Chapter 10
Culture Methods of Pikeperch Early Life Stages

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Abstract Throughout the last decade, intensive rearing of pike perch fry have developed from small research based setups to full commercial scale operations with capacities to support the fry requirements of large scale highly intensified recirculating aquaculture system(s) (RAS) for ongrowing of the species. The methodology has to a large extent been transferred from the knowledge and prior research in marine larval rearing, using live feeds and recirculation technology. Specific adaptations to pikeperch have included feeding strategies that takes into account that pikeperch larvae are reared in fresh water, and the fact that pikeperch are highly cannibalistic already at the pre weaning stage.

Keywords Sander • Weaning • Cannibalism • Larval rearing • Recirculating system

10.1 Introduction

Intensive rearing of pikeperch has reached the commercial stage in several European countries including Denmark and Holland. The coming challenges include improvements in the reliability of fry production and refinements in the procedures leading to reduced production prices of fry, and improved competitiveness of the operators.

Production of fingerlings is the primary bottleneck in pikeperch culture. A critical phase in fingerling production is the early stage of exogenous feeding, where larval digestive capabilities are limited, and only live feeds can be utilized by the larvae (Nyina-wamwiza et al. 2005). These challenges have been overcome in a number of species and methodologies have been transferred between species. The majority of work on development of techniques for production and use of live feed has been conducted on marine species (Støttrup and McEvoy 2003).

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Pikeperch is a freshwater fish, but from a larval rearing perspective, pikeperch in many ways resembles marine species. It produces high numbers of small eggs (Lehtonen et al. 1996) and consequently, it has small first feeding larvae compared with other fresh water fish e.g. salmonids. At an early age pikeperch in natural environments become piscivorous (Hilge and Steffens 1996). In intensive larviculture of pikeperch, cannibalism may cause severe losses if the husbandry requirements and/ or nutritional needs are not better defined. Much effort in intensive pikeperch hatcheries is allocated to prevent cannibalism that seems irreversible if established in a batch of fry (Steenfeldt et al. 2010).

10.2   Live Feed Production

10.2.1   *Artemia*

Production of live feed is a resource demanding task. Much effort must be put into production of a stable quantity and quality of live feed for the larvae (Støttrup and McEvoy 2003).

In commercial intensive pikeperch larval rearing, *Artemia* with an optional supply of rotifers and algae is used for start feeding and larval rearing till the time of weaning (Rønfeldt and Nielsen 2010).

Natural populations of *Artemia* are found in over 300 places around the globe. The environmental conditions vary considerably. *Artemia* are found in waters with temperatures ranging from 6 to 35 °C and a wide range of salinities. *Artemia* produces two types of eggs. During environmentally beneficial conditions *Artemia* produces thin-shelled eggs. These eggs will hatch within short time. During more hostile conditions, with high salinities or low oxygen levels, resting eggs are developed. These eggs can survive for years, are harvested and later used in the aquaculture sector (Lavens and Sorgeloos 1996).

The *Artemia* cysts are hatched in sea water or alternatively fresh water supplemented with 3 % salt e.g. NaCl or sea water derived salt at 27–30 °C. Oxygen consumption is high and sufficient supply is often secured through use of pure oxygen. A harvesting device with a 150 μm mesh is used to concentrate and rinse the cysts after hatching (Lavens and Sorgeloos 1996).

After hatching pikeperch larvae utilize energy from their yolk sac, before shifting to exogenous feeding. Mouth opening happens at 95 Day degrees equivalent to 5 days at 18 °C (Mani-Ponset et al. 1994). This is a critical stage in the rearing process. Fish larval size at time of first feeding or rather the size of its mouth and diameter of esophagus determines the prey size that it will be able to ingest (Busch 1996).

Larvae should be presented with feed that fulfills their nutritional demands and are available in sufficient quantities to ensure, that ingestion rates are maintained at high enough levels to cover assimilation for retention and catabolism.

Rearing of pikeperch larvae on inert diets have been tried with some success (Ostaszewska et al. 2005), but live feed is still the preferred feed used in rearing of pikeperch.

Pikeperch larvae are able to ingest Artemia from first feeding (Steenfeldt et al. 2010). Selected small strains of newly hatched *Artemia* will be ingested by the first feeding larvae. When fish larval mouth gape has increased, larger instar two to three stage Artemia can be used. To increase the nutritional value of the latter Artemia, emulsified preparations of essential nutrients including HUFAs and vitamins are marketed. These contain self-dispersing selections of marine oils, vitamins and carotenoids. Enrichment emulsions are suspended in the water of hatched *Artemia* for 6–20 h before *Artemia* are harvested. The oil globules are readily ingested by *Artemia* and thereby boost their nutritional composition (Moretti et al. 2004). Specially prepared emulsions may be prepared to investigate dietary needs of fish larvae (Lund and Steenfeldt 2011).

