ACTA ICHTHYOLOGICA ET PISCATORIA
Vol. XIX Fasc. 2 Szczecin 1989

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Aquaculture

AN ATTEMPT TO ASSESS EFFECTS OF ILLUMINATED CAGE LOCATION ON COREGONID CULTURE RESULTS

PRÓBA OKREŚLENIA WPŁYWU LOKALIZACJI SADZÓW OŚWIETLONYCH NA WYNIKI PODCHOWU RYB GŁĄBIELOWATYCH (*COREGONIDAE*)

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Results of cage rearing of the whitefish (*Coregonus lavaretus* L.) and *C. peled* Gmel. obtained in the pelagic zone of the lake are better than those from the littoral where pressure of various parasites is strongly marked. Regardless of this trend, however, fish culture in cages placed in different lake zones should be regarded as a highly variable random process, its variability being a net result of both the variation in various environmental processes and interaction of different components of the ecosystem.

INTRODUCTION

The Polish method of rearing coregonid juveniles in cages, based on light-atracted natural food, presents a large potential for intensifying fish production in lakes. In view of diminishing success of the natural spawning in coregonids, the method – coupled with artificial spawning – offers a chance of obtaining considerable amounts of juvenile for stocking purposes. The cage method has been finding an ever-increasing application in cultures of a growing number of species (Żiljukas et al., 1977; Jäger and Nellen, 1980; Schlumpberger and Zieborth, 1981; Champigneulle et al., 1986). The studies published so far demonstrate a diverse nature of cage cultures in limnologically different lakes (Bryliński et al., 1979). Depending on a type of a reservoir, the cage output at the first stage of rearing ranges from 0.1 to 2.8 kg/m^3. Varying outputs occur subsequently, too, in the same lake (Mamcarz and Szczerbowski, 1984), which demonstrates the need to find solution optimal for a given reservoir used for fish cage cultures. Location of cages in a lake which is highly variable morphologically may exert some effect on fish production. To assess this effect, an attempt to culture *Coregonus lavaretus* L. and *C. peled* Gmel. in different zones of the same lake was made within 1978–1980. The present paper summarizes results of the experiment.

MATERIALS AND METHODS

The culture was located in Legińskie Lake (228.3 ha; 37.2 m maximum depth) situated in the upper reaches of the river Sajna (the Łyna-Pregoła catchment). Methods of rearing, environmental conditions in the lake, and research techniques are described elsewhere (Mamcarz and Szczerbowski, 1984; Szczerbowski and Mamcarz, 1984).

The 8 m^3 cages were made of polyester tulle; initially, 1.0 and 1.8 mm mesh sizes were used to be changed after 5 months of culture to 5.5 mm mesh. Natural food was attracted with photocell-controlled cage illumination (24 V/60 W). A 24-h illumination

