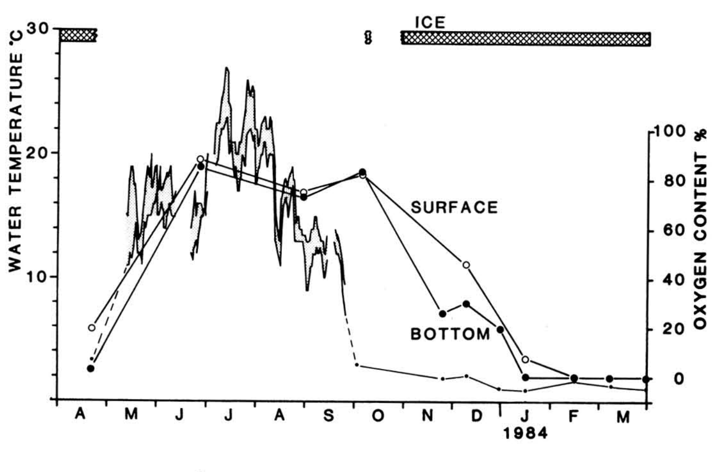

Fig. 2. Seasonal dynamics of temperature and oxygen saturation in Hermanninlampi. The daily variation in temperature is stippled. The circle is for surface, and the dot for bottom, oxygen.

Table 1. Some water quality data for the study ponds.

	Hermanninlampi							Kuikkalampi			
	Depth (m)	Summer mean	Summer range	*n*	Winter mean	Winter range	*n*	Depth (m)	mean	range	*n*
pH	0.3	6.2	5.8-6.7	7	5.9	5.7-6.2	3	0.4	4.9	4.5-5.1	3
	1.5	6.2	5.8-7.1	7	6.2	5.8-6.6	3	3.0	5.1	4.9-5.2	3
Colour mg Pt/l	0.3	87	40-150	7	97	90-100	3	0.4	153	100-200	3
	1.5	118	50-280	7	176	100-280	3	3.0	177	150-200	3
COD Mn mg/l O_2	0.3	8.1	6.5-9.6	7	9.9	8.1-12.2	3	0.4	38.6	34.1-46.5	3
	1.5	9.1	6.8-12.1	6	12.4	10.2-14.7	3	3.0	41.3	37.3-45.2	2
Spec. conduct.	0.3	2.6	2.3-2.8	4	4.3	3.4-5.9	3	0.4	2.9	2.7-3.1	3
(25°C) mS/m	1.5	2.6	2.4-2.8	4	6.2	3.6-7.1	3	3.0	3.1	2.3-3.9	3
P µg/l	0.3	18	10-30	4	17	7-27	3	0.4	97	47-180	3
	1.5	20	10-31	3	17	7-24	3	3.0	108	65-150	2
N µg/l	0.3	472	398-517	3	592	575-620	3	0.4	907	673-1292	3
	1.5	512	449-558	3	620	575-665	3	3.0	1421	923-1919	2
Mg mg/l	0.3	0.9	0.6-1.4	3	0.4	0.13-1.0	4	0.4	0.4	0.4-0.5	2
	1.5	0.6	0.6-0.7	3	0.6	0.13-1.0	4	3.0	0.5	0.5-0.5	2
K mg/l	0.3	1.3	0.8-2.1	3	1.1	0.7-1.3	4	0.4	1.4	1.3-1.4	2
	1.5	1.8	0.9-3.1	3	1.2	0.9-1.5	4	3.0	1.0	0.5-1.5	2
Ca mg/l	0.3	1.6	1.4-2.0	4	2.2	1.6-2.7	4	0.4	2.0	1.8-2.8	2
	1.5	1.2	0.7-1.9	3	2.5	2.3-2.7	4	3.0	2.2	1.9-2.4	2
Na mg/l	0.3	1.8	1.1-2.2	3	1.9	1.2-2.7	4	0.4	1.8	1.5-2.1	2
	1.5	2.6	1.4-3.9	3	3.1	1.5-3.5	4	3.0	2.2	1.3-3.1	2
Fe µg/l	0.3	-	-	-	210	-	1	0.4	179	-	1
	1.5	-	-	-	197	-	1	3.0	174	-	1

3. Material and methods

The chemical and physical properties of the water were measured in the field or in the water research laboratory of the Karelian Institute, University of Joensuu, by standard routine methods.