10.2.2   Rotifers

Supplementation of the *Artemia* diet with a starter diet of rotifers is practiced at some commercial pikeperch hatcheries (Rønfeldt and Nielsen 2010). Rotifers are produced in tanks typically with a volume of 0.5–2 m³, a size that facilitates handling of the rotifers and cleaning of the production systems. The rotifers are fed three to five times daily with baker's yeast and algae or marine oil. It is possible to enrich rotifers by use of algae. The high content of the fatty acid eicosapentaeoic acid (EPA) in e.g. *Nanocholropsis occulata* and docosahexaenoic acid DHA in e.g. *Isochrysis galbana* have made them well suited as live food for rotifers in marine fish hatcheries (Støttrup and McEvoy 2003; Divanach and Kentouri 2000). However, culture of algae is labor intensive (Tapie and Bernard 1988). Alternative enrichment products as the ones mentioned for *Artemia* have been developed. The advantages of these are that they provide a short-term boosting of essential fatty acids and vitamins immediately before the rotifers are transferred to the fish larval rearing tanks (Lavens and Sorgeloos 1996). During the short term boosting the rotifers will fill their guts with oil globules (i.e., bioencapsulate) and serve as vectors allocating the oils to the fish larvae.

10.3   Intensive Larval Rearing

The methodology of intensive rearing of marine fish fry that is practiced in Western Europe has been applied to pikeperch with success. Investment and running costs are high and must be balanced with high productivity to be economical sustainable.

10.3.1 Tank Design

Tanks used for larval rearing in commercial pikeperch farms are typically cylindrical conical (Szkudlarek and Zakes 2007; Steenfeldt et al. 2010). In experimental research, aquaria are frequently used (Molnár et al. 2004). A comparison between cylindrical versus cuboidal tanks concluded, that cylindrical tanks provided a better rearing environment, mainly due to the differences in water flow patterns generated by the two systems (Moore et al. 1994b).

Commercial scale intensive larval rearing in Denmark is typically carried out in cylindrical tanks of 3.5 m³ and a depth of approximately 2 m (Fig. 10.1).

10.3.2 Aeration

Aeration in cylindrical conical tanks is administered by placing an aquarium type air diffuser in the tip of the cone. This creates a water flow where dead zones with stagnant water will not form (Moretti et al. 2005). The flow generated by the gentle aeration lifts the central column of water vertically up through the center of the tank.
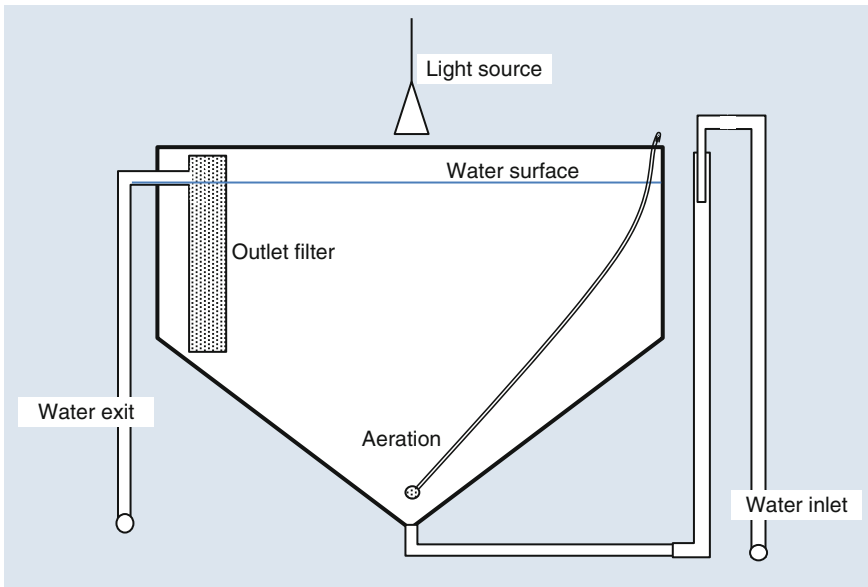

Fig. 10.1 Cylindric-conical larval rearing tank with inlet through the *bottom* and outlet filter through cylindrical submerged filter in the left side of the tank

At the surface the water moves horizontally to the tank edge before being forced down along the tank side towards the cone tip. Besides oxygenation the aeration device also homogenizes the concentration of prey and fish larvae in the tank (Barahona-Fernandes 1978).

