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Mechanism of establishing bimodality in a size distribution of age-0 pikeperch, *Stizostedion lucioperca* (L.) in the Sulejów Reservoir, Central Poland

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The distribution and food of age-0 pikeperch were investigated in the lowland Sulejów Reservoir in Central Poland. Samples were taken weekly, from mid June to mid August 1994, both in pelagic and littoral zones. Up to mid-July, age-0 pikeperch were found to be divided into two distinguished groups. The first group was located in the pelagic zone and consisted of planktivorous specimens; the second group seemed to be restricted to the littoral zone and were predominantly piscivorous already at a very small size (*TL* ~30 mm). These differences in feeding between the two groups of age-0 pikeperch were due to prey fish availability and resulted in a slower growth of pelagic fish, as compared with that of littoral fish. In mid-July, after reaching mean length of about 50 mm, pelagic pikeperch invaded the littoral zone, but they were not able to shift from planktivory to piscivory, as available prey fish were already too big. As larger littoral pikeperch continued foraging on fish, previously established size differences were further strengthened.

1. Introduction

Bimodal size distribution of age-0 pikeperch after their first growing season is a well known phenomenon observed in many European waters (Nagięć 1966, Biro 1972, Tatrai & Ponyi 1976, Van Densen 1985, Buijse & Houthuijzen 1992). Similar bimodality has been described for other percids (Chodorowski 1975, Shelton *et al.* 1979, Timmons *et al.* 1980, McIntyre *et al.* 1987). The establishment of bimodality in the size distribution of young-of-the-year pikeperch depended on to the availability of different prey (Nagięć 1977, Shelton *et al.* 1979, Timmons *et al.* 1980, DeAngelis & Coutant 1982, Van Densen 1985). It also depends greatly on temperature conditions

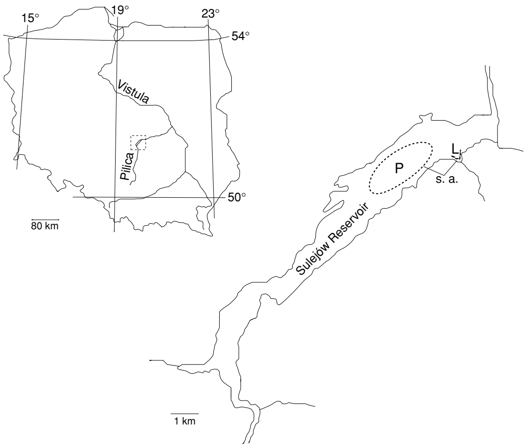

Fig. 1. Sampling area (s.a.) in the Sulejów Reservoir. P – pelagic zone, L – littoral zone.

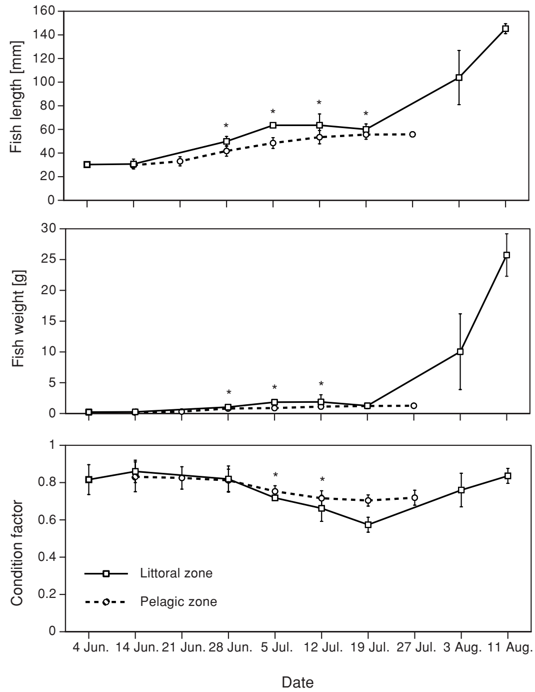

Fig. 2. Changes in total length, weight, and condition factor of age-0 pikeperch from the littoral and pelagic zone of the Sulejów Reservoir during summer 1994; date represents means and *S.D.*; asterisks show significant differences between given means ($p < 0.05$).