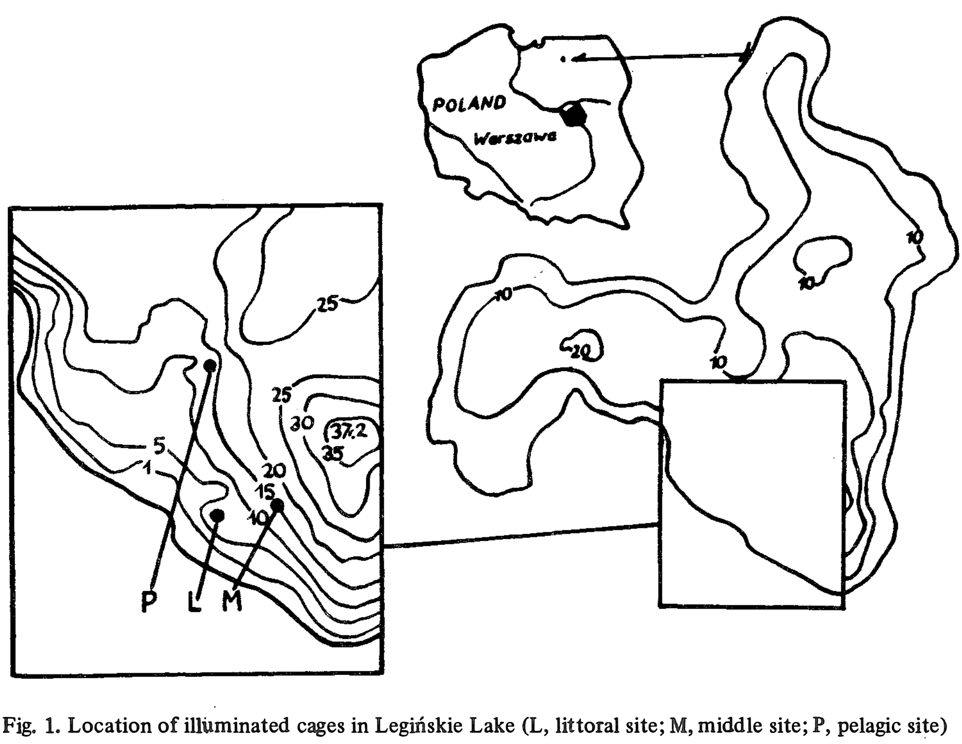

Fig. 1. Location of illuminated cages in Legińskie Lake (L, littoral site; M, middle site; P, pelagic site)

Table 1

Variability of effects of *Coregonus Lavaretus* L. rearing in cages in different zones of Legińskie Lake
(L – littoral; M – middle; P – pelagic)

	No. of cages	Stocking				Catch				Survival (%)
		Date	Number of individuals in cage	Individual length (mm)	Individual weight (g)	Date	Number of individuals in cage	Individual length (mm)	Individual weight (g)	
L	4	31.05.1978	1677 – 2860	24.4 – 27.5	0.086 – 0.154	26.09.1978	12 – 1567	69.6 – 78.8	2.37 – 4.24	0.7 – 54.8
M	3	7.06.1978	2765 – 4773	25.1 – 27.6	0.120 – 0.164	26.09.1978	896 – 2343	60.4 – 70.8	1.43 – 2.38	32.4 – 54.6
P	4	31.05.1978	2225 – 3517	24.4	0.086	26.09.1978	635 – 2145	85.4 – 102.3	4.44 – 7.99	26.2 – 63.9
L	3	26.09.1978	729 – 1567	69.6 – 78.8	2.37 – 3.28	24.04.1979	604 – 1041	117.4 – 133.1	14.6 – 19.9	58.2 – 82.8
M	3	26.09.1978	896 – 2343	60.4 – 70.8	1.43 – 2.38	22.04.1979	711 – 1439	112.7 – 124.3	12.6 – 18.0	61.4 – 79.3
P	4	26.09.1978	635 – 2145	85.4 – 102.3	4.44 – 7.99	24.04.1979	229 – 902	122.4 – 137.9	16.5 – 23.3	36.1 – 53.9
L	2	24.04.1979	1031 – 1325	125.2 – 127.0	17.3 – 19.2	13.07.1979	887 – 1197	142.7 – 147.1	21.5 – 24.0	86.0 – 90.3
M	1	22.04.1979	3442	121.4	16.1	13.07.1979	2479	125.8	15.3	72.0
P	2	24.04.1979	811 – 1483	129.1 – 130.9	19.8 – 21.2	13.07.1979	701 – 1329	141.3 – 147.8	24.3 – 28.5	86.4 – 89.6
L	2	13.07.1979	870 – 1190	142.7 – 147.1	21.5 – 24.0	28.09.1979	714 – 969	154.9 – 155.3	30.4 – 31.3	82.1
M	2	13.07.1979	1210 – 1240	125.8	15.3	27.09.1979	504 – 572	141.8 – 155.1	22.8 – 30.6	40.6 – 47.3
P	2	13.07.1979	686 – 1314	141.3 – 147.8	24.3 – 28.5	28.09.1979	481 – 835	153.6 – 156.5	32.4 – 35.1	63.5 – 70.1
L	2	28.09.1979	697 – 957	154.9 – 155.3	30.4 – 31.3	5.05.1980	233 – 318	182.9 – 187.9	61.2 – 62.9	33.2 – 33.4
M	1	27.09.1979	1035	149.2	27.2	5.05.1980	721	185.2	58.0	69.7
P	2	28.09.1979	467 – 820	153.6 – 156.5	32.4 – 35.1	5.05.1980	54	193.4 – 193.6	73.3 – 77.2	6.6 – 11.6

Table 2

Efects of *Coregonus peled* Gmel. rearing in cages in different zones of Legińskie Lake (L – littoral; M – middle; P – pelagic)

