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FEEDING OF EARLY- AND LATE-HATCHED WHITEFISH IN ILLUMINATED CAGES

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ABSTRACT. In 1992 and 1993 tank-cage rearing of whitefish larvae was carried out. The fish hatched in two different periods: in 1992 larvae hatching took place at the beginning of March (early-hatched whitefish), and in 1993 - in the second half of April (late-hatched whitefish). Each year the larvae were kept in tanks for the first 3 weeks of their life. The tanks were fed with water of 14^0C (group A) and 18^0C (group B). During this period the fish were given artificial feeds. Fish rearing in the next 6 weeks was carried out in the illuminated lake cages (placed in Lake Legińskie), maintaining the division into two groups. While in cages, the fish fed exclusively on the zooplankton. In 1992 cage rearing was quite early in the season (1 April - 17 May), while in 1993 it was rather late (11 May - 20 June).

Feeding activity of whitefish larvae was strictly related to the dynamics of energy content in crustacean zooplankton occurring in the lake. Copepods were the main energetic component of whitefish food during „early" rearing (1992): 0.7 cal. per individual in variant A and about 1 cal. in variant B. In the case of „late" rearing (1993), cladocerans dominated with respect to the energetic value: about 5 cal. per individual in variant A and 3.5 cal. in variant B.

Key words: WHITEFISH LARVAE, REARING, ZOOPLANKTON, ILLUMINATED CAGES

INTRODUCTION

Tank-cage rearing of coregonids is to one of the methods of obtaining stocking material of these fish (Champigneulle and Rojas-Beltran 1990, Mamcarz and Kozłowski 1991). Success of such rearing depends on the adaptation period of the larvae, which had been first raised in tanks, to the conditions of lake cages. The highest mortality of the larvae is observed in the period following fish transfer to a new environment; it is caused mainly by water temperature and availability of food resources (Mamcarz and Kozłowski 1990). Earlier studies showed that these losses could be minimized by placing the fish in lake cages when thermal and feeding conditions in the lake are at their optimal level (Mamcarz 1990b). Moreover, regulation of water temperature during tank rearing of the larvae affects their growth rate (Dostatni et al. 1999). Bigger whitefish, i.e. 16-18 mm long (this being true of the majority of fish reared in cages in higher temperatures), are able to consume prey within size range 0.6-0.8 mm. This increases availability of food resources which would not be available for smaller fish (Mamcarz 1990a, Kozłowski et al. 1992). The objective of this study was to determine the feeding behaviour of whitefish larvae, first during tank rearing, and then in two variants of cage rearing: „early” one (April - mid-May) and „late” (second half of May - mid-June).

STUDY AREA

Cage experiments were carried out in Legińskie Lake, at Łężany. The lake (area 228.3 ha, maximal depth 37.2 m) is classified as vendace-type, with clear summer stratification and cold hypolimnion (6-9^{0}C). Water temperature in the epilimnion exceeds 14^{0}C from May to September. Zooplankton usually contains more than 30 species (Mamcarz 1982). Rotifers are dominated by *Keratella*, *Asplanchna* and *Polyarthra*, copepods by juvenile stages as well as adult *Eudiaptomus graciloides*, and cladocerans - by *Daphnia cucullata* and *Bosmina spp.* (Mamcarz 1982).

MATERIAL AND METHODS

Studies were carried out in 1992-1993, using the tank-cage rearing technology. Whitefish larvae were reared. The first stage of rearing lasted 3 weeks and was performed in tanks, the second consisted of cage-rearing lasting 6 weeks. In 1992 larvae hatching was accelerated, so that the fish hatched already at the beginning of March. This resulted in fairly „early” cage-rearing stage, from April 1 to May 17. In 1993 hatching of the larvae was delayed to mid-April, so cage rearing lasted from May 11 to June 20.

Tank rearing of the larvae was performed in the Experimental Hatchery „Dgał” of the Inland Fisheries Institute. Eyed whitefish eggs obtained from the hatchery of the Fishery Enterprise „Olecko” were transported to „Dgał” hatchery and incubated in two Weiss apparatuses differing as to thermal conditions. In 1992 mass hatching took place on March 10. Early hatching of the larvae was caused by increased water temperature by the end of embryonic development. In 1993 incubation temperature was low (1-2^{0}C), so hatching was delayed until April 18. Hatched larvae were transferred to two tanks (0.8 m^3 each), the stocking rate being about 25 000 larvae per tank. Water temperature was maintained at a constant level, 14^{0}C in tank A and 18^{0}C in tank B. The fish were fed starters. Composition of fish feed and its production technology can be found in Poczyczyński et al. (1995). The whole tank rearing procedure was similar to that described by Kozłowski et al. (1996).