10.3.3 Water Exchange

Water inlet to the tank is in some systems through the tip of the cone (Steenfeldt et al. 2010), or through a pipe protruding down into the water from the surface (Lekang 2007b). In rearing of larval fish, currents in the water must be kept low (Kolkovski et al. 2004). A water exchange rate of 25–50 % per hour is typically used; increasing as the larvae grow and more feed is administered (Steenfeldt et al. 2010).

Tank outlet or drain has two functions: Removal of wastes and maintaining water level in the tank while withholding the reared organisms in the tank (Lekang 2007b). In larval rearing tanks, the mesh size of the outlet screen must let feed organisms pass through the filter, while avoiding that larvae are flushed out. When stocking pikeperch yolk sac larva in Danish systems, a mesh size of 400–500 μm is used (Rønfeldt and Nielsen 2010; Lund and Steenfeldt 2011). The surface area of the filter must be large enough to ensure that the current passing the filter is sufficiently low, to avoid larvae being trapped (impinged) on the mesh. Often cylindrical outlet filters are used i.e. pipes that are perforated and covered with mesh (Moretti et al. 2005).

10.3.4 Water Currents

Water currents in the tanks generated by water exchange affects the stocked fish. Currents velocities less than 10 cm/s are recommended for sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*) (Divanach et al. 1997a). This is accomplished by letting the water in through multiple inlets, or by using large diameter pipes to reduce water pressure to a minimum. Low water exchange in larval rearing tanks i.e. 10–33 %/h (Büke 2002; Lund and Steenfeldt 2011) helps avoiding currents from forming. Skeletal deformities may be a consequence of high currents in the rearing tanks (Divanach et al. 1997a). Causative mechanism likely includes forced high swimming activity (Kihara et al. 2002).

Removing settled solids are traditionally performed by manually siphoning flocculating material from the bottom once or twice daily (Steenfeldt et al. 2010). The vertical sides of cylindrical conical tanks will not accumulate material settling in the tanks. This material will instead build up on the bottom surface, even though this is sloping towards the tip of the cone with an angle of typically 45°. Mechanical automated sweepers are being used in the private sector, consequently reducing labor requirements.

10.3.5   *Recirculating Aquaculture System(s) (RAS)*

In Europe, intensive larval rearing systems in commercial culture are exclusively recirculating aquaculture system(s) (RAS). These systems are preferred by commercial enterprises because of reduced water consumption and high level of control of rearing environment. Because intake of new water to the system is less than 5 % daily, purification of this in accordance to environmental impact legislations are reduced when compared to flow through systems (Steenfeldt et al. 2010).

Intensive rearing systems for pikeperch are in many ways similar to the systems used in rearing of marine larvae. They are typically based on recirculation of the water using mechanical and biological treatment of the water. Recirculation reduces energy consumption related to temperature conditioning of the water, and has advantages in relation to maintaining water quality with limited fluctuations (Blancheton 2000).

In a RAS larval rearing unit the water leaves the fish tanks and passes a mechanical filter where particulate matters i.e. faeces and uneaten feed are removed. The water then passes a biological filter where ammonia is oxidized to nitrite and nitrate before it reaches a trickling filter where carbon dioxide and other gasses in excess are removed and oxygen content is returned to close to saturation. Before the water returns to the fish it may pass a UV irradiation unit for disinfection (Fig. 10.2).

The chemical parameters of water quality should follow the general guidelines for larvae rearing systems including marine larval rearing systems. Supplementation of the inlet water with pure oxygen may be relevant if stoking density is high and water flow low. In larviculture of walleye 112.7 % oxygen saturation did not enhance gas bladder inflation after a 23-days rearing period compared with larvae cultured at ambient oxygen concentrations (Summerfelt 1991).

When feeding pikeperch larvae with *Artemia* having a protein content of 31 % (Helland et al. 2003), 5 % of the feed is nitrogen and the part of this not allocated to growth will be lost to the water surrounding the fish, mainly as ammonia (NH3) and urea (Poppe 1990). Ammonia is toxic to fish at concentrations as low as 0.002 mg/l, but will be in equilibrium with the ammonium ion (NH_4^+). The equilibrium strongly
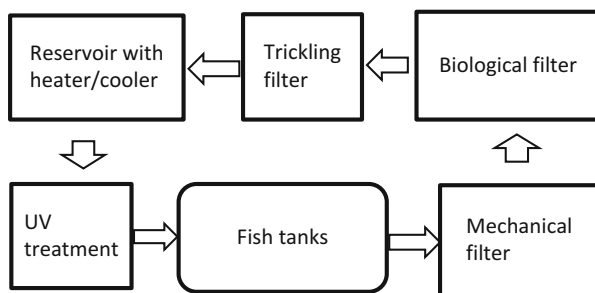