	No of cages	Stocking				Catch				Survival (%)
		Date	No. of indiv. in cage	Indiv. length (mm)	Indiv. weight (g)	Date	No of indiv. in cage	Indiv. length (mm)	Indiv. weight (g)	
L	1	12.06.1979	1000	26.9	0.13	28.09.1979	591	122.4	16.8	59.1
M	1	12.06.1979	1000	26.9	0.13	28.09.1979	233	124.2	18.8	23.3
P	1	12.06.1979	1000	26.9	0.13	28.09.1979	796	127.5	19.1	79.6
L	1	28.09.1979	576	122.4	16.8	5.05.1980	63	147.5	28.3	10.9
M	1	28.09.1979	213	124.2	18.8	5.05.1980	49	161.1	55.8	23.0
P	1	28.09.1979	781	127.5	19.1	5.05.1980	15	157.1	36.8	1.9

was used during fish wintering under ice. The cages, submerged to 3–5 m, were mounted to floating platforme anchored at 3 different parts of the lake (Fig. 1). The culture sites differed in their distance from shore and in depth. The littoral (L), middle (M), and pelagic (P) sites were located 50 m, 100 m, and 280 m off shore, respectively, their respective depths being 9, 14.5, and 13 m.

Before the onset of the experiment (May), larvae of both species were kept at the middle site. In early June, cages at the three sites were stocked with 1600–4700 inds/cage for *C. lavaretus* and 1000 inds. (cage for *C. peled* (Tables 1 and 2). Throughout the culture period, the stocking densities diminished due to mortality and periodic (once or twice a month) removal of fish for examination. In the second year, the contents of some cages containing *C. lavaretus* were pooled, thus reducing the number of cages at different sites.

Stocking density was assessed by weight; the older fry were counted, fish by fish, during consecutive phases of the experiment. Survival rate at different phases and in different cages was determined as per cent survival relative to the stocking density at the beginning of each phase. Survival rate at each site was the mean for the respective cages, related to the initial stocking density at a site. Mean length and weight growth rates for each site were calculated as a mean of values obtained from the respective cages.

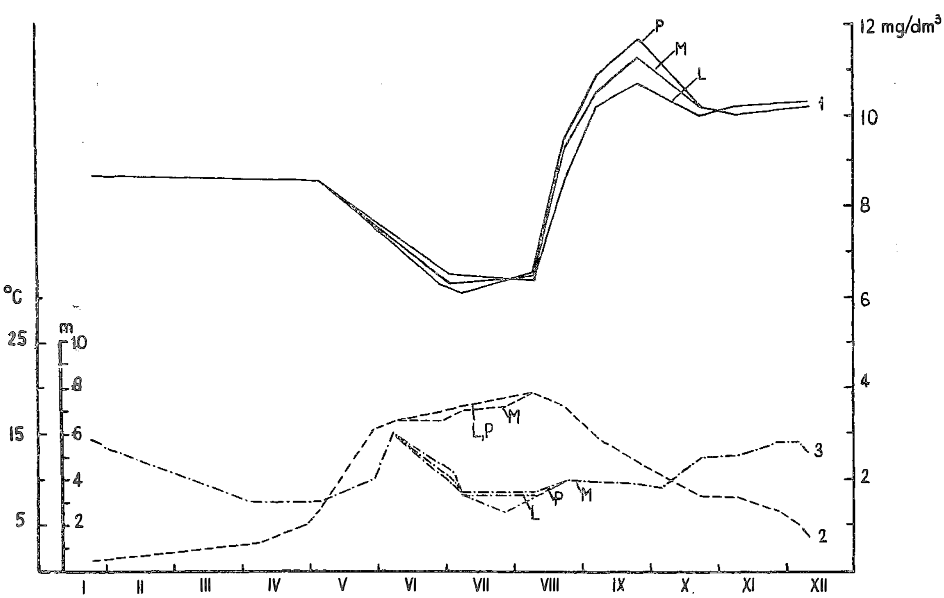

Fig. 2. Changes in water oxygen content (1), temperature (2), and visibility (Secchi depth) (3) within the areas of cage deployment (3 – 5 m) at different Legińskie Lake sites. Sites denoted as in Fig. 1.

Environmental conditions at different sites

In 1978, water temperature, transparency, and dissolved oxygen content (DOC) showed little differences between the three sites (Fig. 2), the sites differing in temperature, transparency, and DOC by 0.2–0.4°C, 0.1–0,2 m, and 0.2–0.4 mg 0_2 /dm^3, respectively. The pelagic site showed the lowest water temperature and DOC as well as the greatest Secchi depth.