Hermanninlampi: Between the end of April and mid-June 1982, 1270 crucian carps were caught by traps having a 5 mm square mesh and another 70 fish by 25 mm gill net. All the fish were measured (total length), weighed and sexed. This material was used for size-specific fecundity, growth, and weight-length relationship, as well as sex ratio estimations.

The absolute egg numbers per female were determined for 5-15 fish in each size class (1 cm intervals) either by direct counting, if approx. 600 eggs or less per fish, or by calculation from the total weight of eggs after weighing two subsamples of 200 eggs each. Ovaries were first preserved in Gilson's fluid (Bagenal & Braum 1971), the ovarian tissues being removed and the eggs damp-dried on filter paper before weighing. In addition, gonad development was followed using Nikolsky's classification (Bagenal & Braum 1971) and by weighing gonads during routine fish handling.

The age and growth of fish were estimated from scales and checked from vertebrae. Back-calculations of growth were made by the method of Monastyrsky (Tesch 1971).

On 20 July 1982 the pond Hermanninlampi was treated with rotenone, i.e. approx. 50 l of 2.5 % solution (25 g rotenone per litre), which was mixed with water and pumped from a row boat through a perforated tube approx. 1.5 m in length to ensure effective distribution of the poison throughout the water column.

The concentration of rotenone used for most fish species is 0.5-1.0 µl/l, but this is not enough for crucian carp. According to Holopainen & Hyvärinen (1985), the LT_{50} values for concentrations of 1, 2, and 4 µl/l of 2.5 % rotenone solution in tap water at 20°C are 36, 22 and 10 hours, respectively. In the pond the concentration was estimated to reach values of about 2.5-3 µl/l, which in the prevailing high temperatures (23-27°C) appeared to be sufficient.

The smallest fish (1-2 cm) died in one hour and all the rest before the next morning. Except for the smallest, separate size class of approx. 1-2 cm, all the fish were collected with hand nets during the next two days.

Most fish surfaced after the application of rotenone and stayed floating when dead. The efficiency of collecting was checked by scuba-diving along two 84-metre transect lines across the pond (only two fish were found on the bottom) and double checking five randomly selected 10 m lines along the shore.

All the collected fish were counted and the total fresh biomass was determined. Three random samples of about 100 fish each were taken from the mass of fish for size frequency analysis.

A rough production estimate was made for the year 1982 on the basis of size frequency distribution on 20 July and the annual length increment as estimated by back-calculation from scales. An average figure of 2.5 cm for the youngest fish (0.5-6.4 g), and of 1.6 cm for the older fish (>6.5 g), was used as an annual length increment. Assuming that the length gain is linear and that half of the annual length increment had been gained by 20 July (see Results and discussion: growth), the initial (spring) and final (autumn) lengths in the middle of each size class were estimated. The lengths were converted to weights by use of the weight-length regression. The mean weight difference in each size class between spring and autumn was multiplied by the number of individuals in this size class. The numbers were regarded as an average for the growing season and the effects of mortality were ignored.

In October 1982, 70 crucian carp originating from Kuikkalampi were introduced into the empty Hermanninlampi. Another 210 fish from the same source were introduced in May-June 1983. Before being released fish were divided into four size-classes, 6.5-7 cm (n=34), 7.5-8 cm (n=152), 9.0-9.5 cm (n=84) and 10-11 cm (n=10), and each size-class was given a different mark by fin-clipping. The growth of the marked fish was checked by trap catches on 5 July, 20 September and 4 October 1983.

Kuikkalampi: approx. 300 fish were caught by traps (5 mm mesh) in October through December, 1982 and another 325 fish in spring 1983.

Waste water pond: 303 fish (approx. 13 kg) were caught by three traps (25 mm mesh) in one night at the end of September 1982.

4. Results and discussion

4.1. Population size

In spring 1982 the population size of crucian carp (>3 cm) in Hermanninlampi was estimated to be approx. 44 000 (29 000/ha). This number includes the 40 345 fish that were removed from the pond in July after rotenone treatment, plus the correction due to collecting efficiency (about 2 300 fish, see below) and the yield of previous trap catches (1 270 fish). The double checking of shore transects and bottom gave an estimate of 300 fish (about 1 kg). Inside the dense *Potamogeton* stand in the middle of the pond approx. 2 000 small (2-3 cm) fish (in total again about 1 kg) were estimated to have been left in addition. In all, the collecting efficiency was 95 % for numbers and more than 98 % for biomass. The number of fish smaller than 3 cm which were not collected efficiently may have been high but their biomass would have been low.

