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SHORT RESEARCH NOTE

Deep spawning of perch (*Perca fluviatilis*, L.) in the newly created Chabařovice Lake, Czech Republic

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Abstract The egg strands of perch were found at up to a depth of 20.2 m and, on average, 88% of perch spawning activity occurred at depths greater than 3 m. Almost all the egg strands were deposited on dead vegetation. Ignoring deeper strata may cause drastic underestimation of perch spawning success in lakes.

Keywords SCUBA diving · Aquatic vegetation · Common reed *Phragmites communis* · Eurasian water milfoil *Myriophyllum spicatum* · Spawning substrate · Lake management

The spawning grounds of European perch *Perca fluviatilis* L. are generally assumed to be included in the 0–3 m depth layer of most lakes and rivers (e.g. Thorpe, 1977; Viljanen & Holopainen, 1982; Treasurer, 1983). Much deeper spawning (in an extreme case up to a depth of 12–15 m) is documented only for perch from two pre-alpine lakes, Lake Geneva (e.g. Gillet & Dubois, 1995; Dubois et al., 1996) and Lake Constance (Probst et al., 2009), and from a newly created opencast mine lake Chabařovice, where Čech et al. (2009) found perch egg strands down to a depth of 16.6 m. According to Jones (1982) and Probst et al. (2009), by using deeper spawning sites perch avoid the harmful effect of storms, waves or currents on their eggs. Here a SCUBA (Self Contained Underwater Breathing Apparatus) diving field survey of perch spawning is reported in relation to depth preferences.

Fieldwork was conducted during 28 April–1 May and 19–20 May 2008 in Chabařovice Lake, Czech Republic, which has an area of *c*. 200 ha, volume of 18×10^6 m^3 and maximum depth of 22 m. This water body has no obvious limitation to perch spawning activity in terms of depth and spawning substrates, which are represented by large numbers of dead trees, dislodged branches, bushes, beds of dead common reed *Phragmites communis*, worm weed *Artemisia* sp. and common rush *Juncus effusus* drowned during the filling of the lake (Čech et al., 2009). The large stands of live submerged vegetation, composed primarily of curly pondweed *Potamogeton crispus,* were much less abundant in the lake in 2008 compared to 2007 ($\ll$5% of the 2007 situation; cf. Čech et al., 2009). The old stands of curly pondweed had severely degraded in late fall 2007 and due to the fast filling of the lake in early spring 2008 new plants failed to grow to the same extant as in spring 2007. Contrary to that, mass and numbers of Eurasian water

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milfoil *Myriophyllum spicatum* and common stonewort *Chara vulgaris* remained the same (comprising *c*. 25% of the 2008 submerged vegetation; cf. Čech et al., 2009).

Three SCUBA divers monitored the depth distribution of egg strands and spawning substrates of perch in depth layers of 2–4, 4–6 and 6–8 m. Additional dives were made to depths >8 m. The divers swam parallel to each other at minimum horizontal distances of 5 m apart, each sampling the space of 3 m on either side of him (mean dive duration ± SD 73 ± 5 min; mean dive length ± SD 858 ± 144 m). At the same time as this SCUBA research, the whole littoral zone of the lake (depth layer 0–2 m) was sampled visually from the boat using polarized glasses. The sampling methodology was similar to that described by Čech et al. (2009) including measurement of the depth of egg strand deposition with the accuracy of 0.1 m and identification of the spawning substrate to the plant species or functional group (e.g. curly pondweed, trees and branches). Temperature and dissolved oxygen in the whole water column were measured using a calibrated YSI 556 MPS probe on 28 April and 19 May (midday). Surface water temperature was measured daily (morning; for details see Čech et al., 2009) from 15 March in order to catch the beginning of perch spawning period at 8–10°C (Kubečka, 1992).

During the two sampling surveys of the lake, 10 day dives were carried out (comprising over 36 h underwater) during which 581 individual egg strands of perch were found ($n_{28\ \text{April–1 May}} = 422$; $n_{19–20\ \text{May}} = 159$). In late April to 1 May, no egg strands were found to be close to hatching, i.e. in an eyed eggs stage (developmental stage VI according to Guma'a, 1978) which corresponds well to the previous findings of Čech et al. (2009) from late April 2007. During the second survey, many egg strands were close to hatching or in the process of hatching (embryos leaving the egg envelope). In the depth layer 4–6 and 6–8 m, 100 and 83.3% of egg strands, respectively, were in the eyed eggs stage (at least), whereas, in the water >10 m deep it was only 6.0% (no egg strands were observed in water shallower than 4 m).