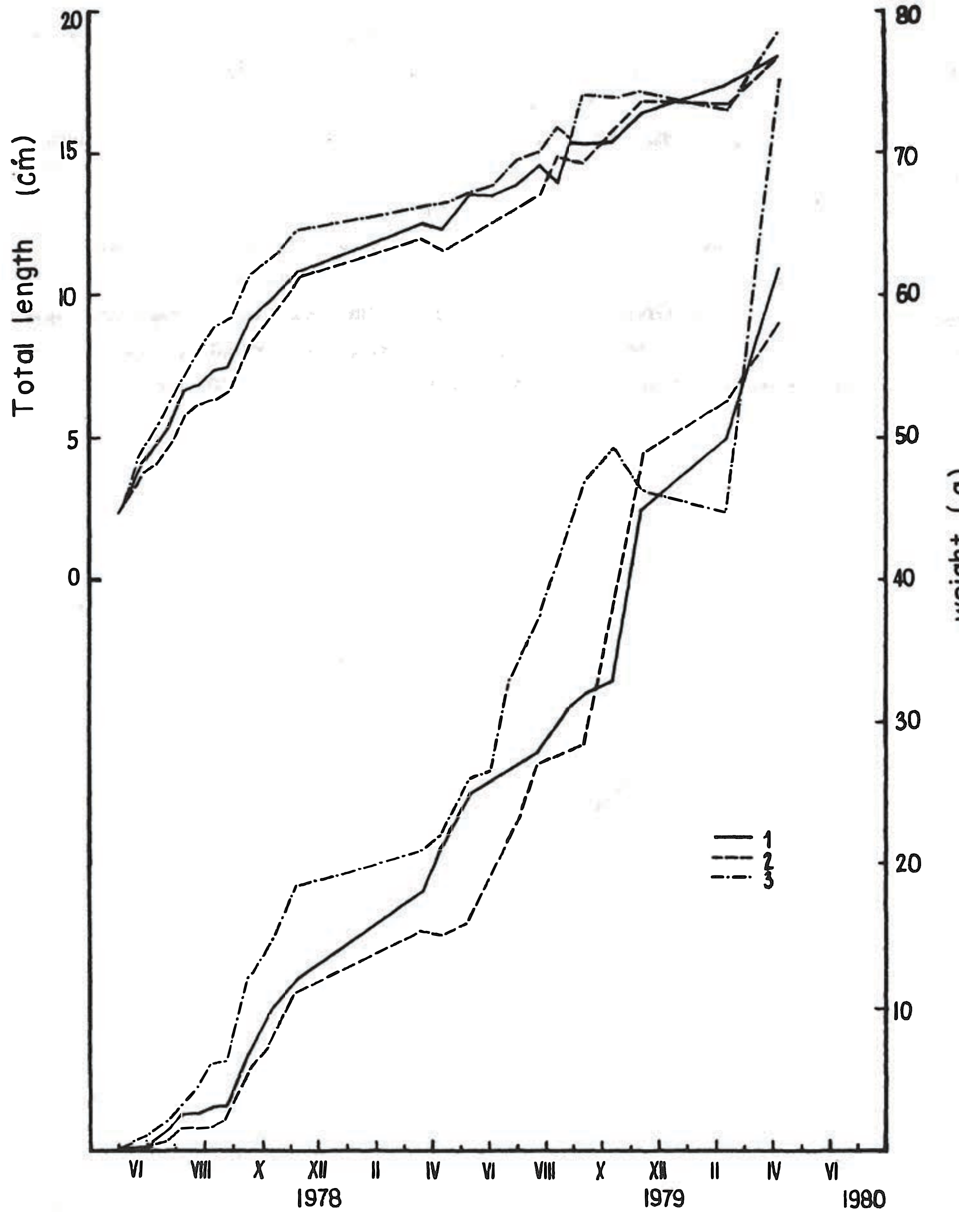

Fig. 3. Whitefish body length and weight growth in cages at different Legińskie Lake sites. 1, littoral site; 2, middle site; 3, pelagic site