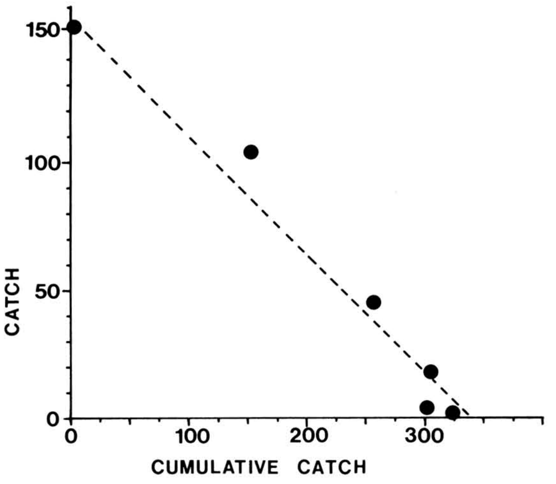

Fig. 3. Six successive daily catches of the removal trapping in Kuikkalampi in May 1983. Three traps were used; the line was fitted by eye.

In spring 1983 the decreasing catch per effort suggested almost total removal of the population in Kuikkalampi by trapping (Fig. 3). Application of the method of Zippin (1956) gave a population estimate of 332 ± 22 (mean ± 95 % confidence limits) in spring. Together with the 300 fish removed in autumn this gave a population estimate of about 630 individuals (3 150/ha). This may have been an underestimation because the traps were ineffective in catching individuals shorter than 6 cm, but the complete absence of small individuals from both trap and hand-net catches suggests that their abundance was low (see below).

Although quite high, the population density and biomass in Hermanninlampi were similar to those reported earlier for ponds in Central Europe and the USSR that are also inhabited only by crucian carp. These ranged from 9 600 ind. per ha (biomass unknown) to 69 800 ind. (269 kg) per ha (Cerny 1971, Nikolskiy & Shubnikova 1980).

In ponds with crucian carp as the sole species the high population densities are usual, but when other fish species are present the densities are low, down to only 1-2 fish per ha but with a much larger fish size (≥20 cm) (Hamrin 1979, Penczak et al. 1981). The lower population density in Kuikkalampi in comparison to Hermanninlampi was probably due to the more extreme abiotic conditions in this pond. Low pH (4.5-5.2) and a very high humic load can limit both food production and the reproductive success of fish.

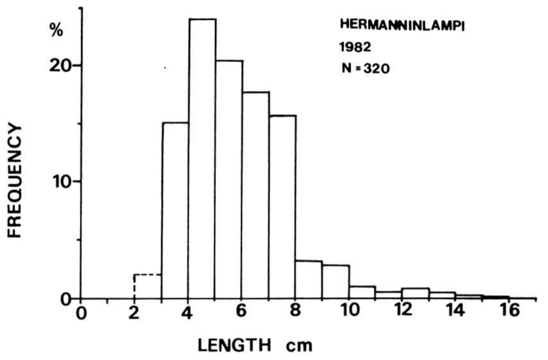

Fig. 4. The length distribution of crucian carp in the pond Hermanninlampi using samples from fish poisoned on 20 July 1982. The collection was considered not to be 100 % effective for fish shorter than 3 cm.

4.2. Population structure

The mean weight of fish in Hermanninlampi was approx. 3 g, corresponding to a length of approx. 6 cm. More than 90 % of all fish were less than 8 cm in length and only approx. 3 % were more than 10 cm (Figs. 4 and 5). Only a few individuals were longer than 15 cm, the largest one being 23 cm long and weighing 310 g (age 12–13 years).

In Kuikkalampi the population consisted mainly of fish of between 6 and 9 cm (Fig. 5). The largest fish caught was only 12.1 cm long (age 8 years).

The catch from the waste water pond consisted almost entirely of one age group (2+), with a length of approx. 10–14 cm (Fig. 5). A few older sexually mature fish were caught but none of the youngest age groups were because of the large mesh size of the traps.