The depth distributions of the egg strands differed dramatically between the two sampling dates (Kruskal–Wallis test; $H_{1,579} = 231.67$, $P < 0.0001$; Fig. 1), being much deeper in mid-May compared to late April to 1 May. The shift of spawning activity from shallower towards deeper layers was most probably induced by the increase of temperature in the upper layers of the water column (>13°C down to 5 m in mid-May; Fig. 2) corresponding to the results of Gillet & Dubois (1995, 2007) and Čech et al. (2009). During the first sampling survey of Chabařovice Lake 76.1% of the egg strands were found at depths greater than 3 m (the peak of perch spawning activity was in the 2–4 m depth layer at 11.8°C; no egg strands were found

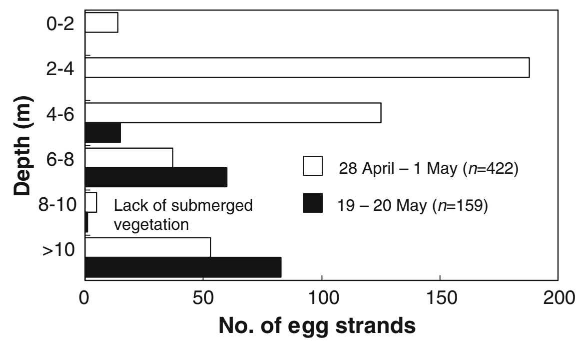

Fig. 1 Depth distributions of perch egg strands in Chabařovice Lake in spring 2008 during 28 April–1 May (mean depth 5.0 m) and 19–20 May (mean depth 10.0 m). Note that in comparison to the 6–8 and >10 m depth layers in the 8–10 m depth layer a noticeable lack of appropriate spawning substrate was observed (except of common stonewort no live vegetation present; very few dead common reed, worm weed, trees and branches)

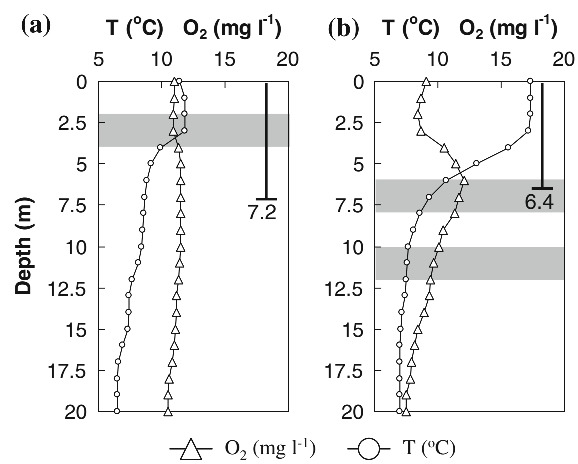

Fig. 2 Comparison of the vertical profiles of temperature and dissolved oxygen measured at noon on (**a**) 28 April and (**b**) 19 May 2008 in Chabařovice Lake. *Grey bars* indicate the depth layer where most egg strands occurred during the first (28 April–1 May) and the second (19–20 May) sampling surveys. The *vertical bars* show the Secchi disc depths

deeper than 12 m), and during the second sampling survey this increased to 100% (the peak of perch spawning activity was in the 6–8 and 10–12 m depth layers at 9.3 and 7.6°C, respectively; 31 egg strands were found deeper than 12 m). In 2007, Čech et al. (2009) observed, in the same lake, that during 24–26 April 87.2% of perch egg strands were deposited at depths greater than 3 m and during 2–3 May this proportion increased to 96.7%. Similarly, Huff et al. (2004) have shown that in Lake Giles, Pennsylvania, 92% of egg strands of the closely related yellow perch *Perca flavescens* (Mitchill) were located at depths greater than 3 m whereas in Lake Geneva, perch egg strands were never observed in water <3 m in depth (Gillet & Dubois, 1995). It seems that ignoring the deeper strata may, at least in some lakes, cause drastic underestimation of perch spawning success and their potential for recruitment.