Larvae pre-reared in tanks were transferred to two illuminated cages (each of 4.7 m^3) (Mamcarz and Nowak 1987) placed in surface waters of Legińskie Lake. During cage rearing the fish fed exclusively on lake zooplankton attracted to the cages by light (during night, a 60 W/24 V bulb placed over the water surface). Water temperature was measured daily. Zooplankton samples were collected twice a week to evaluate natural food resources in the lakes. Samples were collected inside an empty cage placed in the lake alongside with the fish cages. Plankton net was used, dragged vertically within this cage (Galliot and Maufoy 1983). Samples were preserved in 4 % formalin; all organisms were counted and determined to genus. Plankton crustaceans were measured (about 30 organisms of each taxon) using a microscope ocular with a scale (accuracy - up to 0.1 mm). Share of particular zooplankton components was established based on their amount and energetic value. Equations given by Vijverberg and Frank (1976) were used for copepods and cladocerans; they describe the relationship between body length (L) and energy content (E) of the organisms. Value of 1 mcal was assumed for nauplius forms (Densen 1985). To analyse feeding behaviour of the fish in cages random samples were collected with a dip net, at midnight, at the same time as zooplankton samples. Fish samples of 50 individuals were preserved in 4 % formalin. Size-distribution of the fish larvae was established in the laboratory: fish were divided into 5 mm size-classes, beginning from the range 10-15 mm (the smallest fish). Food tracts were taken from each sample and their content analysed under a microscope, determining qualitative composition and numbers of prey consumed by the fish. Whitefish feeding was analysed each year with respect to the two major groups of prey: copepods and cladocerans. Share of each diet component (within each fish size-class) was determined in terms of quality and energy content, similarly as for zooplankton (L/E relationship).

RESULTS

FOOD RESOURCES

„EARLY" FISH REARING: 1 APRIL - 17 MAY 1992

On the day of fish stocking into the cages water temperature in the lake was low, 4-5^{0}C. Low temperatures lasted till the end of April. At the beginning of May temperatures increased rapidly, reaching about 13^{0}C by the end of the experiment. Low numbers of all zooplankton groups persisted throughout the experiment; maximal

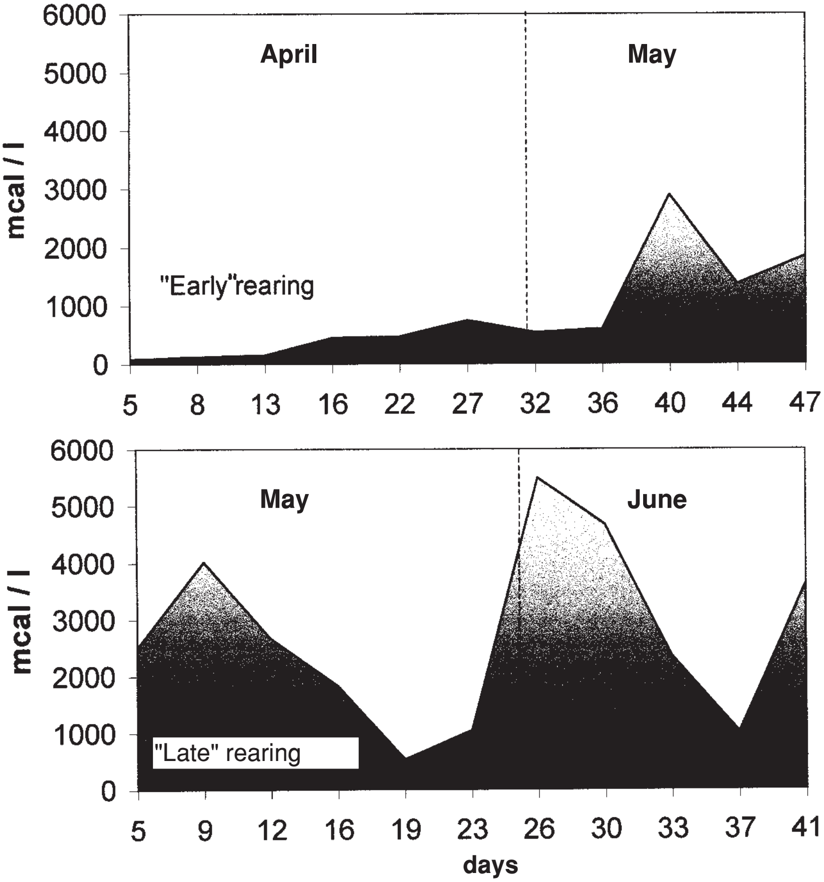

Fig. 1. Energetic value of zooplankton in an illuminated cage Lake Legińskie in 1992 and 1993.

numbers were recorded in mid-May, but even then they did not exceed 400 organisms /dm^3. Copopods dominated all the time, but their share changed from 93 % in April to 67 % in May. Numbers of cladocerans was very low in April, and their increase was observed only in May - up to 25% of all zooplankton numbers. Rotifers were important only at the beginning of May, when their share reached 30 % of the total number of zooplanktonic organisms. As a result, energy content of the zooplankton changed, reaching a maximum of 2.9 cal/dm^3 (12.2 J/dm^3) during May peak of zooplankton development (Fig. 1). Energetic value of cladocerans reached 65 % notwithstanding their relatively low numbers (Fig. 2). In April „energy" value of the zooplankton did not exceed 1 cal/dm^3 (4.2 J/dm^3), and copepods played a decisive role - up to 98 % of this value (Fig. 2).