Fig. 10.2 Schematic drawing of water flow in a RAS system, sequencing the main units of holding and processing the water

depends on pH. Below pH 9 the equilibrium is shifted towards the ammonia ion and at pH 7 the shift towards the ammonia ion is almost 100 %. Nitrification where ammonia is oxidized to nitrite and nitrate is a fundamental part of a RAS system. Nitrification is optimal at pH around 8–9 (Lekang 2007a). The derived products nitrite and nitrate are much less toxic to fish. Rearing of salmon in constant concentrations of 84–99 mg/l nitrate-nitrogen had no adverse effects. Nitrite toxicity in freshwater though is reported at concentrations 50–100 times lower than in seawater; caused by the nitrite having an affinity for the Cl^- uptake system of the fish (Kroupova et al. 2005).

The rearing environment in recirculating aquaculture system(s) (RAS) is more stable than in flow through systems. Parameters such as temperature, pH, salinity etc. can be adjusted to ideal levels of the target species. Although bacterial load of recirculation systems can be high, the bacteria may have probiotic effects.

It is well known that the RAS microbial flora includes both chemoautotrophic (e.g. nitrifiers) and heterotrophic bacteria, that actively consume oxygen and organic matter. Such bacterial communities harbor species that are obligate or facultative pathogens and that may cause disease in fish (Michaud et al. 2009). However, the main part of the heterotrophic bacterial compartment is constituted by neutral microbes, contributing to maintain a good microbial water quality by occupying niches and prevent proliferation of harmful species (Michaud et al. 2009; Attramadal 2011).

10.3.6 Feeding Strategy

Using rotifers is believed to reduce the difference in time between early and late first feeding larvae in a batch (Rønfeldt and Nielsen 2010). The procedure used was 2 days of feeding with rotifers followed by 1 day of co-feeding with *Artemia*, where after only *Artemia* was used.

Feeding pikeperch larvae with live feed normally used in marine aquaculture i.e. rotifers and *Artemia* is not an ideal situation. *Brachionus plicatilis* and *Artemia* originates from saline ecosystems, and will not survive for more than a few hours in the fresh water environment in a pikeperch rearing facility. Use of freshwater rotifers is a possibility, but there is no commercially available alternative live prey organism to *Artemia*.

A commonly adapted feeding strategy is pulse feeding where live feed organisms are added to the tanks a number of times daily. The alternative continuous feeding seems not to increase growth or survival in larval fish, presumably due to their inherited behavioral and physiological adaptation to conditions of varying prey availability (Rabe and Brown 2000).

Overfeeding will increase number of uneaten organisms accumulating on the bottom, consequently deteriorating water quality. Cost of live feed is an economic burden and feed loss is minimized by the industry. The nutritional value of live feed is highest at the time of feeding (Lavens and Sorgeloos 1996). Maximizing the quantity of feed

ingested at this time will result in the highest possible nutritional quality of the feed ingested and can be increased by introducing a starvation period before feeding.

Optimized pulse feeding is a balance between addition of high quality newly enriched live feed to the tank and high ingestion rates by the larvae followed by a period where the prey is continuously flushed from the tanks by the water exchange until the prey density is low in the tanks and larval ingestion is reduced and appetite increases before next feeding. Administering live feed two to four times daily seems enough to cover the demands of pikeperch larvae (Rønfeldt and Nielsen 2010) and a period of darkness reduces larval activities (Batty 1987) and ensures high ingestion rates when feed is introduced in the morning before light is turned on (Lavens and Sorgeloos 1996).

By distributing the prey organisms from the reservoir tanks to the larval rearing tanks by pipelines, manpower costs can be reduced. If the reservoir tanks can be cooled to e.g. 5 °C, the detrimental effect of the nutritional quality of the prey will be small (Lavens and Sorgeloos 1996).

Maintaining a high level of hygiene in the rearing system is a balance between how frequent deposited material is removed from the tank and how often the larvae are disturbed by this procedure. Survival of *Artemia* in fresh water is minutes to hours. Consequently significant numbers of *Artemia* will die in the tanks before being ingested by larvae. Dead Artemia accumulate on the tank bottom and if not removed bacteria and fungi will proliferate. Consequently tanks need to be physically cleaned daily. This is in most facilities carried out by siphoning up from the tank bottom by suction devices powered by gravity (Moretti et al. 2005). Manual tank cleaning is labor intensive and automated systems for tank cleaning has been implemented at commercial farms. Automated systems are designed as brushes moving along the bottom. This has the advantage of being able to run for long time periods at slow speeds, thereby not disturbing the fish. Even with automated systems, material is resuspended in the water column and cleaning remains a balance between removal of material and minimizing resuspension of debris.