during spring and early summer, which determine the time of both pikeperch and their prey fish spawning as well as their growth rate (Tolg 1961, Biro 1972, Koonce *et al.* 1977, Van Densen & Vijverberg 1982, Van Densen 1985). Shift to piscivory, which accelerates pikeperch growth rate, is one of the main events that influences their recruitment to the fishery (Van Densen 1985, Buijse & Houthuijzen 1992). The onset of piscivory has been noticed for pikeperch as small as 20 mm (Van Densen 1985), but usually they start to feed on fish after achieving size greater then 30 mm (Nagięć 1966, Tatrai & Ponyi 1976, Zalewski *et al.* 1990b).

To better understand determinants of the onset of piscivory, incorporation of other factors than temperature and prey availability might provide further insight. As juvenile percids are unevenly distributed in waters and undergo vertical and horizontal migration (Post & McQueen 1988, Treasurer 1988, Wang & Eckmann 1994), it seemed to be highly probable that such behavior may contribute to the onset of pikeperch piscivory and in consequence to the variation in strength of their year classes.

To answer whether this assumption is true in a reservoir, investigations of age-0 pikeperch distribution, growth rates and feeding patterns were undertaken simultaneously in the open water and in the littoral zone of the lowland Sulejów Reservoir. This reservoir is characterized by poorly developed vegetations in the littoral zone.

2. Materials and methods

Investigations were conducted at Sulejów Reservoir situated in Central Poland on Pilica River, the main left side tributary of Vistula River (Fig. 1). Due to water level fluctuations the reservoir's area varies (average area is about 1 500 ha), and in consequence the reservoir is almost devoid of littoral macrophytes.The average depth is 3.3 m, maximum depth, close to the dam, is 11 m.

Pelagic fish samples were taken in the mid part of the reservoir, 3–4 km upstream from the dam (Fig. 1). Fish from a littoral zone were collected in transitory shoreline zone between Tresta Bay and the open reservoir.

Age-0 fish in the littoral zone were collected using beach-seine net with mesh size 1.0 mm. In the pelagic zone, young-of-the-year fish were sampled by bongo net (0.5 m diameter, 1.0 mm mesh size), pushed by a motor boat for 2 min. at 3 depths: surface, 2 m, and 4 m, with a speed of 2 m s^{-1}. Catches on each depth were repeated 3 times.

Sampling, both in littoral and pelagic zone of the reservoir, was carried out weekly, during the nights, starting from the June 4, to the August 11, 1994. All collected fish were preserved in 10% formaline, then weighed to the nearest 0.01 g and measured (*TL*) to the nearest 0.5 mm, in the laboratory. Fulton's condition factor was calculated for each