The comparison between size frequency given by rotenone treatment and trapping reveals limitations of the latter in population size analysis (Figs. 4 and 5). Theoretically a 5×5 mm square mesh should retain crucian carp with lengths of more than 25 mm, while a 25 mm square mesh should catch a 90 mm fish, if the height:length ratio of fish is assumed to be 0.28 (see Fig. 9). This explains the lower limit of fish size in the waste water pond but not in the two others (Fig. 5). The possible reasons for the lack of 30-60 mm fish from the 5-mm mesh traps are: 1) habitat choice (e.g. the fish stay in the very shallow littoral), 2) lower swimming activity, 3) ability to avoid, or escape from, the traps and 4) vulnerability to cannibalism in the trap. The most probable of these is the habitat choice, but several factors could be involved.

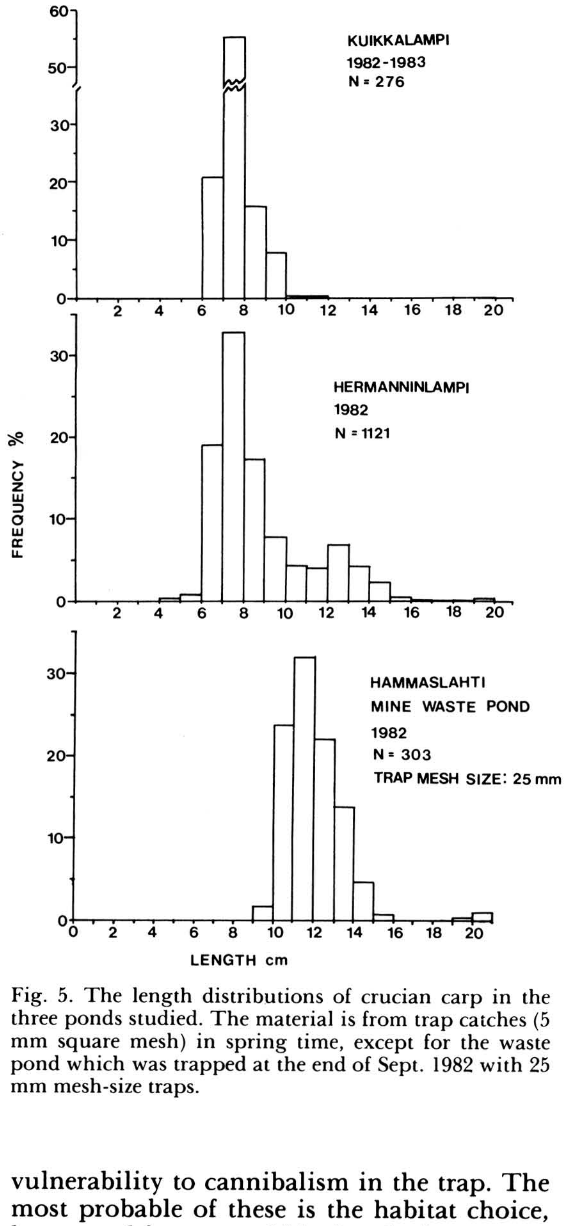

Fig. 5. The length distributions of crucian carp in the three ponds studied. The material is from trap catches (5 mm square mesh) in spring time, except for the waste pond which was trapped at the end of Sept. 1982 with 25 mm mesh-size traps.

The peaked size structure in dense populations of crucian carp given by Nikolskiy & Shubnikova (1980) and Cerny (1971) was suggested as due to a high mortality rate. Cerny (1971) reported an annual mortality rate of 0.52–0.83 for one population. The scarcity of fish older than 4 years suggested high adult mortality in the Hermanninlampi population as well. Ciepielewski (1967) suggested that the cause of this heavy mortality was abiotic. He presumed that the typical size structure was due to frequent winterkills selectively affecting older age groups. Long periods of complete anoxia are regular phenomena in most of these ponds but they are by no means lethal under normal conditions (Holopainen & Hyvärinen 1985). The ultimate cause of irregular winterkills in dense populations could be energy shortage due to an intraspecific resource competition keen enough to disturb the late-summer collection of winter-reserves (for glycogen store dynamics, see Hyvärinen et al. 1985). The low survival of older fish could result from a relatively poorer nutrition situation when a different quantity or quality of food is actually required.

In dense populations juvenile mortality can be high because of intraspecific predation (cannibalism). Our preliminary experiments indicate that crucian carps readily attack and eat fry and young fish of their own species.

The sex ratio in fish up to 14 cm in length was 1:1 in Hermanninlampi but the proportion of females was already much higher (80 %) between 14 and 15 cm, while all the fish larger than 15 cm were females.