10.3.7   Stocking Density

Before stocking, the concentration of larvae in the transport unit can be quantified by subsampling a number of known volumes followed by manually counting the number of larvae in each. Transfer of a specific number of larvae to the larval rearing unit is now possible by volumetric transfer (Steenfeldt et al. 2011).

In commercial aquaculture, economic considerations necessitate culture regimes that may induce stress responses in the reared organisms. Various stressors may induce stress responses (Costas et al. 2008). High stocking densities are known to elevate levels of plasma cortisol in larger sized fish (Pickering and Potinger 1989).

Experimental evidence of an optimal stocking density of pikeperch larvae in intensive rearing units have generally found increased survival and growth rates with reduced densities (Szkudlarek and Zakes 2007). This has been counterbalanced though, by the increased number of larvae stocked at higher densities up to

the highest tested density of 100 larvae per liter. The same overall conclusion was made by (Moore et al. 1994a) when comparing the densities of 20 and 60 larvae per liter. Laboratory experiments in very small units (1–32 ml) did result in a positive correlation between mortality and reduced density (Tagawa et al. 2004). The use of very small water volumes may have influenced these results though. High densities reduce production costs if larval quality and survival is not affected. In crucian carp (*Carassius carassius* L.) best results were obtained using 50 larvae/l. Effects of high stocking densities were limited though at densities of 200–600 larvae/l (Zarsky et al. 2011). In Asian seabass (*Lates calcarifer*) stocking densities of 20–80 larvae/l were correlated to survival ($R^2 = 0.89$) but growth was not correlated to stocking density ($R^2 = 0.08$), (Salama 2007).

Commercial scale hatcheries producing marine fish e.g. sea bass (*Dicentrarchus labrax*) stock around 100 larvae per liter (Büke 2002) which is comparable to the density of larvae stocked in commercial intensive production of pikeperch. Stocking density varies with species with the highest stocking densities at up to 140 larvae/l in sea bass and sea bream, 30 larvae/ l in turbot and <10 larvae/l for halibut (Shields 2001).

10.3.8   Water Currents and Turbulence

Sea bass (*Dicentrarchus labrax*) develop higher ratios of skeletal deformities in currents higher than 10 cm s^{-1} (Divanach et al. 1997b). General recommendations for aeration in 2–12 m^3 tanks for sea bass and sea bream larvae are below 60 l min^{-1} (Moretti et al. 2005). Increasing aeration to above 600 ml/min in 250 l rearing tanks had negative effects on survival on turbot larvae (Person-Le-Ruyet 1989). Effects of high aeration levels in larval rearing tanks were attributed to direct physical effects on turbot larvae rather than indirect effects on prey availability (Gaignon et al. 1998).

When exposing pikeperch in 54-L tanks to turbulent conditions by administering 800 ml air min^{-1} through an air stone at the bottom of the tank, larval growth decreased and gas bladder inflation was delayed and never reached the almost 100 % inflation rate that characterized the control group (Rønfeldt and Nielsen 2010). A low water exchange rate is necessary to avoid feed being flushed from the tanks and to ensure that larvae are not trapped on the outlet screen of the tank.

10.3.9   Surface Film

Removal of surface film is necessary to reduce bacterial buildup in the tanks and to create conditions that facilitate filling of the gas bladder (Summerfelt 1996; Moore et al. 1994b; Barrows et al. 1993). Excessive buildup of a surface film will also act as substrate for bacteria and fungi. Removal of surface film can be done manually, by skimming the whole surface at regular intervals. Surface skimmers that aggregate the surface film and trap it in a reduced area of the surface are used in European sea bass and

gilthead sea bream culture (Moretti et al. 2004). Surface skimmers are floating frames that use air that blows along the surface through a hole in the frame. The airflow draws the surface film through the hole where it is collected inside the trap. The trapped surface film must be removed regularly either manually, or by automated suction devices. An alternative method used in walleye and pikeperch culture is the surface spray method (Summerfelt 1996; Summerfelt et al. 2011). Use of this method implies that the surface film and its associated microorganisms are forced down into the water column.

