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Mass rearing of juvenile whitefish in brackish water using live zooplankton

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The reintroduction of whitefish of Pomeranian Bay origin to Puck Bay (southern Baltic) has been underway since 1993. Stocking has been conducted with juveniles weighing 1–2 g. In 2002, a program was initiated to rear whitefish fry in a manmade brackish water pond located at a sewage treatment plant close to the sea. The fish were fed live zooplankton which was filtered from purified wastewater. Until the current program, this zooplankton was not utilized. The mean weight of the 30 000 fry at the start of rearing on 26 June was 1.2 g. The final mean weight was 21.2 g on 22 October when over 3200 fish were released into Puck Bay as a supplement to the stocking program. The mean growth rate obtained by the fish was 0.82 mm day^{-1}, but the survival rate was only 11% due to heavy losses in July caused by the sudden deterioration of water conditions in the pond.

Introduction

Whitefish (*Coregonus lavaretus* (L.)) was common in Puck Bay until the 1970s; thereafter catches fell to occasional fish. Overexploitation and changes in the aquatic environment, mainly pollution and the exploitation of bottom resources have had the greatest negative impact on the population. The reintroduction of whitefish was initiated after there had been considerable improvement in the biological and hydrological status of Puck Bay. Since 1993, the bay has been stocked annually with 50 000 to 190 000 summer fry originating from Pomeranian Bay whitefish spawning stock. The fry (average mass of 1–2 g) are released directly into the sea where they are initially under strong predation, especially from the abundant stickleback and perch populations. Bearing in mind that stocking larger whitefish fry would improve program results in locations where there are predators (Jokikokko *et al*. 2002), a special pond was built in 2002 at the sewage treatment plant at Swarzewo for rearing fry each year from June to September.

Domestic sewage and animal manure have traditionally been used to fertilize fish culture ponds in several Asian and European countries (Bahrends *et al*. 1980). Some fish farms in Poland utilize either raw or purified sewage in the rearing of whitefish (Tucholski 1994). Using zooplankton (reared or wild) to feed fry is a well-known and widely-applied technique both in freshwater (Huet 1971, Szlauer 1974, Flüchter 1980, Szczerbowski 1993, Tucholski 1994) and sea water (Van der Meeren 1991, Tilseth 1993, Olsen 1993, Maeland *et al*. 2000). In Finland, millions of whitefish fry for stocking are reared in freshwater ponds where they feed solely on natural food (Leskelä

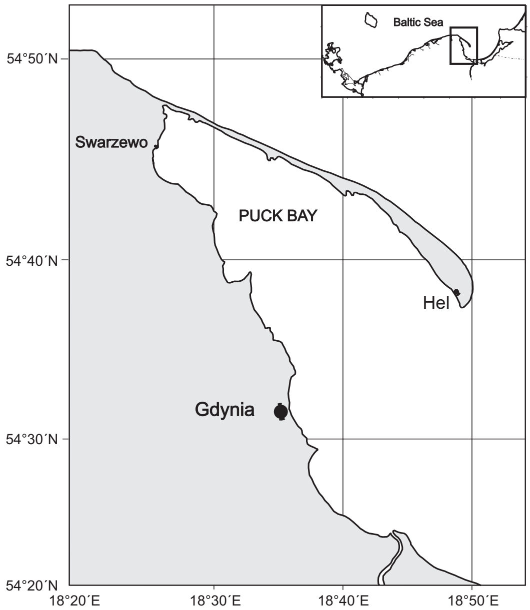

Fig. 1. Situation of the wastewater treatment plant at Swarzewo.

et al. 1998, Jokikokko *et al.* 2002). The method applied at Swarzewo has not been used frequently in this type of fish rearing. The fry are reared in a man-made pond fed with seawater (salinity approximately 5‰–8‰) from the nearby Puck Bay, without the addition of either raw or purified sewage. The fry are fed live zooplankton which is filtered from purified wastewater from the plant. Previously, this zooplankton was drained directly into the sea.

In autumn, after reaching a size which protects them from predators, the fry are released into Puck Bay as a supplement to the stocking program of this species. The main benefits of this method are the utilization of surplus live zooplankton, which is a high quality, free feed, and the improved effectiveness of whitefish stocking.

The aim of the paper is to present the concept and results of rearing whitefish fry using the above described method.

Material and methods

Facilities

The sewage treatment plant belongs to the "Swarzewo" Water-Sewage Company at Swarzewo and is located near Puck Bay (Fig. 1).

The surface area of the rearing pond is 2600 m^2 and its depth ranges from 1.25 m near the inflow to 1.75 m near the outlet (1.5 m on average). The seawater which fills the pond was pumped from Puck Bay and filtered through a gravel-sand filter in order to remove stickleback as well as small scraps of plants and algae. The pond water was aerated twenty-four hours a day by a blower with a system of 40 membrane diffusers. It was also possible to control the system using an oxygen probe.