4.3. Growth

The weight-length relationship in Hermanninlampi (W is the weight in g and L is the length in cm) for both sexes combined was $W=0.009L^{3.174}$ ($r=0.94$, $n=179$), for males alone $W=0.012L^{3.016}$ ($n=53$) and for females $W=0.008L^{3.236}$ ($n=94$). The relationship between fish length (y) and lateral radius of the scale (x) was of the form $y=0.357x^{0.885}$ ($r=0.99$, $n=127$).

The back calculation of growth gave different growth curves in each of the three basins (Fig. 6). There was no difference in growth between females and males in Hermanninlampi, but in good conditions the female growth rate has been reported as exceeding that of males (Schäperclaus 1953).

The fishes introduced into the empty Hermanninlampi pond showed rapid growth in summer 1983 (Fig. 6). The daily length increment during the 112-day period (1 June to 20 September) was 0.8 to 0.9 mm in all size classes, corresponding to a daily weight increment of 0.7 g in the smallest and of 1.5 g in the largest fish (Table 2).

These figures equal those given by Schäperclaus (1953) and Hakala (1915) and probably represent values near the maximum growth rate of crucian carp. According to Schäperclaus (1953), this species is able to grow up to 9.5 cm (15 g) in its first summer in artificial ponds with superabundant food and to reach a length of 25 cm in the third summer with a weight of approx. 360 g.

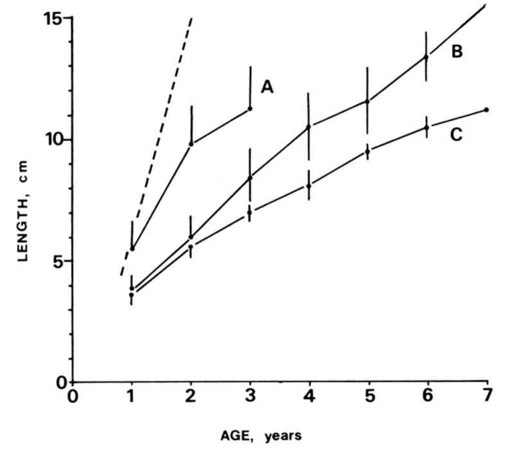

Fig. 6. The growth of crucian carp in the ponds based on back-calculation from scales. — A: Hammaslahti waste pond. — B: Hermanninlampi. — C: Kuikkalampi. The broken line shows the rapid growth of fish introduced in 1983 into the empty Hermanninlampi (Table 2).

In natural conditions, however, the mean growth rate has been reported as reaching only 2.4-5 cm in the first summer and then levelling off at 1.5-4 cm per year, depending on the conditions (Papadopol 1967, Disler 1971, Cerny 1971, Makara 1980, Budakov et al. 1981).

The more rapid growth of fish in the waste water pond may have been caused by the regular reduction of the population by fishing. The growth of crucian carp in Hermanninlampi (before poisoning) and in Kuikkalampi was close to that reported by Cerny (1971) in some other dense pond populations.

4.4. Fecundity

The total number of eggs per female in Hermanninlampi in 1982 (Fig. 7) was much lower than that reported by Astanin & Podgorny (1968), perhaps due to high population density. The crucian carp is a fractional spawner and lays its eggs in several batches during the summer.

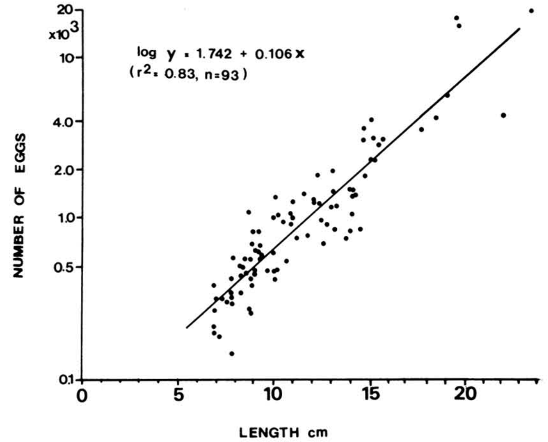

Fig. 7. The size-specific number of eggs in crucian carp in Hermanninlampi in 1982.

The "fecundity" estimates here include all size classes of eggs present in ovaries, so the real number of eggs laid during the summer may be much lower. Even some of the ripe eggs will probably not be deposited, as is the case in carp (Gupta 1975) and tench (Lucowicz & von Proske 1979).