Using artificial spawning substrate lifted to the surface Gillet & Dubois (1995, 2007) have reported perch spawning at up to a depth of 12 m and Dubois et al. (1996) up to a depth of 15 m in Lake Geneva. With SCUBA divers, Probst et al. (2009) found egg strands up to a depth of 15 m in Lake Constance and Čech et al. (2009) up to a depth of 16.6 m in Chabařovice Lake. A maximum spawning depth of 12 m was recorded for yellow perch from Lochaber Lake, Nova Scotia, by Aalto & Newsome (1989) and at 15 m from Lake Giles by Huff et al. (2004) (both SCUBA research). In Chabařovice Lake in 2008, egg strands of perch were observed at depths of 20.2, 19.8, 19.6 (two records), 19.4 (two records), 19.3 and 18.9 m (i.e. also in the deepest part of the lake), which are the deepest records ever. Following the primary idea of Čech et al. (2009), these findings suggest that perch can use the whole lake and any depths for spawning, when under no temperature, oxygen and substrate limitation.

Due to the sporadic occurrence of live submerged vegetation (see above), almost all the egg strands were deposited on dead vegetation (93.8% during the first sampling survey and 88.1% during the second sampling survey). In late April to 1 May, the most frequently used substrate for egg strand deposition was common reed followed by worm weed, whereas in mid-May the most frequently used were trees and branches, followed by worm weed and common reed (Fig. 3). A preference for dead submerged vegetation (also in cases when abundant live vegetation was

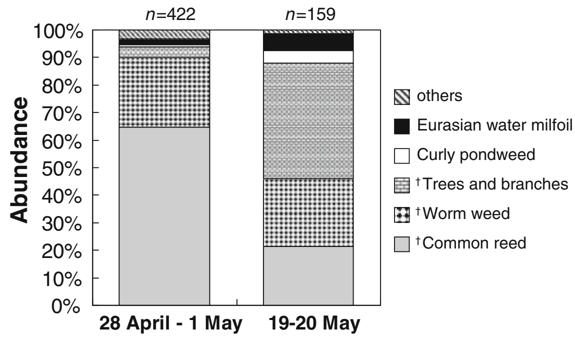

Fig. 3 The composition of spawning substrates used by perch in Chabařovice Lake in spring 2008 during the first days of spawning and at the end of spawning when most of the spawning events occurred in deeper parts of the lake (cf. Fig. 1). † indicates dead plants, bushes or trees. 'Others' category includes: bare bottom, common stonewort *C. vulgaris*, common rush *J. effusus* and water buttercup *Batrachium aquatile*

present at that time) as well as the obvious shift to trees and branches as a common spawning substrate during May (trees and branches occurred mainly in the deeper layers in Chabařovice Lake) was documented by Čech et al. (2009).

Since this study is part of a long-term project focussing on succession processes in a newly created lake (drowning of closed opencast mine Chabařovice started in 2001) the results have strong implications for overall lake management. Despite the extensive stocking programme focussing on larger individuals of pike *Esox lucius* L., zander *Sander lucioperca* (L.) and wels catfish *Silurus glanis* L. (since 2005; for biomanipulation purposes), perch is still the most abundant predatory fish in the lake (Kubečka et al., 2007; J. Peterka, M. Čech, unpublished data). However, the most important perch spawning substrates—beds of dead common reed and worm weed—reveal signs of progressive degradation, and this substrate will disappear from the lake within several years. Since the live vegetation is not such a suitable spawning substrate for perch and, moreover, its presence in the lake is less predictable in time and depends on the weather conditions during the year and the system of lake filling (Čech et al., 2009), without any intervention into the lake ecosystem, there is a hidden potential for a sudden collapse of the perch population. Considering the degradation of beds of dead vegetation, from year to year instability of lake phytocoenose and very deep presence of trees and branches, within few years the only spawning substrate for perch, especially in shallower parts of the lake (<10 m), would be boulders, mud and technical carpet (all highly inappropriate spawning substrates). For that reason, installation of an artificial spawning substrate (e.g. Gillet & Dubois, 1995; Pedicillo et al., 2008; Probst et al., 2009) would, in the near future, be an important means of both sustaining the stock of perch and for overall management of the lake's ichthyofauna.

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