Zooplankton was filtered through HYDROTECH Drumfilter 1203 microsieves with 200 μm mesh size from where it flowed into the pond with freshwater.

Pond water temperature (°C) and oxygen (O_2) concentration (mg l^{-1}) were measured automatically with a WTW TriOxymatic 700 oxygen probe located 50 cm below the surface.

Fish

On 27 June 2002, 30 000 whitefish fry of an average weight of 1.2 g were released into the pond. The fry originated from eggs collected from the whitefish broodstock of Pomeranian Bay origin, which is kept at the Inland Fisheries Institute farm at Rutki. The fish were transported from the hatchery to the pond at Swarzewo (a distance of about 65 km) in plastic bags with water, oxygen and anaesthetic.

Control measurements

Temperature and oxygen concentration were measured daily at 07:00 and 15:00. Salinity was measured every five days with an ARGENT refractometer, and water pH was measured with an AQUATEST kit. The amount of supplemental seawater added to the pond in m^3 was recorded by a flowmeter at the pumping station. Weight and length of the fish were determined monthly (except in September). The average daily increment (G_L) in mm day^{-1} of the fish was calculated for every sampling period and at the end of rearing by adapting a formula used by Støttrup *et al.* (1998), where $G_L = (L_t - L_0)/(T_t - T_0)$.

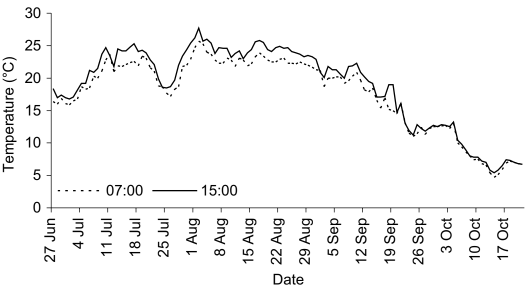

Fig. 2. Water temperature in the pond at Swarzewo during the period of whitefish fry rearing (27 June–22 October 2002), measured at 07:00 and 15:00.

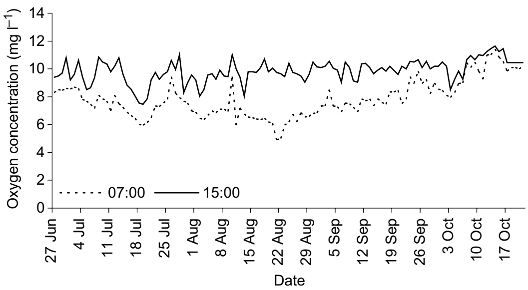

Fig. 3. Oxygen concentration (mg l^{-1}) in the pond at Swarzewo during the period of whitefish fry rearing (27 June–22 October 2002), measured at 07:00 and 15:00.

Specific growth rate (G, % day^{-1}) for the same periods was calculated according to the formula of Houde and Schekter (1981): $G = 100(e^g - 1)$, where $g = [(\ln W_F - \ln W_I)t^{-1}]$ and W_I and W_F are the initial and final mean wet weights, respectively, and t is the duration of the growth period in days (Altinok & Grizzle 2001).

Results

Hydrological conditions

Water temperature at the beginning of rearing in June 2002 was 16 °C. The maximum recorded temperature was 27.7 °C on 2 August during a two-week long heat wave, after which it slowly dropped to 5.4 °C by mid-October (Fig. 2). Continuous aeration ensured that the oxygen concentration in the water remained within the range of 6–11 mg l^{-1} (Fig. 3). Water salinity varied from 6.5% to 7.5‰, while pH was rather stable at 7.0–7.2.

The intense growth of green algae *Spirogyra* sp. from day 22 of rearing on necessitated mechanical removal.

Water was drained and added several times in amounts ranging from 10 to 1158 m^3 daily. From 15 to 31 July, a total of 5512 m^3 of water was exchanged, i.e. approximately 140% of the pond capacity.

Fish feeding

The supply of zooplankton started on the second day of rearing. During the first 14 days, microsieves were in operation from 10 to 24 hours daily. Zooplankton was later delivered continuously 24 hours a day in the following microsieve regime: 10 minutes of down time, one minute of revolutions and rinsing. Apart from occasional pauses in feeding due to high temperature, fish deaths or cleaning the pond of *Spirogyra* sp., the fish were active and fed intensively all the time *ad libitum*. The amount of food supplied was adjusted by regulating the volume of water flowing through the microsieves in accordance with the amount of uneaten zooplankton which was observed in the fish pond. The total daily ration of zooplankton was not assessed, however, control measurements taken at the outflow of the microsieves revealed that up to 295 g of wet zooplankton was filtered every 10 minutes. Random sampling showed that most of the zooplankton biomass was composed of *Daphnia magna* (size 992–3100 μm) and *D. longispina*. Other species included *Cyclops* sp., *Eucyclops* sp. and *Brachionus* sp. as well as about 20 other, less numerous species. At no time during rearing were the fish given artificial feed.