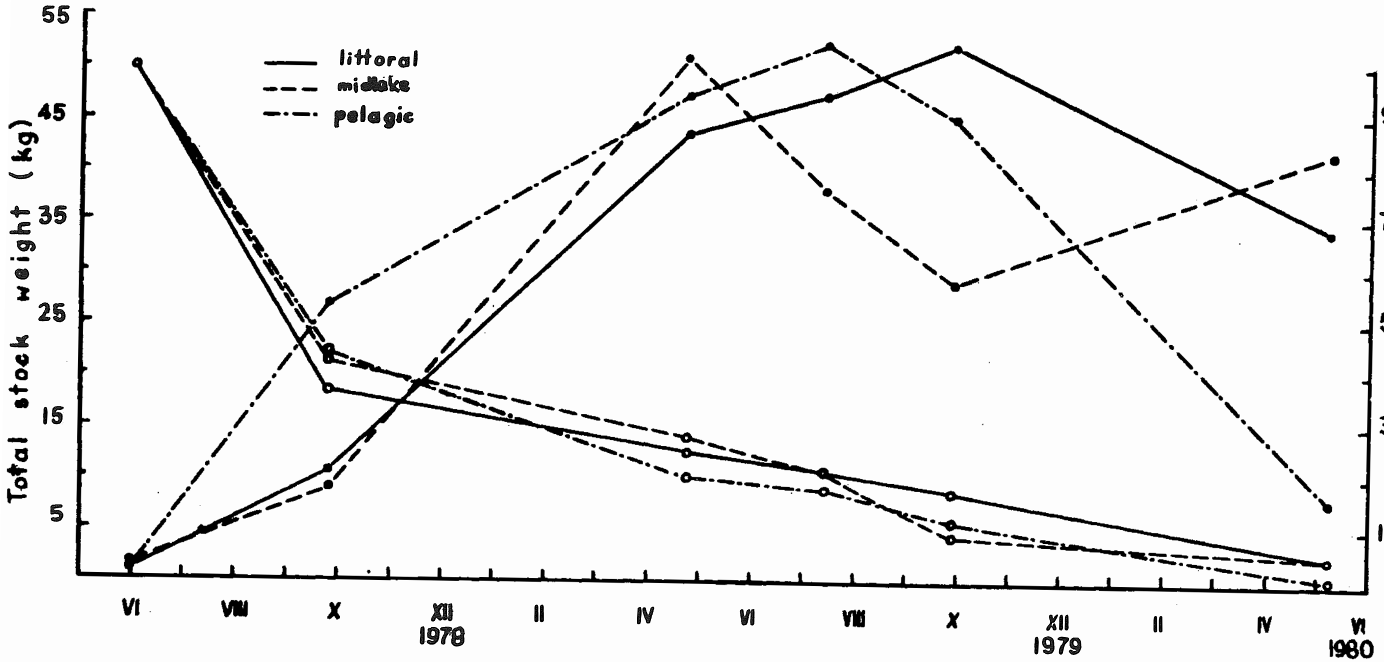

Fig. 4. Survival (o) and production (•) of whitefish in cages at different Legińskie Lake sites

C. Lavaretus culture in different lake zones

The stocking material consisted of *C. lavaretus* fry of varying size, obtained from the earlier May culture. Those individuals released to the pelagic site cages and to some of those at the littoral site weighed practically half the weight of the remaining ones (Table 1). In spite of that, the pelagic site fish soon proved to be the fastest growing ones and remained so throughout most of the time of the experiment (Fig. 3). In late September 1978, the pelagic site *C. lavaretus* attained mean weight and length of 5.7 g and 9.2 cm, respectively. At that time the respective means for the littoral and middle site individuals were 3 g/7.5 cm and 2g/6.5 cm. The size of fish kept in different cages varied considerably (Table 1): individual weights at the pelagic, littoral, and middle sites were observed to vary within 4.4 –8.0 g, 2.4–4.2 g, and 1.4–2.4 g, respectively.

The *C. lavaretus* survival rate during the summer 1978 stagnation was low regardless of the site (Fig. 4). Mean survival of 37% was recorded at the littoral site, slightly higher values (exceeding 40%) being observed at the middle and pelagic sites. The rate of survival was found to vary considerably between cages at each site, the survival rate ranges of 0.7–54.8%, 32.4–54.6%, and 26.5–63.9% being recorded in the littoral, middle, and open lake zones, respectively (Table 1).

The total fish biomass produced in cages is the outcome of interaction between growth and mortality in each cage. The pelagic site proved the best one in this respect since by the end of September the four cages at the site yielded more than 25 kg of juvenile *C. lavaretus*, i.e., more than the yield from 7 cages at the two remaining sites (Fig. 4).

Wintering of the fish took place during the "winter of the century" (1978/1979). Mean air temperature over December – March was –5.5°C; the lake was ice-bound until mid-April. In spite of that, the fish grew fast, the between-sites growth rate differences being similar to those recorded the previous year. The pelagic site *C. lavaretus* grew at the fastest rate and attained more than 20 g mean weight and 12 cm mean length (Fig. 3). The fish at the remaining sites grew to slightly smaller sizes. The between-cages variability in fish size was still observed, with the fish weight ranging within 16.5–23.3 g, 14.6–19.9 g, and 12.6–18 g at the pelagic, littoral, and middle sites, respectively (Table 1). The stocking densities levelled off as a result of wintering: in April 1979 the cages contained from 20.3 to 28.3% of their initial densities (Fig. 4). The total fish biomass produced varied from 43.6 to 51 kg at the highest.