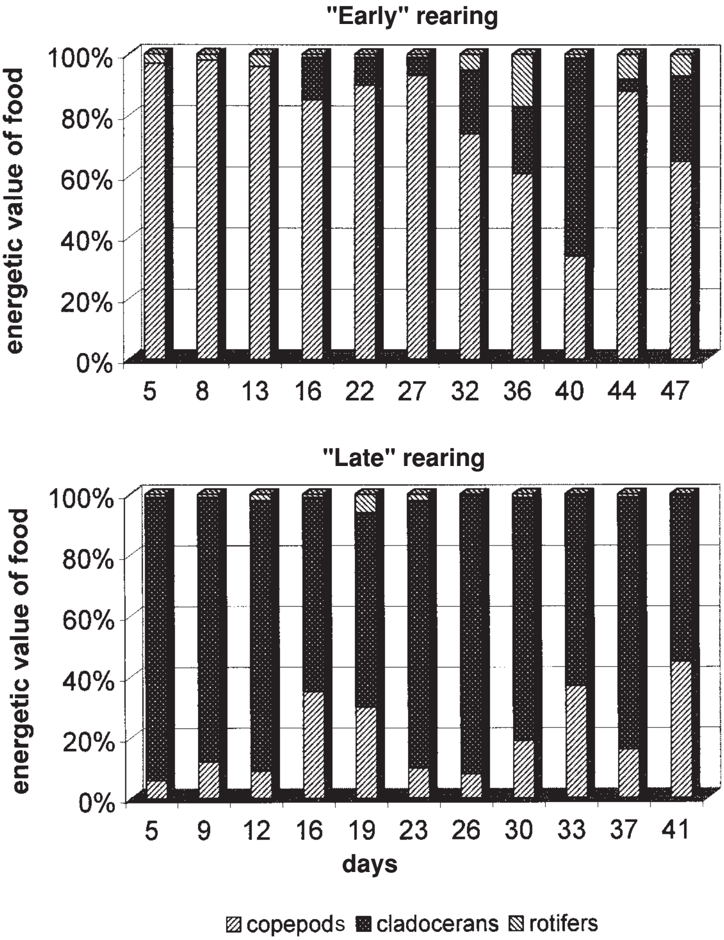

Fig. 2. Energy content (%) of the zooplankton in an illuminated cage. Lake Legińskie, 1992 and 1993.

„LATE" FISH REARING: 11 MAY - 20 JUNE 1993

Water temperature in the lake was high throughout the rearing period, at the level of 18-20^{0}C. Two peaks of zooplankton development were recorded: at the beginning of May (800 organisms/dm^{3}) and in the second decade of June. Contrarily to the preceding year, cladocerans dominated in the zooplankton, their percentage ranging from 30 % (during plankton minimum at the end of May) to 80 % of total organism numbers (during June peak). Share of copepods was much lower than the year before, from 13 % in mid-May to 60 % on June 20. Rotifers appeared more abundantly at the turn of May and June, reaching 33 % of total numbers of zooplankton organisms.

Energy content of the zooplankton exceeded 4 cal/dm^3 (16.2 J/ dm^3) during May peak of development. During the second peak (first decade of June), it reached 5.5 cal/dm^3 (23.1 J/dm^3) (Fig. 1). Cladocerans were most important; their share was always higher than 50 %, reaching 93 % of the total energy content of the zooplankton in mid-May (Fig. 2). Copepods were of some significance only at the end of May and in June (up to 45 % of the energy content).

FEEDING OF WHITEFISH LARVAE ON THE ZOOPLANKTON

Feeding behaviour of whitefish larvae in the rearing cages was analysed taking into consideration the two most important groups of food organisms: cladocerans and copepods. Rotifers were of little importance throughout the whole experiment, both as regards their numbers and energy content.

„EARLY" REARING (1992)

Number of prey organisms consumed by the fish corresponded to the dynamics of zooplankton development in the environment. Diet of fish pre-reared in tank in 14°C (variant A) was dominated by copepods: from about 30 organisms per one larvae at the

