Turbidity decreases anti-predator behaviour in pike larvae, *Esox lucius*

Maiju Lehtiniemi, Jonna Engström-Ost & Markku Viitasalo

*Finnish Institute of Marine Research, P.O. Box 33, FIN-00931 Helsinki, Finland,
(e-mail: maiju.lehtiniemi@fimr.fi)

Tvärminne Zoological Station, University of Helsinki, J.A. Palménin tie 260, FIN-10900 Hanko, Finland

Received 10 February 2004 Accepted 17 July 2004

**Key words:** water clarity, light intensity, predator signals, hiding, first-feeding fish

**Synopsis**

We tested how algal turbidity and light conditions influence anti-predator behaviour of first-feeding pike. Results showed that pike larvae were able to detect the predator by both chemical and visual signals in turbid water. However, the anti-predator behaviour was reduced in turbid water compared with clear water. Larvae hid in the vegetation in the presence of predator cues more in clear water than in turbid water. The attack rate on zooplankton in clear water was lower in the presence of predator cues, whereas no such difference was detected in turbid water. Both of these results indicate that turbidity acted as a refuge for larvae. Light proved to be an important regulating factor for feeding pike in the absence of predators, demonstrated as lowered attack rates in 50% light level in both clear and turbid water. This indicates that long-term turbidity may be critical for small larvae, which need to feed continuously to survive.

**Introduction**

Predator detection and predation avoidance are crucial for all prey. Predation may be avoided either by decreasing the possibility to be detected by a predator or by reducing the chance of being caught and eaten (O’Brien 1986, Lima & Dill 1990). Light conditions and turbidity of water greatly influence the use of vision in aquatic environment (e.g. Brönmark & Hansson 2000). Fish usually depend on vision despite many environmental constraints like high light attenuation and scattering, but under conditions of poor visibility they may substitute vision by auditory senses, lateral line system or olfaction (Wootton 1994).

The eutrophication of many freshwater and coastal marine ecosystems is altering the water quality dramatically. Increased nutrient loads multiply the amount of phytoplankton, which increases the sedimentation rate and turns the water turbid during spring and summer (Bonsdorff et al. 1997, Karjalainen 1999 and references therein). Turbidity decreases the water clarity and hampers the use of vision (Utne-Palm 2002).

Pike, *Esox lucius* L., is a common fish in most lakes in Europe and North America and in the coastal areas of the brackish water Baltic Sea and an important species for recreational fisheries (Urho 2002). It spawns during spring (Urho et al. 1990) and feeds on zooplankton during its larval stage. The pike is an ambush predator inhabiting vegetated areas of shallow waters (0–1.5 m) both as a larva and as an adult (Urho et al. 1990, Casselman & Lewis 1996). Even very young pike larvae are able to detect and respond to various cues from a predator aiming to minimise their conspicuousness (M. Lehtiniemi, unpublished observations), thus increasing survival.

Turbid conditions are common in shallow lakes, estuaries and coastal areas, which serve as nursery areas for several fish species. Turbidity is shown to have negative effects on adult fish by decreasing feeding (Craig & Babaluk 1989) and the reaction distance in prey detection (Vinyard & O’Brien...
1976, Utne 1997, De Robertis et al. 2003). However, it has been reported that intermediate turbidity may be favourable for larval fish and unfavourable only for adult fish due to different visual fields (Boehlert & Morgan 1985, Utne-Palm 2002, De Robertis et al. 2003). Larvae require high densities of food because their prey search volume is small (Boehlert & Morgan 1985). In eutrophic, turbid waters prey density may be higher compared with oligotrophic clear waters, which further favours fish larvae. Thus, the influence of turbidity is complex affecting unequally different sized fish. Light characteristics (spectrum and attenuation) and species-specific optimum and tolerance light levels further complicate the effects of turbidity (Miner & Stein 1993). It is not known how algal turbidity and diminished light affect the responses of larval fish to predators. The sensory systems of young fish are not yet fully developed (Fuiman & Werner 2002), which may affect the senses they use in predator avoidance in turbid conditions.

The objective of the present study was to reveal how algal turbidity influences the anti-predator behaviour of first-feeding pike larvae (10 days post-hatch). We hypothesised that the pike responds more frequently to chemical and less to visual predator signals in turbid water. Although chemical signals are easily diffused in water, they may be important to fishes in detecting predators (Wootton 1994). We conducted experiments both in turbid and clear water with lowered light, in order to distinguish between the effects of particles in water (i.e. turbidity) and diminished light on the behaviour of fish.

Material and methods

Fish

We obtained 5-day-old pike larvae, *Esox lucius* L., in May 2002 from Trollbøle fish hatchery in Ekenäs, SW coast of Finland, the northern Baltic Sea. Pike eggs had been collected from wild caught adults, hatched and reared in large tanks with a constant flow-through of river-water in the fish hatchery. We transported 1000 pike larvae with yolk sacs to the nearby laboratory of the Tvärminne Zoological Station, University of Helsinki in a plastic bag containing oxygen-rich water. We randomly selected 100 larvae for the experiments. Prior to the experiments we acclimated the larvae for 5 days in 30 l tanks with a constant flow-through of brackish water (6%), in a 16:8 light:dark regime in a temperature controlled room (~12°C). We fed the larvae with natural zooplankton (>100 μm) twice a day. We measured the body length ([mean ± SD] 14.1 ± 0.37 mm) of 10 larvae after the experiments with a binocular microscope for background information. Finally we released the larvae to the sea.

We used perch, *Perca fluviatilis* L., as a predator in the experiments because it is a common piscivore in the area. We caught the perch (body length ~15 cm) from the littoral zone with a fish trap placed at 1.5 m depth in a nearby bay in the evening and emptied the following morning. We kept the perch in 30 l tanks with continuous aeration and fed them with pike larvae until the experiments. We returned the perch to the sea after the experiments.

Turbidity and light conditions

We adjusted the water turbidity to a level that corresponds to conditions that pike larvae may experience in shallow bays during the spring. We obtained turbidity by adding algal suspension (the flagellate *Brachiomonas submarina* Bohlin, ESD 7.5 μm) to the experimental water. We obtained *B. submarina* from the culture collection of S. and G. Hällfors at Tvärminne Zoological Station where it was cultured in Tv2 medium (Hällfors & Hällfors 1992). We quantified the algal density by microscopic counting and analysed chlorophyll a content with a Shimadzu UV-2101PC spectrophotometer at 664.5 nm wavelength. The experimental cell density was 150 000 cells ml⁻¹, which corresponds to a bloom density in nature (Bagge & Niemi 1971). This density makes the water visually turbid and light green in colour. The chlorophyll a content was 49.5 μg l⁻¹, which is typical for highly eutrophic shallow waters.

The experimental room had no windows, only light coming from two lamps (Osram 40 W white halogen) hanging ~1.5 m above the aquaria. We measured the light intensity at the bottom of the aquaria with a LICOR irradiance meter with the detector pointing upwards, and it...