Survival and growth

Of the 30 000 fish stocked in the pond only 3208 survived to the end (11% survival rate). Approximately 200 individuals died as a result of manipulation during transport and release. No additional deaths were recorded during the first month of rearing. In contrast, heavy losses occurred on 27 July. The increasing temperature of the stagnant water, combined with the very intensive growth of *Spirogyra* sp. and the decay of some of the supplied zooplankton, could have been the factors which were responsible for the sudden worsening of environmental quality, thus causing mass mortality. However, according to veterinary opinion, the behavior of the fish (they swam with their bodies tightly twisted) and the internal symptoms exhibited by them pointed to possible neurotoxin contamination also connected with environmental conditions. After the water was exchanged again, no further deaths were recorded during rearing.

Mean length and weight of the fry were 52.8 mm and 1.2 g, and 142.5 mm and 21.2 g at the start and the end of rearing, respectively (Table 1). There was considerable variation in growth (Figs. 4 and 5). The largest fish was 18.3 cm long and weighed 51.4 g. The mean growth rate (G_L) obtained during 174 days of rearing was 0.75 mm day^{-1} , while the specific growth rate (G) for that period was 4.86 (Table 1).

Discussion

Success in fish rearing depends mainly on ensuring good water quality, adequate aeration and a sufficient supply of preferred food. The concentration of substances which are harmful to fish in the purified water of the Swarzewo plant does not allow whitefish fry to be reared directly in it. There is also a lack of adequate freshwater run-off in the area to feed a rearing pond. This is why the fry are reared in a pond which is fed by seawater from the nearby Puck Bay. Although the rearing conditions designed for the whitefish were adequate, a number of environmental factors were difficult to control in the unusually hot summer of 2002, and several organizational oversights which accompanied this newly-run project contributed to the high mortality rate of the fry.

Water pumped from the shallow coastal zone was sometimes of limited use since it contained a significant amount of algae *Spirogyra* sp., which passed through the sand-gravel filter and grew intensively in the pond, especially in July. Strong sunlight, the relative shallowness of the pond and the lack of water flow brought the water temperature up to 27.7 °C on the warmest days. Although this temperature is on the upper limit for whitefish, this species can withstand such conditions provided an aeration system is installed (Pelczarski 1998) and there are no excessive *Spirogyra* blooms. In non-aerated ponds with water-flow, a temperature above 25 °C causes whitefish mortality (Hochman & Klas 1976). In July, the water movement in the pond produced by the air diffusers, which was sufficient under normal conditions, was nearly stopped due to intensive *Spirogyra* growth. This led to a decline in oxygen concentration and limited fry mobility and feeding. It also necessitated periodic cleaning of the pond. Similar observations were made by Massaut (1999). The lack of water movement accompanied by high temperature, and a constant inflow of food which decomposed as it was not fully consumed due to less intense feeding during this period, probably caused an increase in the level of ammonia (NH_4). Unfortunately, the NH_4 level was not measured.

The severity of certain diseases which occur in freshwater is sometimes reduced by increasing salinity. However, disease-causing

Table 1. Length, weight, and growth rates G_L (by length) and G (by weight) of whitefish fry reared on zooplankton from 26 June to 22 October 2002 in the brackishwater pond at Swarzewo.

Date of sampling	Age (days)	No of fish sampled	Total length (mm)			G_L (mm day^{-1})	Weight (g)			G (% day^{-1})
			Range	Mean	SD		Range	Mean	SD	
2 May 2002	0	100	8–14	12.2	1.6			0.0055		
26 June 2002	56	100	35–64	52.8	5.4	0.73	0.2–2.2	1.2	0.4	10.09
27 July 2002	87	30	55–96	79.2	12.2	0.77	1.8–8.2	5.4	2.1	8.24
29 Aug. 2002	120	50	82–134	105.8	11.7	0.78	5.1–17.2	10.9	3.0	6.53
22 Oct. 2002	174	75	115–183	142.5	12.9	0.75	9.2–51.4	21.2	7.3	4.86

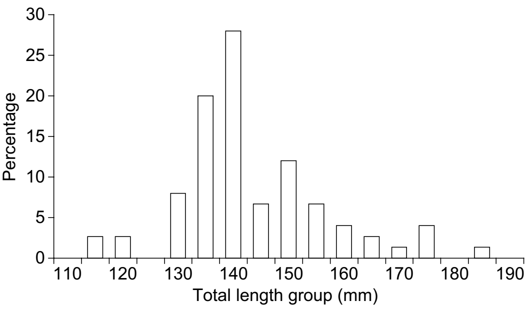

Fig. 4. Length distribution of whitefish autumn fry at Swarzewo at the end of rearing on 22 October 2002.