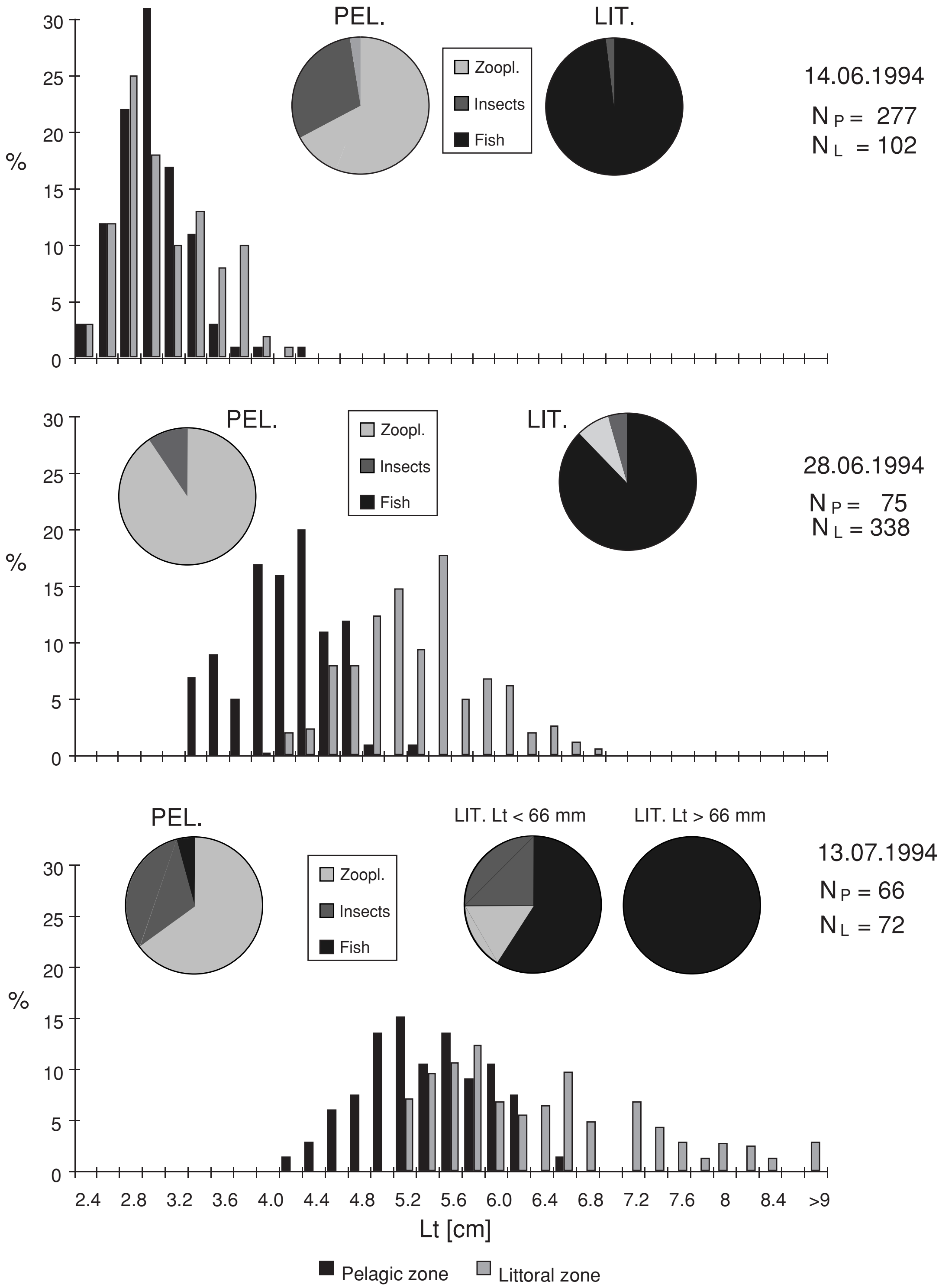

Fig. 3. Size distribution of age-0 pikeperch collected from the littoral and pelagic zone of the Sulejów Reservoir during summer 1994. Inserts show biomass percentage composition of main prey categories in the stomach contents of pikeperch.

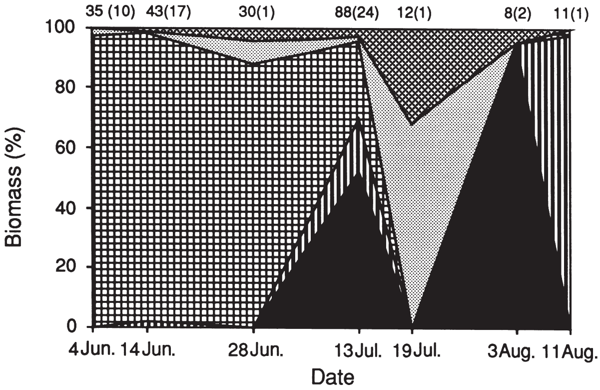

Fig. 4. Temporal changes in the biomass percentage composition of main prey categories in the stomach contents of age-0 pikeperch from the littoral zone of the Sulejów Reservoir during summer 1994. Numbers above the panel represent number of stomachs analyzed (in parenthesis number of empty stomachs).