The advantage of this system is that no manual removal of surface film is needed. A comparison between effects of surface skimmers and surface sprays on gas bladder inflation in pikeperch concluded that the surface spray gave slightly higher gas bladder inflation rates than surface skimmers i.e. 96 % versus 100 % (Rønfeldt and Nielsen 2010) whereas the control group with no surface film removal resulted in 62 % gas bladder inflation. In an experiment on walleye surface spray removal gave 62.3 % gas bladder inflation compared with 41.7 % inflation using surface skimmers and 21.7 % in a control group (Boggs and Summerfelt 2003).

A surface film will develop in tanks when feeding live prey. Especially when using enriched prey, an oily surface film quickly develops on the water surface (Moretti et al. 2005). The surface film will not pass through the outlet filters and must be removed to avoid bacterial build up in the tank environment.

10.3.10   Gas Bladder Inflation

Removal of the surface film is especially important during the period where the larvae fill their gas bladder. This is a very critical phase in the larval rearing period (Summerfelt 1996; Rønfeldt and Nielsen 2010).

Gas bladder inflation in pikeperch reared at around 18–20 °C takes place 7–14 days post hatch (Rønfeldt and Nielsen 2010).

Pikeperch is a physoclist fish i.e. the opening between the gas bladder and the digestive tract is only open during the few days when the gas bladder is initially filled. Filling of the gas bladder is an active process where the fish larvae swims towards the water surface and gulps an air bubble by protruding its jaws through the water surface (Summerfelt 1996). If the water surface is covered by a film of oily substance, the larvae will not be able to gulp the air (Chatain and Ounais-Guschemann 1990). The pneumatic opening between the gas bladder and the digestive tract closes after a few days, and the fish will have lost the ability to fill and benefit from the gas bladder later in life. Fish without gas bladders will be negatively buoyant and will orient the body in a non-horizontal position in the water, constantly compensating for the negative buoyancy by jerking forward movements of the body. The excess energy used for this constant anti gravitational swimming activity, causes these fish to allocate less energy to somatic growth and they will become smaller than fish with filled gas bladders (Demska-Zakes et al. 2003). Fish filling their gas bladders in tanks where surface film has not been removed adequately will risk transferring bacteria from the surface film to the gas bladder, leading to gas bladder inflammation or aerocystitis (Ostaszewska 2003).

In walleye gas bladder noninflation was concluded to be a result of ingestion of bacteria and organic debris into the gas bladder 6–11 days posthatch. At 12 days post hatch the pyloric sphincter developed and separated common bile duct the intestine from the pneumatic duct in the stomach (Summerfelt 1996).

Fish without inflated gas bladders will survive relatively well in aquaculture systems but will allocate more energy to swimming activity and thus show reduced growth (Ostaszewska 2003). If no effort is done to remove these, they will form part of the standing stock during juvenile rearing and ongrowing. Within the group of fish with non-inflated gas bladders high frequencies of deformed fish will be present. The typical deformity observed in these fish is pre-haemal lordosis where the mid-posterior part of the vertebrae bends upwards. This is caused by the excessive swimming to compensate for negative buoyancy that builds up muscle that leads to an uneven load on the spine (Steenfeldt et al. 2010). Fish with pre-haemal lordosis do not present themselves well on the market. By discarding the fish at an early stage the economic burden of growing fish that are to be discarded is avoided (Steenfeldt et al. 2010). The earliest convenient time is when fish are moved from the hatchery to the weaning facility. The fish are anesthetized in a bucket using e.g. MS-222 or ethylene glycol mono phenyl ether. Fish with non-inflated gas bladders will sink to the bottom, and the ones with inflated gas bladders will float on the surface. Fish with non-inflated gas bladders can then easily be discarded and the remaining moved to the weaning system.

10.3.11   Turbidity

Turbidity is traditionally reduced if possible, by mechanical filtration and adsorbtion to biofilters or by water renewal. In intensive larval rearing systems, abioseston is minimized to reduce the availability of substrate to pathogenic bacteria.

Pikeperch in nature thrive in turbid water though (Jepsen et al. 1999). In a number of species, increased turbidity has positive effects on larval performance (Utne 1997, Vogel and Beauchamp 1999; Robertis et al., 2003). Increased turbidity likely reduces interactions among individuals but may have varying effects on different species, depending on their search volume and foraging mode (Utne 1997).

Positive effects of turbidity on larval feeding have been related to the modification of light and contrast conditions and reduced interactions between individual larvae (Meager and Utne-Palm 2008). Reduced foraging search volume in turbid water may reduce prey ingestion rates in turbid conditions (Vogel and Beauchamp 1999). The risk of being preyed upon may be increased in clear water though (Robertis et al. 2003). The multiple factors affected by turbidity advocates for species specific intermediate optimal turbidities (Meager and Utne-Palm 2008).