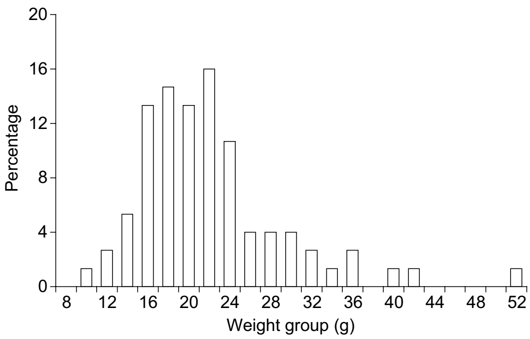

Fig. 5. Weight distribution of whitefish autumn fry at Swarzewo at the end of rearing on 22 October 2002.

microorganisms can be transferred with sea water. These organisms may occur in the water without causing harm until the chemical balance of the environment is disturbed by detergents, antibiotics or an increase in pH, thus activating the toxins. This type of event is suspected to have caused the mass mortality of fish in July in the fry pond. The event occurred shortly after a water exchange, when the water temperature was 18–19 °C, i.e. prior to the high temperature period.

In Finland, cases of fish deaths in brackish waters with similar symptoms in the fish were caused by the ichthyotoxic haptophyte *Prymnesium* sp. and the hepatotoxic cyanobacterium *Planktothrix agardhii* (Lindholm *et al*. 1999). However, none of these organisms was confirmed in either the pond at Swarzewo or Puck Bay. The concentration of hepatotoxins produced by the cyanobacterium *Nodularia spumigena,* which was confirmed only in the coastal waters, was too low (1.3 μg l^{-1}) to have caused the fish mortality.

During future rearing seasons at Swarzewo it will be necessary to limit the zooplankton supply during very warm days, to combat *Spirogyra* growth by mechanically removing it, to exchange the pond water more frequently and to improve control of the chemical factors of the water. These steps correspond to those recommended by Massaut (1999) who maintains that current management practice should be directed at correcting problems resulting from uncontrolled phytoplankton development.

There was a significant difference between the growth rate of the whitefish fry in the pond at Swarzewo which were fed *ad libitum* with externally supplied zooplankton, and that of fry living in ponds under natural conditions. In northern Finland, growth of one-summer-old whitefish reared for large-scale stocking purposes in semi-natural ponds without predators and fed freely on natural zooplankton varies considerably among ponds and years. Three-fold differences in weight from year to year are common among ponds. The smallest fish may weigh 1.5 g and the largest up to 15.0 g (S. Niva pers. comm.). The present results of whitefish growth are comparable with or slightly better than those obtained at Swarzewo in freshwater (Pelczarski 1998). A more apt comparison is that between the growth rate of the Swarzewo fry and the one obtained with the control fry sample from the same hatch at Rutki. These fry were reared in plastic tanks with a volume of 1 m^3 and at a density of two specimens per litre at a maximum water temperature of 20.7 °C. They were fed 2 mm commercial dry feed (DanaFeed, BioMar, Aller Aqua) (H. Kuzmiński pers. comm.). In comparison with the average weight of the Swarzewo fry (21.2 g), that of the Rutki fry (11.8 g) after the same time period was almost half only. Likewise, the specific growth rate G of the Rutki fish (4.51) was lower than that of the Swarzewo fish (4.86) for the same period.

Wild whitefish in Lake Mjosa (Norway) grew up to 12 cm during their first summer and autumn (Naesje *et al*. 1986), while the fry at Swarzewo attained an average length of 14.3 cm. Whitefish fry reared in cages in Polish lakes and fed with zooplankton attracted by light reached 12–14 cm and weighed from 12–15 g in autumn (Szczerbowski 1983), which is much less than at Swarzewo. The mean length of whitefish autumn fry reared in a pond with purified sewage ranged from 10.2 to 15.7 cm and the mean weight from 8.9 to 32.1 g (Tucholski 1994). It should also be pointed out that the growth of the Swarzewo fry was positively impacted by the decrease of stock density which occurred during the fish death event in July.

The species composition and availability of the zooplankton in the stabilization pond fully corresponds to the food preferences of whitefish. Although zooplankton production depends on the prevailing conditions in the stabilization pond, it does assure good feeding conditions for a large number of fry. The 1996 production level of zooplankton was about 150 g m^{-3} (Pelczarski 1998), and in 2002 it appeared to be at a similar level although the observed abundance visibly decreased in October. Therefore, rearing fry should be limited here to the end of September.

Developing a whitefish rearing system in brackish water was a thoroughly new undertaking in Polish coastal aquaculture. Despite the setbacks, this system appears to be promising, even if the rearing techniques and technology applied will require some improvement.

Acknowledgements

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