The next cage culture season and the second wintering brought no significant changes in fish growth at the three sites, with the pelagic site fish maintaining their fastest growth (Fig. 3) until the termination of the experiment. The ultimate fish growth rate and production in cages were significantly affected by survival rate in different cages and sites. It was particularly evident during the second wintering of the pelagic site fish with as little as 6.6–11.6% of the September stock survival (Table 1; Fig. 4).

C. peled culture in different lake zones

Three cages placed in different zones of the Legińskie Lake were stocked in 1979 with *C. peled* whose density was half that of *C. lavaretus* (Table 2). In this case, too, better results of cage culture were obtained in the pelagic zone. By late September, the survival of *C. peled* at that site was 79.6%, 19.1 g mean individual weight being recorded (Fig. 5). The survival rate and mean individual weight at the middle site were 23.3% and 18.8g, respectively. The poorest growth (16.8 g) was observed in the littoral, with 59.1% of the

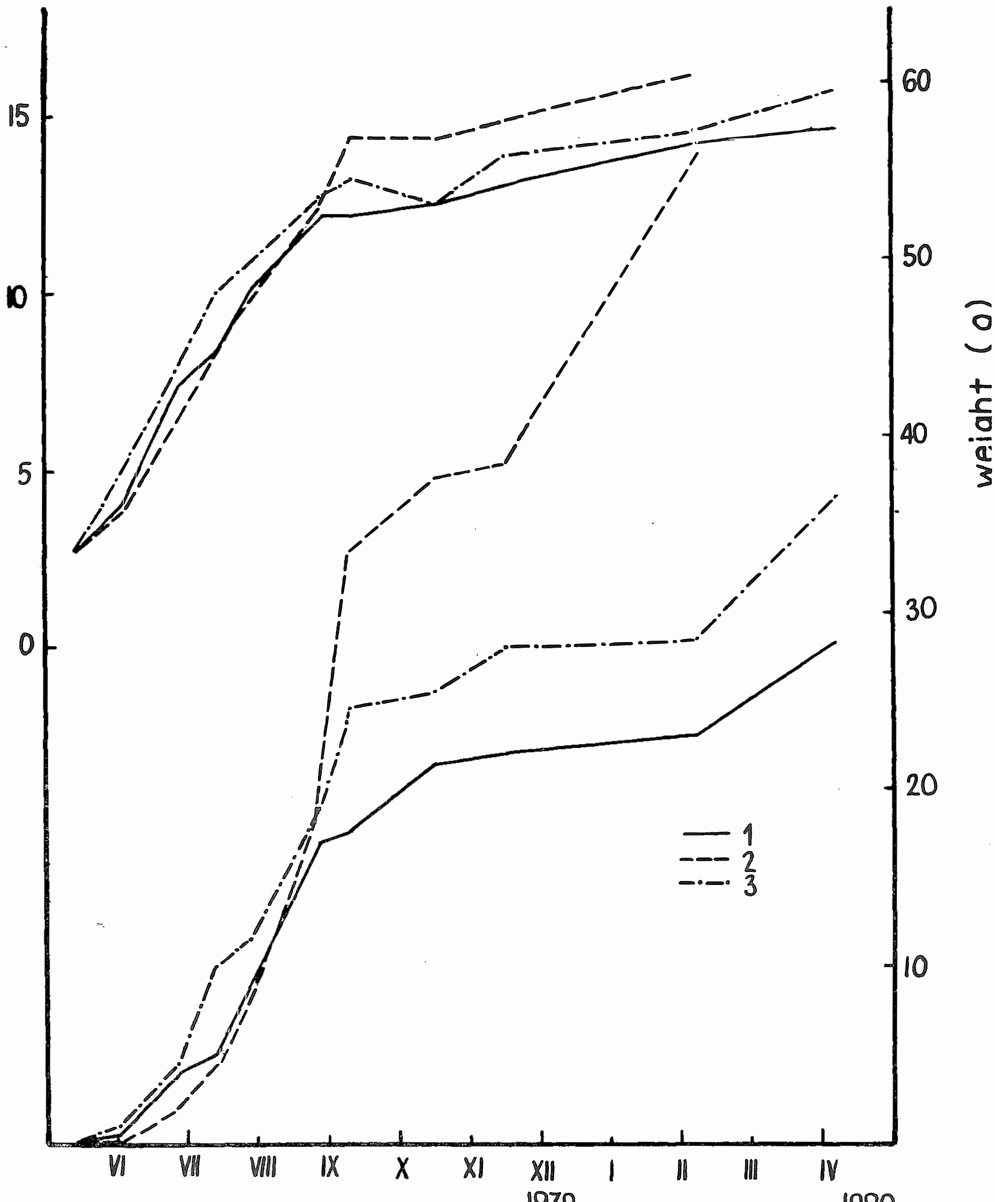

Fig. 5. *Coregonus peled* body length and weight growth in cages at different Legińskie Lake sites. Sites denoted as in Fig. 3.