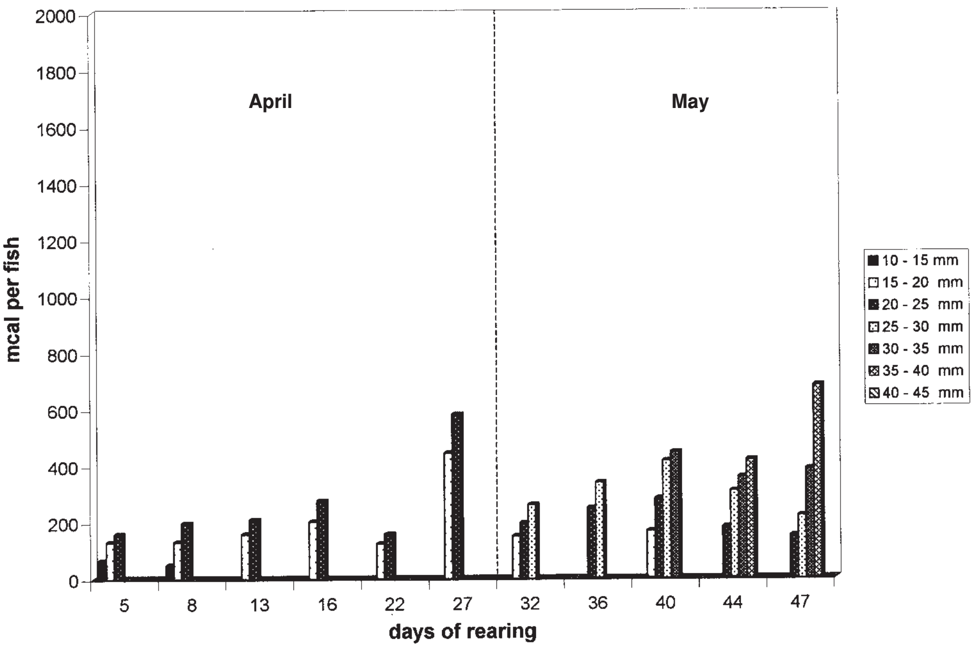

Fig. 3. Energetic value of copepods consumed by whitefish larvae („early" rearing, cage A).

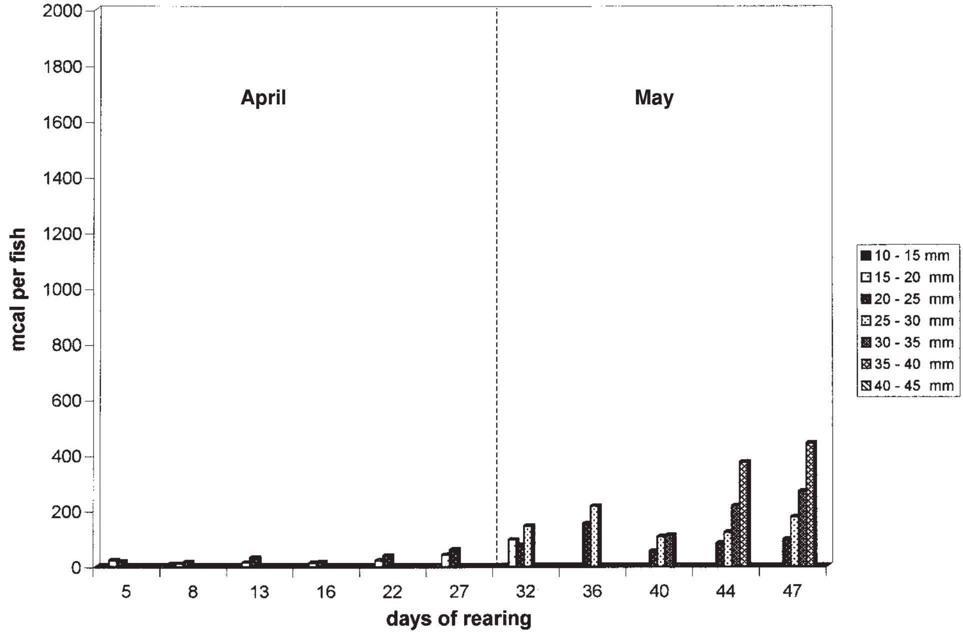

Fig. 4. Energetrc value of cladocerans consumed by whitefish larvae („early" rearing, cage A).

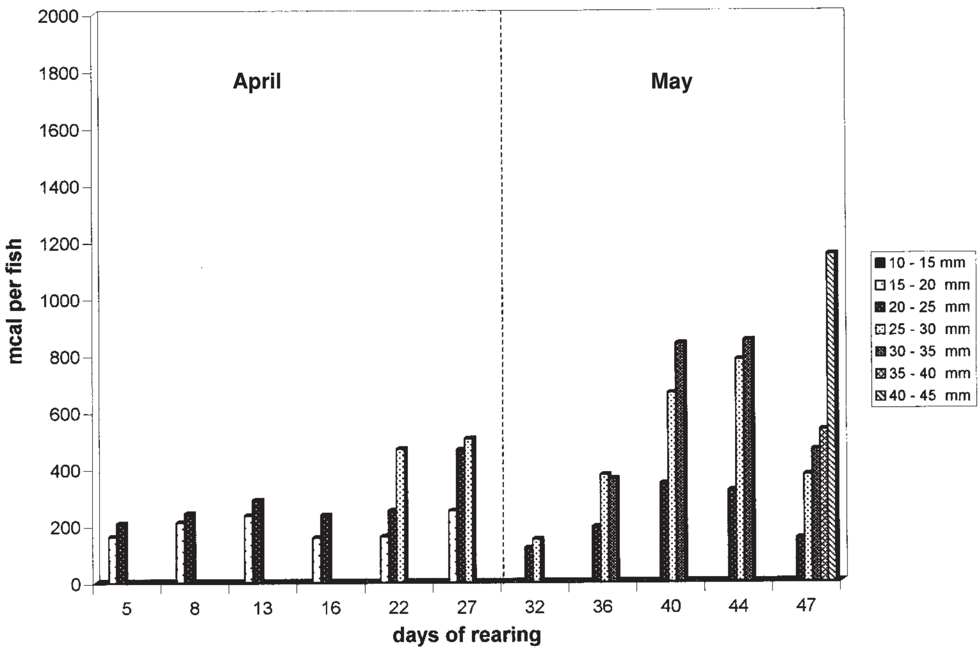

Fig. 5. Energetic value of copepods consumed by whitefish larvae („early" rearing, cage B).