No empty gonads were noticed and there were gonads in all developmental stages during the sampling period. In routine weighing between 24 May and 15 July 1982 female gonads showed a slight increase in their gonadosomatic index (GSI, gonad weight/total weight × 100) from 2.8 to 3.7. The GSI of males remained at approx. 1.7 during this time. Before 20 July at least two spawning periods are indicated by our observations of two markedly different size classes of fry in the pond.

Spawning is reported to occur at water temperatures of 17-20°C (Hakala 1915, Schäperclaus 1953, Astanin & Podgorny 1968) and the fry hatch at a length of 4.2-4.9 mm after five days at 18-20°C (Schäperclaus 1953).

In Hermanninlampi the crucian carp matured at the age of 3-4 years, but the fish from the waste water pond showed no signs of gonad development at the age of three summers. Other workers have reported the maturation of this species as occurring at an age of 1-4 years (Schäperclaus 1953), depending on population density, growth (Astanin & Podgorny 1968), and temperature (Gupta 1975).

4.5. Biomass and production

The total biomass of crucian carp in Hermanninlampi in mid-summer 1982 was calculated as approx. 130 kg (87 kg/ha). This equals the maximum total biomass in roach-dominated mesotrophic lakes in Finland (Toivonen 1964, Sumari 1975), but it is only one-third of the biomass of crucian carp in some small ponds in Central Europe and the USSR (see chapter 1, population size). The high biomass and high numbers in the youngest age groups in Hermanninlampi indicate a high production, which was calculated as 140 kg a year (93 kg/ha). This gave an annual P/B ratio of 1.1.

Brofeldt (1920) reported the production of crucian carp fry in a natural food pond at Evo fishery research station as being as high as 142 kg/ha.

The introduced fish (Table 2) showed a growth production of about 39 kg in 112 days, which, with a mean biomass of 22 kg, yielded a P/B ratio of 1.8 for the growing season. These values were based on 3.5 % adult mortality and excluded the reproductive output, which, according to our preliminary results (numbers and size-structure of young fish), is equal to growth production (Piironen & Holopainen, unpubl.).

4.6. Body shape and condition factor

The coefficient of condition is commonly used in fish biology to indicate the physiological state or general well-being of fish, especially in order to compare food conditions. Fulton's condition index (K) is the relation of weight (W) to the third power of length (L) and Clark's variation excludes the weight of the visceral mass (stomach contents, gonads and liver), all of which can show large annual size variation.

In Hermanninlampi, Fulton's coefficient of condition (K) showed a positive linear relationship with fish length (Fig. 8) and a significant difference between years ($P<0.001$, analysis of covariance). Low values in 1982 represent the original dense population (introduced from Kuikkalampi 35 years ago) before poisoning, whereas those in 1983 represent the newly introduced population (also coming from Kuikkalampi) with low density and a rapid

Table 2. Growth of the introduced fish in the pond Hermanninlampi in summer 1983. The fish were introduced in October 1982 (70 fish) and in May 1983. 1 June 1983 was chosen as the starting point for growth.

		1 June, 0 days	5 July, 35 days		20 Sept, 112 days	
		mean	mean	range	mean	range
Size class I (6.5-7.0 cm)	length (cm)	6.9	10.3	7.3-10.6	15.8	14.9-16.6
	weight (g)	5.2	20.04	6.18-22.54	88.6	75.55-99.16
	length gain (cm)		3.4		8.9	
	weight gain (g)		14.8		83.4	
	n	34	11		8	
Size class II (7.5-8.0 cm)	length (cm)	7.7	11.5	10.4-13.2	18.3	14.6-21.7
	weight (g)	6.9	26.83	19.88-47.68	146.8	72.1-268.36
	length gain (cm)		3.8		10.6	
	weight gain (g)		19.9		139.9	
	n	152	48		18	
Size class III (9.0-9.5 cm)	length (cm)	9.3	12.2	12.1-13.7	19.6	17.7-21.3
	weight (g)	12.3	43.7	35.94-53.32	182.3	140.14-227.29
	length gain (cm)		2.9		10.3	
	weight gain (g)		31.4		170.0	
	n	84	20		10	
Size class IV (10-11 cm)	length (cm)	10.4	14.5	13.1-15.4		
	weight (g)	19.2	63.29	45.77-73.35		
	length gain (cm)		4.1			
	weight gain (g)		44.1			
	n	10	4			

growth rate (Table 2). Since the body shape of crucian carp varies among water bodies (Fig. 9) and can vary during growth or with environmental changes, the use of condition factors appears limited in this species (a critical study on the use of this factor with some other fish species has been recently made by e.g. Gershanovich et al. 1984). Thus, the difference in *K* values is partly due to a change in the height index (100 height/length) of the introduced fish. The index increased from 29 at the end of May (n=20, SD=0.01) to 34 in early July (n=11, SD=0.03) and to 38 in late September (n=16, SD=0.01) (Fig. 9).