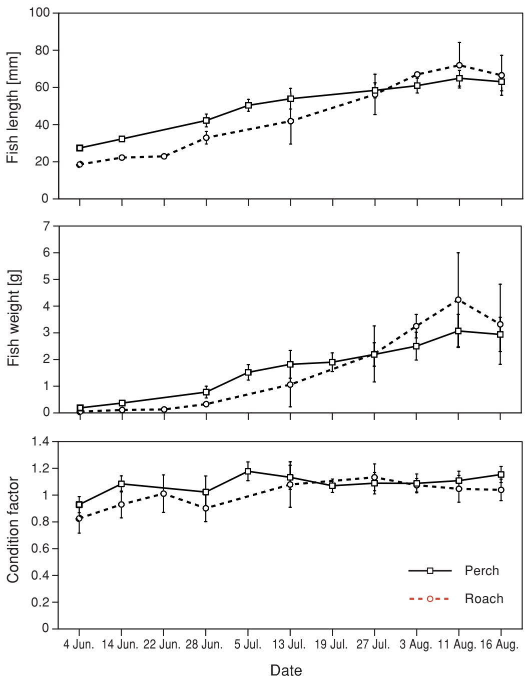

Fig. 5. Changes in total length, weight, and condition factor of age-0 roach and perch from the littoral zone of the Sulejów Reservoir during summer 1994. Date represents means and *S.D.*

fish (Tesch 1971). Stomach contents of age-0 pikeperch was weighed (wet weight) to the nearest 0.1 mg and analyzed individually, identifying the general prey categories (mainly to orders — in the case of zooplankton, and to species — in the case of fish) under a binocular microscope. The weighed mean contribution, by number and weight, of a given prey category to the food of pikeperch in the given sample was calculated (Hyslop 1980). For comparison of differences in length, weight, and condition between age-0 pikeperch from littoral and open water, Student's *t*-test for differences between two means was applied. (Means and standard deviations (*S.D.*) are presented in the figures).

3. Results

From the beginning of June, young-of-the-year pikeperch grew much faster in the littoral zone than fish from an open water area (Fig. 2). Then, their average weight and length became very similar for a short period in mid-July. It was accompanied by a very low condition factor of pikeperch, especially those from the littoral samples. Size distributions of pikeperch in the respective periods are presented in Fig. 3. Starting from a similar size distribution in the beginning of June, two weeks after distinct size segregation between fish from littoral and pelagic zones was found. In the following two weeks instead of expected further increase of these differences, a high number of small individuals was observed in the littoral zone, and their sizes corresponded to those of pelagic fish.

Analyses of stomach content of pelagic and littoral pikeperch revealed marked differences in their prey composition. Pikeperch in the littoral zone became piscivorous at a very small size of ~30 mm (Fig. 4). From the beginning of June they had started feeding on juvenile roach, then from mid-July cannibalistic foraging upon smaller conspecifics was observed. Finally, in August the diet was dominated by juvenile perch.That latter shift towards cannibalism coincided with a reversion of mean sizes of roach and perch (Fig. 5) in the environment. The above pattern was disturbed in one case, when only small individuals were present in the littoral sample, and all of them contained exclusively zooplankton and insects in their stomachs (Fig. 4; July 19).