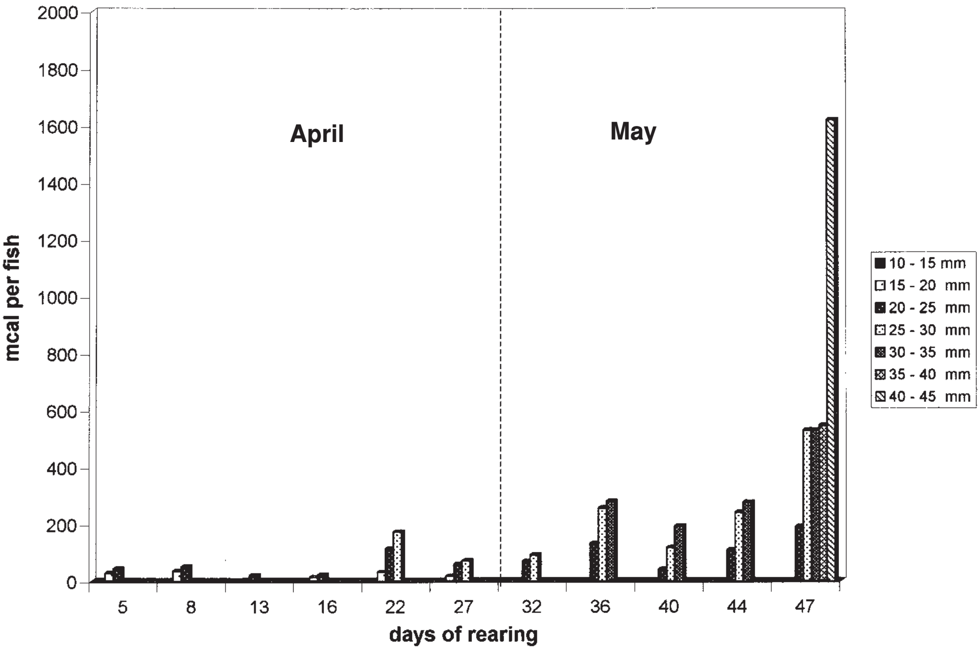

Fig. 6. Energetic value of cladocerans consumed by whitefish larvae („early" rearing, cage B).

beginning of April to more than 150 organisms in mid-May and the biggest fish 35-40 mm long. Cladocerans were consumed at a maximal rate of 65 organisms per one fish so their role was of little importance. Copepods were also the main energetic component of whitefish diet during „early" rearing (Fig. 3). Their energetic value reached almost 700 mcal per fish in the biggest size-class. Cladocerans became an important energetic component of the diet only by the end of rearing, when it reached 450 mcal per fish (Fig. 4). Diet of the fish pre-reared in 18°C (variant B) was also dominated by copepods, with one peak by the end of April (up to 120 organisms per fish), and another one in the last week of rearing (when the average number of prey organisms consumed by the biggest fish exceeded 250 per fish). Energy from copepod consumption reached 1100 mcal per fish (Fig. 5). Cladocerans became more important only in mid-May, when the biggest whitefish (40-45 mm) consumed about 150 organisms daily. Share of Cladocera in energy content exceeded at that time 1.5 cal per fish (size-class 40-45 mm) (Fig. 6).

„LATE" REARING (1993)

Feeding activity of whitefish larvae was strictly related to the dynamics of zooplankton numbers in the environment. Three periods could have been distin-

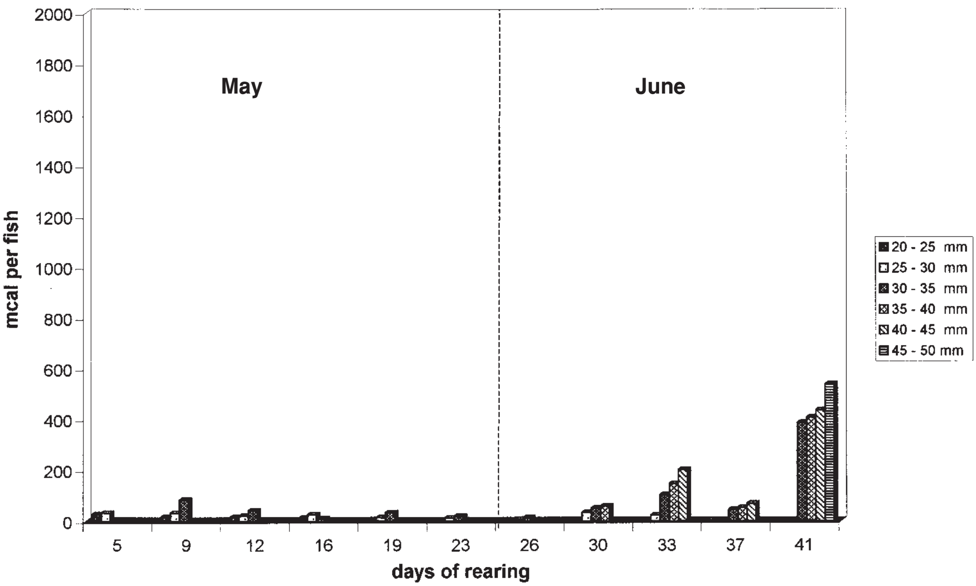

Fig. 7. Energetic value of copepods consumed by whitefish larvae („late" rearing, cage A).