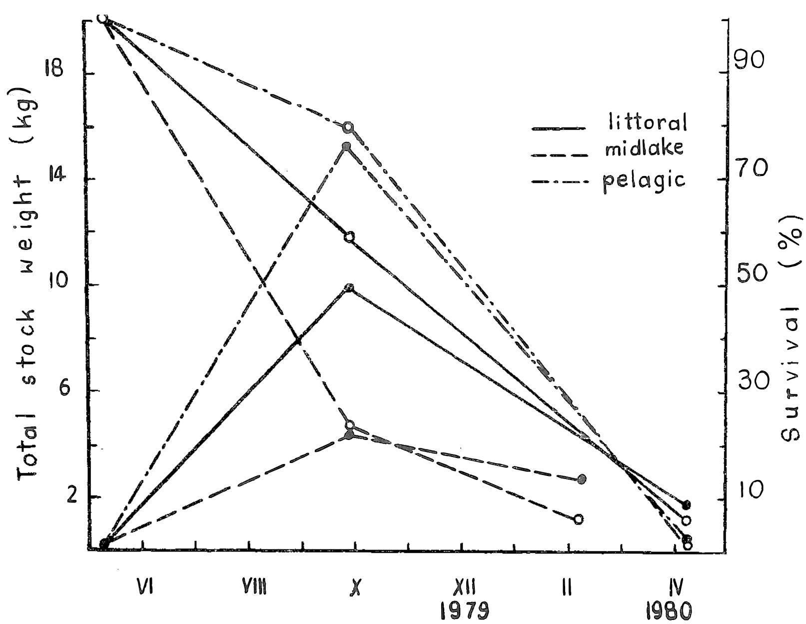

Fig. 6. Survival rate (o) and production (•) of *C. peled* in cages at different Legińskie Lake sites

fish survival (Table 2). Differences in growth and survival are reflected in differentiated yields from cages at each site. In autumn 1979, the total *C. peled* biomass produced at the pelagic, littoral, and middle sites was about 16 kg, 10 kg, and 4.5 kg, respectively (Fig. 6).

In late autumn and winter 1979/1980, *C. peled* grew slowly, except for the middle site fish with half their initial stocking density remaining after earlier mortality, the low density triggering rapid growth of the survivors (Fig. 5). From 1.5 to 6.3% of the initial stock survived wintering under ice, the largest losses being incurred by the pelagic site, as was also the case with *C. lavaretus*.

DISSCUSION

In addition to selecting a lake for fish cage culture, a choice of cage location may be of a considerable importance. According to the recommendations in force at present (Bryliński et al., 1975), cages should be located as far away from littoral vegetation as possible, macrophytes creating a habitat for gastropods and parasites. On the other hand, the distance off shore is limited by the length of electric wire necessary for illumination. Thus the choice of location is a compromise between technological potential of the culturist and prophylactic precautions. In view of the lack of reports on effects of cage location, it was impossible to predict these effects on the culture under study.

The results obtained during the coregonid culture in cages placed in different parts of the Legińskie Lake show that the effects may be substantial. The total weight of *C. lavaretus* in the pelagic site cages was twice that produced at the remaining sites. A similar effect was obtained in the *C. peled* culture. Advantages of the pelagic site were evident both in terms of fish growth and survival, but concerned the first season of culture only. The results obtained for older fish kept in cages were highly variable and failed to confirm the advantages of placing the cages in the pelagic zone.

Concurrent studies on the health of fish kept at the three sites (Waluga, 1979, 1980) showed parasitic protozoans (*Ichthyobodo necatrix* Pinto, *Cryptobia branchialis* Nie, *Ichthyopthirius multifilis* Fouq., *Trichodina sp., Chilodonella sp., Trichophrya sp.*) to have played the major role in the survival of the two fish species, starting from the earliest stage of life. The protozoan invasion intensity was particularly high in the littoral, the invasion being delayed and much less intensive in the pelagic zone. In addition, algae and detritus were observed settle and sediment on the skin and gills of individuals of the two species culture (Waluga, 1980; Mamcarz and Worniałło, 1986), a phenomenon much stronger in the littoral zone, too, compared with the pelagic site. In late May (early June invasions of cercariae of *Diplostomum spathaceum* Rud. and *D. clavatum* Nord. were recorded. The highest intensity and incidence of invasions were observed in the littoral; a lower parasitic pressure occurred at the middle site and the lowest in the pelagic zone. As a result of the strong invasions, all the fish in two cages died out twice in the littoral. On the other hand, the heaviest invasions of *Proteocephalus* cestode plerocercoids took place in the pelagic cages. Thus, effects of parasitic zonality on the cage-reared coregonids are clearly demonstrated by the fish health survey.