Pikeperch in the open water habitat fed on

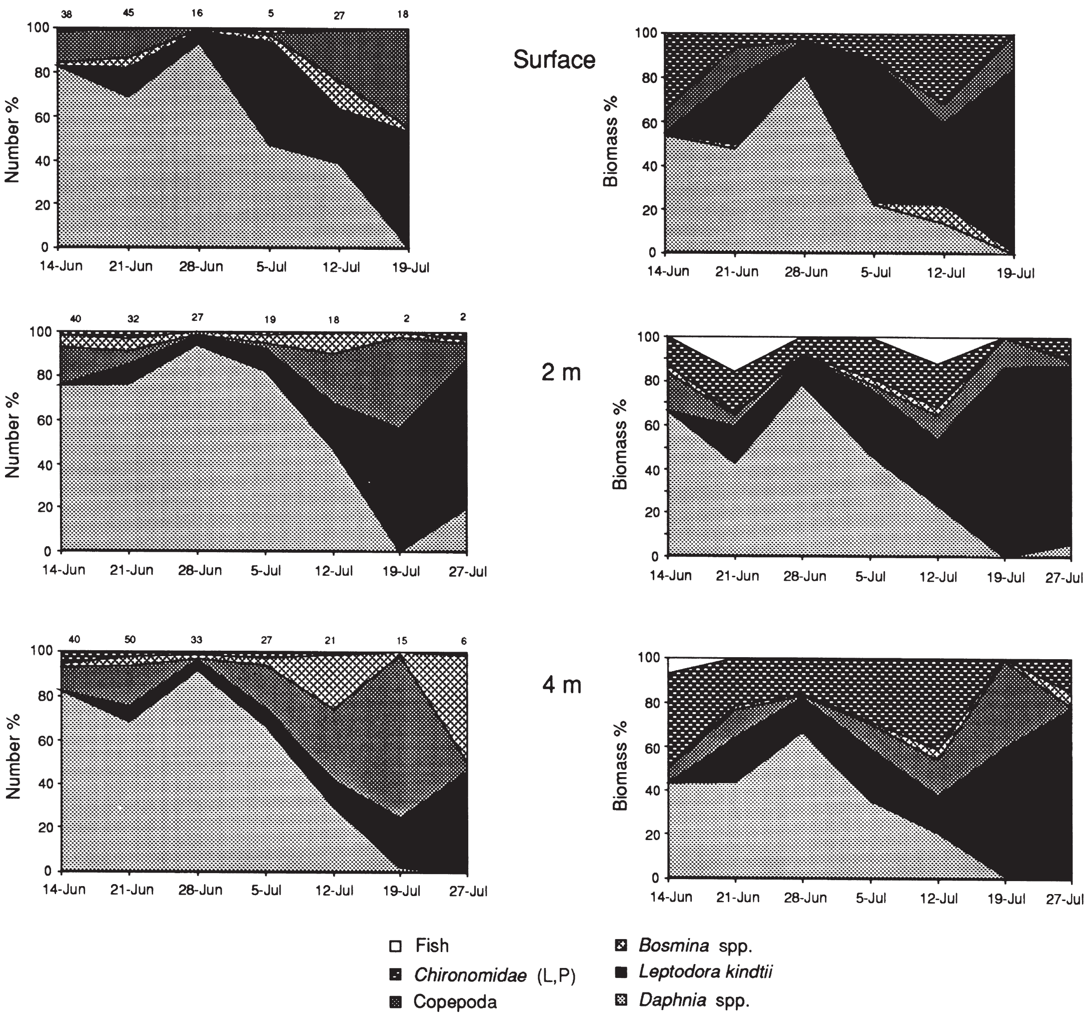

Fig. 6. Temporal changes in the percent numerical composition and biomass percentage composition of main prey categories in the stomach contents of age-0 pikeperch collected from different depths in the pelagic zone of the Sulejów Reservoir during summer 1994.

zooplankton all the time (Fig. 6), and presence of prey-fish was noticed only in the stomachs of three out of 481 examined specimens. Food contents changed gradually through June from the numerical dominance of daphnids to the dominance of *Leptodora kindtii*, copepods and *Bosmina* spp. later in July. That pattern was generally consistent despite the depth of pikeperch occurrence. Young-of-the-year roach, the main food of pikeperch of similar sizes in the littoral zone, did not occur in the pelagic zone for almost the entire June. In July only large specimens entered the pelagic zone while smaller individuals stayed permanently in the littoral area (Fig. 7).