Effects of turbidity on larval walleye are well studied (Summerfelt 1996), but effects on larval pikeperch are less investigated. Wild pikeperch thrive in turbid water (Jepsen et al. 1999). When adding clay to the rearing water, (Rønfeldt and Nielsen 2010) found earlier gas bladder inflation and earlier onset of first feeding in tanks with turbid water. Larval rearing of pikeperch is often carried out in clear

water despite the knowledge that both larval pikeperch and walleye seems to perform better in turbid water (Bristow and Summerfelt 1994; Bristow et al. 1996).

In pikeperch larvae in turbid water (59.7±7,5 NTU), 21±8 % had inflated gas bladder on day 8 post hatching, compared to 0 % larvae reared in clear water (>1 NTU) (P≤0.001). The effect was alto significantly different at day 11, (P≤0.001) but not on day 9 and 10 where gas bladder inflation only tended to be higher in larvae reared in turbid water (Rønfeldt and Nielsen 2010).

In the same experiment, a higher percentage of larvae in turbid water had started feeding on day 6 and 7 post hatching (30±10 and 100±0 respectively) compared to larvae reared in clear water (10±10 and 45.5±5.7 respectively). Length of the larvae reared in turbid water was significantly higher on day 13 (P=0.044) and 15 (P=0.001) and tended to be higher in the remaining days from day 8 to 14. Survival was not affected significantly by turbidity.

Rearing larvae in green water has the combined effects of increased turbidity, plus the effects of possible positive nutritional effects of microalgae if assimilated by the fish larvae. The algae may serve as a water quality stabilizer (Houde 1975). The positive nutritional effects of microalgae can be caused by the fish assimilating microalgae directly or by zooplankton feeding on microalgae and thus increase their nutritional value to the fish (Houde 1975). Juvenile pikeperch reared in turbid water ponds selected larger invertebrate prey species to a fish size where piscivorous feeding was expected (Zingel and Paaver 2010).

The effect of green water technology on pikeperch was tested by addition of chlorella algal paste to the rearing water (Rønfeldt and Nielsen 2010). The effects were not as clear as the effects of adding clay. This may have been due to the lower turbidity reached (16.7±3.5 NTU) compared to the clay caused turbidity reaching 59.7±7.5 NTU.

10.3.12   Light Intensity

Light intensity is a very species specific factor. In rearing of European sea bass 500 lux at the surface is recommended. In sea bream 3000–5000 lux is needed (Moretti et al. 2004). Pikeperch larvae are reared at lower light intensities e.g. 50 lux (Lund and Steenfeldt 2011; Steenfeldt et al. 2011) and 140 lux (Rønfeldt and Nielsen 2010). Higher light intensities at the surface will aggregate the larvae in the lower part of the tank. Introduction of a daily dark period might be beneficial if larvae will not approach the brightly illuminated water surface, especially during the period of gas bladder inflation (Trotter et al. 2003). A dark period can be part of a feeding strategy where feeding are omitted during the dark period. An 8–12 h dark period is typically used in intensive pikeperch larval rearing. Continuous feeding seems not to have any positive effects.

10.3.13   Quantification of Mortality

When larval tanks are siphoned, quantification of mortality is to some extent possible (Lund and Steenfeldt 2011). Larger outbreaks of mortalities will be clearly visible in the siphoned material (Steenfeldt et al. 2011). By counting the numbers of dead fish the loss of fish from each tank can be estimated. Exact quantification of mortality is difficult though. At temperatures of 18 °C bacterial activity is significant and dead larva quickly disintegrates and become difficult to quantify.

10.4   Weaning

The weaning facility basically consists of ordinary fish rearing tanks of PE, Fiber glass or concrete. Water flow must be sufficient to maintain good rearing conditions in the tank i.e. change of one tank volume/hour (Steenfeldt et al. 2010). Increasing the water exchange rate to three times/hour reduced survival and growth at a commercial pikeperch farm (Steenfeldt et al. 2010).

10.4.1   System Design

Tank shape and water in- and outlet vary between facilities and attention must be paid to observation of larval behavior in the tanks. Currents in the tanks must be sufficiently low to allow larvae to maintain position in the tank and outlet screens must be observed to ensure that no live larvae are trapped on the screen.