In this context it is interesting to consider the causes of the better growth parameters displayed by the fish kept in the pelagic zone. As shown by the dynamics of mortality in *C. lavaretus* and *C. peled*-stocked cages, the prevalence of the pelagic site did not result from any quantitative changes in the stocks. One may then conclude that the higher growth rate in the open lake area resulted from more abundant food resources present there. This conclusion, because of the lack of comparative data on zooplankton composition in different zones of the lake, can be a hypothesis only. The fragmentary data available on zooplankton density and composition at the littoral and middle sites (Table 3) show the abundance of food organisms to increase toward the shore. In addition, it is, however, difficult to reconcile the abundant pelagic food hypothesis with the analysis of find force and direction distributions. In view of the prevailing NW winds, the zooplankton is expected to be displaced toward the southern shores of the lake, which has been in fact observed. The literature contains an ample body of data demonstrating wind effects on zooplankton distribution in lakes (Baker and Baker, 1976;

Heaney, 1976; George and Edwards, 1976; Szlauer, 1976; Frempong, 1984).

On the other hand, noteworthy is the strongest *Proteocephalus* plerocercoid invasion at the pelagic site, the fact being indicative of a greater role of copepods (intermediate hosts) in the diet of coregonids kept in that zone. One may then get an impression that large zooplankton concentrations were formed in the pelagic zone, and that the better. growth of fish resulted from a more efficient consumption of copepods. Abundant literature on various groups of zooplankton (Brooks, 1957; Patalas, 1969; Starn, 1971; George and Edwards, 1973; Preissler, 1977) demonstrates that patchy, rather than zonal, distribution of zooplankton in water bodies is a rule. This is also the case in the Legińskie Lake (Dębowski, 1979, Mamcarz, 1988). Spatial structure (patchiness) of zooplankton has been subject to complex analyses and mathematical modelling procedures (Okubo, 1974; Dubois, 1975; Wróblewski and O'Brien, 1976). Patchiness is more and more frequently considered to be a result of habitat heterogeneity in various ways limiting distribution of living organisms (Hillbricht-Ilkowska, 1985). Under the circumstances then it seems that to assess the productive potential of cages placed in different lake zones is a highly complicated problem. It would be grossly erroneous to consider it solely in a simplistic manner as an effect of the distance from shore. In spite of the observed advantages of the pelagic site, growth and survival of coregonids in cages are highly variable chance phenomena, their variability resulting from interactions of different compartments of the ecosystem.

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PRÓBA OKREŚLENIA WPŁYWU LOKALIZACJI SADZÓW OŚWIETLONYCH NA WYNIKI PODCHOWU RYB GŁĄBIELOWATYCH (*COREGONIDAE*)

STRESZCZENIE

W celu określenia wpływu lokalizacji sadzów oświetlonych na wyniki podchowu *Coregonidae* podjęto próbę wychowu narybku siei *Coregonus lavaretus* L.) i pelugi (*C. peled* Gmel.) w trzech różnych miejscach w jeziorze Legińskim: na stanowisku litoralowym (50 m od brzegu, głębokość jeziora 9 m), środkowym (odpowiednio 100 i 14,5 m) oraz pelagicznym (odpowiednio 280 i 13 m). Stwierdzono zdecydowaną przewagę stanowiska pelagicznego, zarówno pod względem przeżywalności ryb jak i ich wzrostu. Od czerwca do września sieja uzyskała w pelagialu średnią masę 5,7 g przy długości 9,2 cm, w litoralu odpowiednio 3 g i 7,5 cm, a na stanowisku środkowym – 2 g i 6,5 cm. Podchowywana w mniejszych zagęszczeniach peluga uzyskała w pelagialu masę 19,1 g, na stanowisku środkowym 18,8 g i w litoralu 16,8 g. Zanotowano dużą zmienność wyników w poszczególnych sadzach i porównywanych stanowiskach. Niezależnie od zarysowanej strefowości w oddziaływaniu pasożytów na ryby i przewagi stanowiska pelagicznego, efekty produkcyjne w sadzach oświetlonych są zjawiskiem losowym o dużym zakresie zmienności, wynikającym z interakcji różnych elementów ekosystemu.

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Received: 1987.12.03