4. Discussion

Year-class strength of pikeperch as in the case of other percids may depend on many abiotic and biotic factors. The main abiotic factors for pikeperch and closely related species, walleye are water temperature conditions (Busch *et al.* 1975, Koonce *et al.* 1977, Willemsen 1977, Serns 1982), wind (Clady 1976) and water level (Henderson 1985, Ploskey 1985, Zalewski *et al.* 1990a, 1995). Biotic factors are mainly cannibalism, predation (Forney 1971, Chevalier 1973, Tarby 1974, Nielsen 1980, Hartman & Margraf 1993), and availability of

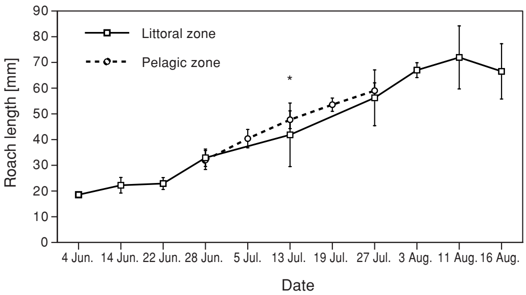

Fig. 7. Changes in the total length of age-0 roach from the littoral and pelagic zone of the Sulejów Reservoir during summer 1994. Date represents means and *S.D.*; asterisk shows significant difference between given means ($p < 0.05$).

proper size prey fish (Forney 1974, Van Densen 1985, Buijse & Houthuijzen 1992, Hartman & Margraf 1992). All these factors influence directly or indirectly the onset of piscivory which is a critical period in further development of juvenile pikeperch (Buijse & Houthuijzen 1992), leading usually to their bimodal size distribution (e.g. Nagięć 1966, Biro 1972, Van Densen 1985). Fish from the larger modal group are more likely to survive the first winter and contribute to the adult stock, than the smaller ones (Chevalier 1973, Oliver *et al.* 1979, Nielsen 1980, Post & Evans 1989, Buijse & Houthuijzen 1992).

The establishment of the bimodal size distribution in age-0 pikeperch cohort may involve many interactive processes. It was shown in the case of Sulejów Reservoir that the bimodality might result from differences in spatial distribution and consequently differences in feeding patterns. In the littoral zone, where numerous cyprinids occurred, pikeperch become piscivorous at a very small size of 30 mm (Fig. 3). Conspecifics that occupied the open water with much lower availability of prey fish (prey fish entered this zone after achieving size, which excluded them as a potential prey), were forced to feed on zooplankton. It is well known that after achieving 5–7 cm age-0 pikeperch have to shift their diet towards fish, otherwise their growth is halted (Biro 1972, Van Densen 1985, Buijse & Houthuijzen 1992). This size corresponds to that of fish which moved from pelagic to littoral zones in the mid-July.

Invading the littoral zone these small individuals could hardly find prey fish of the appropriate size, being instead eaten by larger conspecifics. After a short period the amount of small pikeperch in the littoral zone rapidly declined, mainly as a result of cannibalistic pressure. As cannibalism among pikeperch is rare in situations of alternative prey fish abundance (Willemsen 1983), its occurrence as well as the lowest pikeperch condition factor in the shoreline zone observed at that time, may indicate the critical period in prey fish availability. The buffering role of cannibalism during the observed shift in pikeperch foraging from roach to perch has also been documented. All these interactions further increased size differences between the large piscivorous pikeperch in the littoral zone and the small zooplanktivorous individuals in the open water. Whether the above mechanism of the establishment of size bimodality in juvenile pikeperch cohort is common should be verified in multi-year investigations. Other water bodies with better developed littoral zone and different juvenile pikeperch densities and fry communities structures should be a part of these investigations.

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