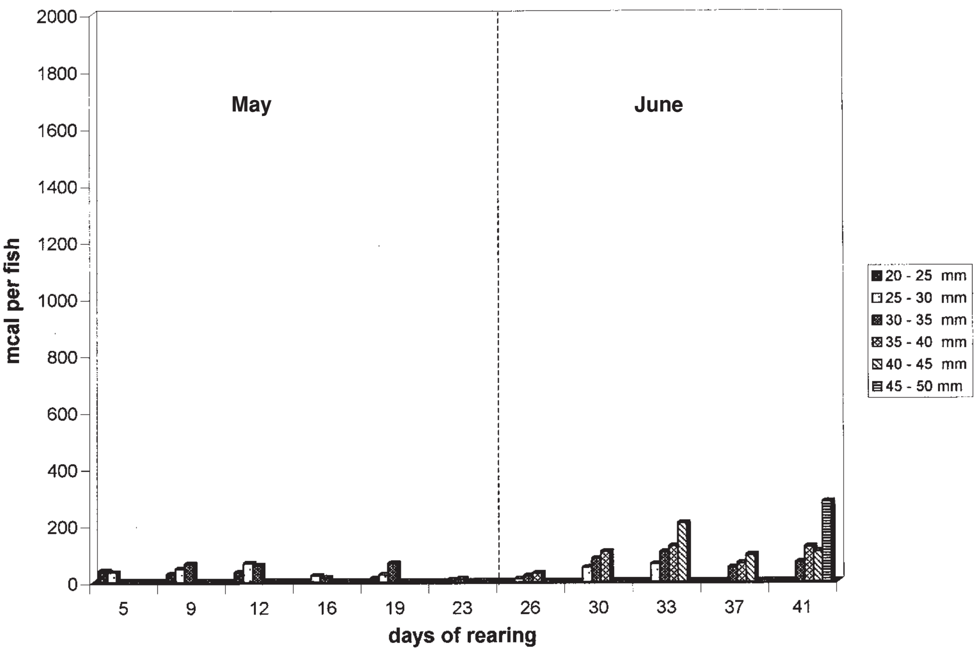

Fig. 8. Energetic value of copepods consumed by whitefish larvae („late" rearing, cage B).

guished: the first maximum (at the beginning of the experiment), a minimum (at the turn of May and June), and an another maximum in June. In contradistinction to the previous year (1992), copepods were not important diet component, neither as regards their numbers nor the energy value (Figs. 7 and 8). Food tracts of the fish pre-reared in 14^0C contained mostly cladocerans: up to 70 organisms per one fish at the beginning of the experiment, and almost 300 in the second half of June and the biggest fish (45-50 mm). Cladocerans were also most important as the source of energy in the diet, and their maximal energy value per one fish was over 5 cal at the end of the experiment (Fig. 9). This was probably caused by a considerable drop of fish density and increased impact of the biggest fish upon big cladoceran forms from the genera *Leptodora*, *Bythotrephes* and *Daphnia*. Whitefish pre-reared in 18^0C showed similar feeding activity, strictly related to the dynamics of energy levels in the zooplankton. Cladocerans were constantly the most important component of the diet, and in mid-June (when density of the fish stock decreased) prey number per one fish amounted to over 300 in the case of the biggest whitefish (45-50 mm). Number of consumed copepods did not exceed 90 per fish. Share of cladocerans as the source of energy in whitefish belonging to the size-class 45-50 mm was maximally 3.6 cal per fish (Fig. 10). Copepods were of negligible importance, supplying only 0.3 cal per one fish (Fig. 8).

FOOD RESOURCES AVAILABLE TO WHITEFISH

Utilisation of zooplankton resources by whitefish larvae was determined by the relations between fish and prey size. Smaller fish (and, thus, also smaller mouth) were limited as regards availability of food resources. The biggest prey organisms found in the food tracts of whitefish larvae smaller than 15 mm did not exceed 0.8 mm. Food tracts collected from fish size-class 15-20 mm did not contain prey organisms bigger than 1 mm. On the other hand bigger fish, of body length over 20 mm, were able to consume all zooplankton organisms i.e. to use in full energy sources of the environment. This refers most of all to whitefish, the hatching period of which had been delayed. In contradistinction to these fish, „early" hatched whitefish pre-reared in 14^0C and transferred to lake cages (size-classes 10-15 and 15-20 mm) were unable to utilise all zooplanktonic organisms occuring in the environment. These unavailable resources represented from 70 % (at the beginning of April) to about 15 % (in the first week of May) of all energy resources of the zooplankton.