The inter- and intrapopulation variation in height index in the small material collected in this study (Fig. 9) was in the range 26-44. The differences among ponds are obvious and seem to be larger than the variation among size classes in any one population. The difference between fish in Kuikkalampi and the progeny of the same population in the emptied Hermanninlampi again shows the ability to change shape according to environmental conditions, but the relative importance of genetic and environmental factors is unknown.

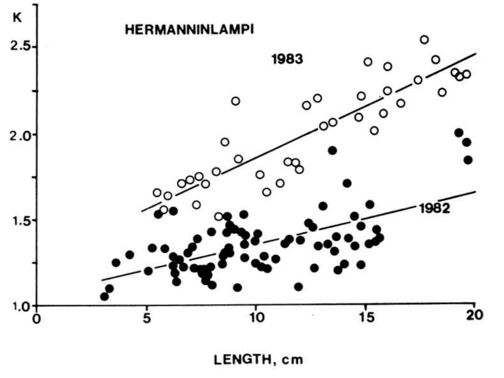

Fig. 8. Fulton's coefficient of condition (K = weight/length^3) for crucian carp of different sizes (L, cm) in Hermanninlampi. The dots are for the original stock in 1982 ($K = 1.06+0.03L$, r=0.37, n=77) and the circles for the transplanted stock in 1983 ($K = 1.27+0.06L$, r=0.76, n=37).

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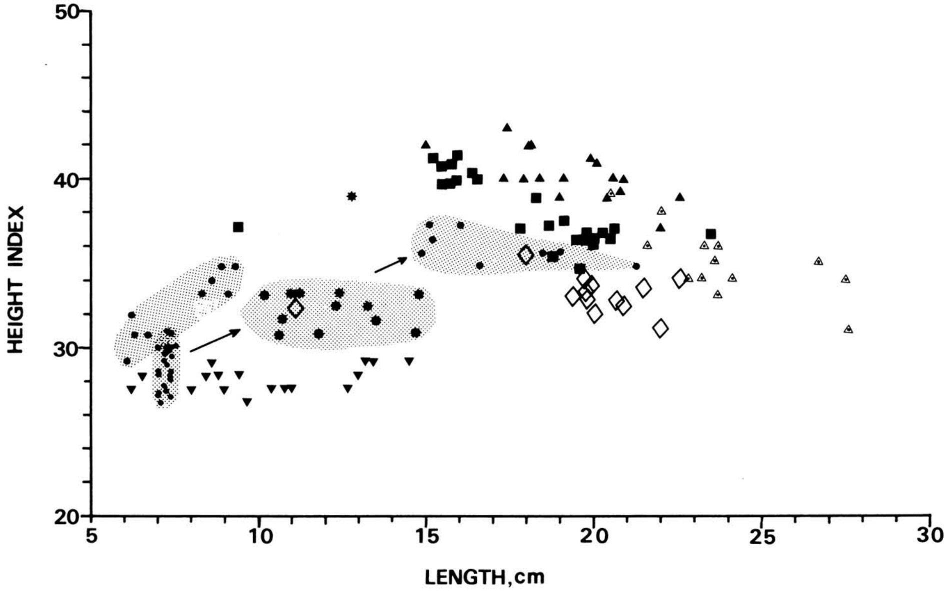

Fig. 9. The size-specific height index (100 × height/length) for six populations of crucian carp in the study area. The stippled areas with arrows show the development of the introduced fish in Hermanninlampi. On the left is the original stock from Kuikkalampi in spring 1983; the middle area represents July and the area on the right shows the situation in Sept. 1983. The uppermost stippled area on the far left is for the progeny of the introduced fish in 1983. ▼ = Ijäkkälänlampi; ▲ = Patsonlampi; ■ = Kivilampi (Fig. 1); ◇ = Hammaslahti waste pond and ◬ = Marjalanlampi (Fig. 1).

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