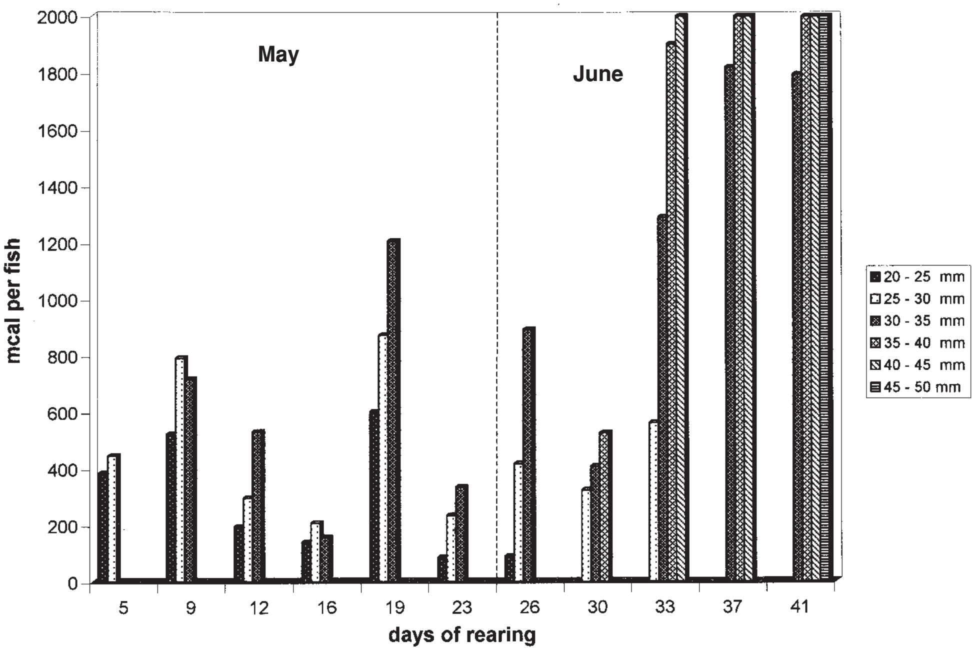

Fig. 9. Energetic value of cladocerans consumed by whitefish larvae („late" rearing, cage A).

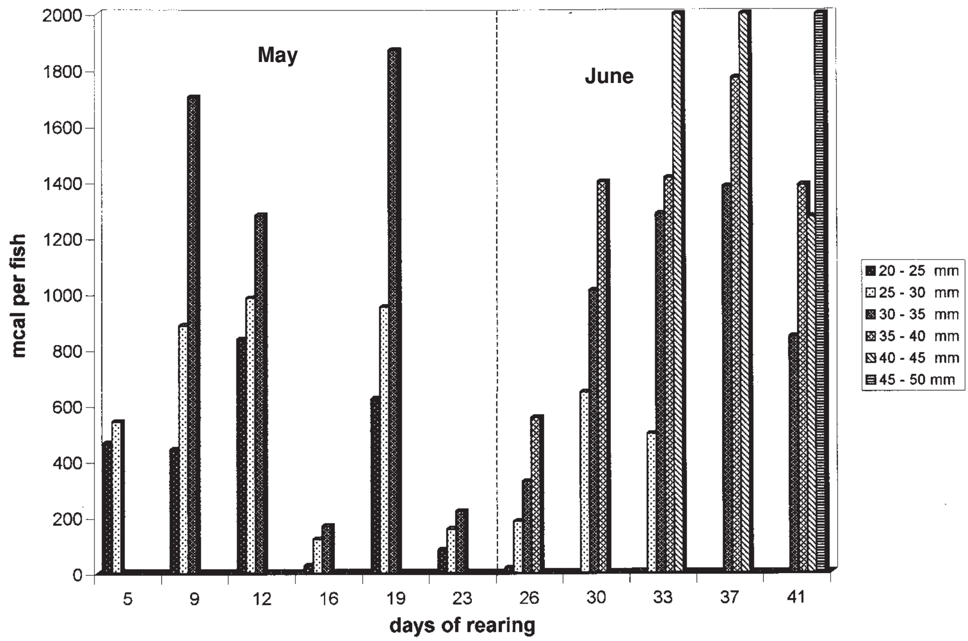

Fig. 10. Energetic value of cladocerans consumed by whitefish larvae („late" rearing, cage B).

DISCUSSION

Maximal numbers of plankton organisms in cage environment ranged at the beginning of this stage of fish rearing from a 100 organisms/dm^3 in April 1992 to about 800 organisms/dm^3 in mid-May 1993. According to Dąbrowski (1976) feeding minimum for whitefish larvae was 50-70 zooplanktonic organisms in 1 l of water. Energy requirements increase rapidly as the fish grow. Laboratory experiments showed that whitefish of body length 20 mm had to consume about 500 prey organisms daily, while those 30 mm long - already as many as over 1000 (Kriegsman 1970). On the other hand, data pertaining to whitefish feeding in natural environment showed that numbers of prey consumed varied considerably, but were usually lower than in laboratory experiments (Lindström 1962, Salojârvi 1979, Husko et al. 1988). Among other things, this is due to mosaic distribution of zooplankton in lake environment (Salojarvi 1979, Ponton and Müller 1988) and diversified light conditions (Hoagman 1973). Number of zooplankton crustaceans consumed by whitefish larvae in our experiment conformed to changes taking place in zooplankton abundance in the environment. Mean numbers of consumed prey organisms was fairly diversified: from 20 at the beginning of „early" rearing period and the smallest fish (size-class 10-15 mm) to about 400 per fish in the case of the biggest size-classes (45-50 mm) at the end of „late" rearing period (second half of June). As regards particular size-classes, within the same class bigger fish usually consumed more prey. On the other hand, whitefish from the same size-class but pre-reared in higher temperature (18^0C - variant B) usually consumed more plankton organisms than those pre-reared in 14^0C (variant A).

Energetic value of whitefish food was strictly related to the amount and quality of consumed zooplankton. During „late" rearing (1993) cladocerans were the main source of energy, while in „early" (cold) rearing period of 1992 the fish food consisted mostly of copepods. These results conform to those obtained earlier by Mamcarz and Murawska (1988), Mamcarz (1990a) and Kozłowski (1993). Energetic value of the diet of the biggest whitefish was several times higher than of the smallest fish, most of all thanks to the presence of large cladocerans from the genus *Leptodora*. Whitefish larvae (especially bigger ones) showed food selectivity already from the beginning of the experiment and consumed mostly copepods and cladocerans although there were many smaller plankton organisms available (rotifers, nauplii). This was especially noticeable during „late" rearing, when cladocerans dominated in fish diet (from 70 organisms per fish at the beginning of rearing to over 300 in the second half of June).

In the case of the smallest fish (10-15 mm) originating from „early" rearing (1992), nauplii were the most important component of the diet. According to Karjalainen et al. (1991) nauplii are the best food for coregonids immediately after yolk-sac resorption. Rotifers were not important as whitefish food, neither with respect the their quantity nor energetic value. This supports earlier observations of many authors that coregonids were not interested in rotifers, both in cage culture and in natural environment (Marciak 1979, Salojârvi 1979, Dąbrowski et al. 1984, Kozłowski 1993).

Relation between fish and prey size determines utilisation of the food resources by coregonids. Fish of a given size-class are able to consume only a definite range of prey sizes, related to the size of fish mouth opening. The latter depends on jaw length (Shirota 1970, Dąbrowski and Bardega 1984, Ponton and Müller 1990). Smaller larvae, with shorter jaws and smaller mouth opening, have limited possibilities of utilising the existing food resources. Prey available for whitefish larvae cannot be bigger than 0.2 mm (Nijazov 1989), so that energy levels available to these fish are limited to some 0.02-9.6 % of the potential energy resources of zooplankton in Lake Legińskie (Mamcarz 1990a). This limitation was true of the smallest fish (10-15 and 15-20 mm; part of the fish pre-reared in 14°C). The biggest prey organisms found in the food tracts of whitefish larvae smaller than 15 mm were never bigger than 0.8 mm, and in the size-class 15-20 mm prey size usually did not exceed 1 mm. Bigger whitefish, of more than 20 mm (majority of fish pre-reared in 18°C) were able to use all energy resources contained in cage zooplankton. Similar trends were noticed in earlier studies (Mamcarz and Murawska 1988, Mamcarz 1990a, Kozłowski 1993). Hence, regulation of water temperature during tank pre-rearing of whitefish larvae may result in fish big enough to fully utilise energy resources of the environment. This was the case when fish hatching was delayed (1993 experiment).

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STRESZCZENIE

ODŻYWIANIE SIĘ SIEI W SADZACH OŚWIETLONYCH O PRZYSPIESZONYM I OPÓŹNIONYM TERMINIE WYKLUCIA

W latach 1992 i 1993 przeprowadzono basenowo-sadzowy podchów larw siei wyklutej w dwóch różnych terminach: w 1992 wyklucie nastąpiło na początku marca (sieja „wczesna"), natomiast w 1993 w drugiej połowie kwietnia (sieja „późna"). W każdym roku przez pierwsze 3 tygodnie larwy podchowywano w basenach zasilanych wodą o temperaturze 14°C (grupa A) oraz 18° C (grupa B). W tym okresie ryby karmiono paszą sztuczną. Przez następne 6 tyg. podchów kontynuowano w pierwotnych grupach w oświetlonych sadzach toniowych (Jez. Legińskie), gdzie ryby odżywiały się wyłącznie zooplanktonem. W 1992 r. odbył się podchów sadzowy „wczesny" (1 kwietnia - 17 maja), zaś w 1993 podchów „późny" (11 maja - 20 czerwca).

Aktywność pokarmowa larw siei ściśle wiązała się z dynamiką zmian wartości energetycznej zooplanktonu skorupiakowego w środowisku. Głównym komponentem energetycznym pokarmu siei w podchowie „wczesnym" (1992) były widłonogi: 0.7 kalorii na osobnika w wariancie A oraz ok. 1 kalorii w przypadku największych ryb z grupy B. W pokarmie dostępnym w podchowie „późnym" pod względem energetycznym dominowały wioślarki: ok. 5 kalorii na osobnika w wariancie A oraz 3.5 kalorii w wariancie B.

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