Weaning facilities for intensive rearing of pikeperch fry in Western Europe are recirculation systems much resembling systems used for rearing of marine larvae. Outlet water from the tanks passes mechanical, biological and trickling filters before returning to the fish tanks. Temperature and water quality monitoring and manipulation equipment are implemented and often UV sterilization units will reduce bacterial load in the systems (Moretti et al. 2004).

The larvae are moved to a dedicated weaning facility prior to weaning. At this stage the larvae are easily irreversibly damaged by physical handling (Lund and Steenfeldt 2011). Consequently transfer are best carried out without trapping them on a landing net, but by reducing the volume of water in the larval rearing tanks and transferring the larvae with the remaining water to the weaning facility.

Temperature changes between the larval rearing unit and the weaning facility should be minimized and the fish starved a day before transfer (Moretti et al. 2004).

10.4.2   Weaning Strategy

In pikeperch attempts to wean larvae at 9 days post hatch resulted in significantly reduced growth when compared with weaning at day 15 post hatch (Hamza et al. 2007). Kestemont et al. (2007) found weaning of pikeperch on 19 days post hatch to have highest survival and growth but also highest cannibalism when compared with weaning at 12 or 26 days post hatch (Steenfeldt et al. 2010) found no significant differences in growth between pikeperch larvae weaned on day 16 or larvae fed *Artemia* till day 29. Larvae weaned on day 7 were significantly smaller though, already on day 16 post hatch and remained smaller till day 29. In commercial intensive rearing of pikeperch, weaning as early as possible is targeted to reduce the costs of feeding *Artemia* when compared with feeding dry feeds (Steenfeldt et al. 2010). The industry aims at initiating weaning on day 14–17 post hatch.

During weaning the quantity of *Artemia* is gradually reduced while the quantity of dry diets is increased (Kestemont et al. 2007) or remaining constantly high to facilitate larval ingestion of the inert diet.

Tanks must be cleaned daily to remove feed loss and mortality outbreaks ameliorated promptly to reduce losses to i.e. bacterial infections.

The dietary requirements of pikeperch larvae are not as high as in many marine larval species with respect to HUFA levels (Lund and Steenfeldt 2011). Use of high quality diets with pre-hydrolized diets (Kolkovski 2001) may improve larval performance and increase larval quality. A test of four commercially available weaning diets i.e. Nippai, EWOS Aglonorse No 1, Weanex 500 (Dana feed) and Gemmawean (Skretting) were tested on pikeperch in 2007 (Steenfeldt and Lund 2008). The experiment was conducted in a triplicate setup in 350 L-tanks measuring 1 by 1 m. Co-feeding with *Artemia* lasted 5 days with a gradual delay of time of feeding *Artemia* until on day 6 where no *Artemia* was added. After 20 days fish fed Dana feed and EWOS were larger ($\alpha = 0.05$) than fish fed Skretting or Nippai. Fish fed Weanex 500 had higher survival than the remaining treatments ($\alpha = 0.05$). Average survival of all fish during weaning was 79.6 %. There was a tendency towards lowest mortality caused by cannibalism in the fish fed Nippai. This may have been an effect of the lowest growth registered for this feed and lowest number of fish registered with a weight of above 1.1 g at the end of the trial. A similar relation between high growth and low cannibalism was observed by (Kestemont et al. 2007).

10.5   Cannibalism

Cannibalism is often categorized as type I and type II. In type I cannibalism the prey is only partly ingested whereas in type II the whole prey is swallowed (Kestemont et al. 2003). The intensity of cannibalism is generally determined by the ratio between predator gape size and prey size (Smith and Reay 1991). A high predator to prey gape size ratio is usually required in type II cannibalism (Baras and Jobling 2002; van Damme et al. 1989; Hecht and Appelbaum 1988).

Cannibalism types 1 and 2 also make quantification difficult since parts of or whole larvae may be ingested by cannibalistic individuals in the tanks.

Cannibalism is a known problem in rearing of a number of fish larval species (Hecht and Pienaar 1993). Both genetic and behavioral factors seem to cause cannibalism. In European seabass and Eurasian perch initial stocking density and initial size heterogeneity influenced cannibalism in both species whereas a number of other factors gave ambiguous results (Kestemont et al. 2003).

In pikeperch high mortality due to cannibalism may reduce the number of larvae produced significantly (Steenfeldt et al. 2011). The cause of cannibalism in pikeperch seems not to be different times of hatching, (Steenfeldt et al. 2011) but seems to be related to high growth rates during larval life (Kestemont et al. 2007).

In walleye survival in turbid water was significantly higher than in clear water (Bristow and Summerfelt 1994). The higher mortality in the clear water may have been caused by cannibalism since the more uniform distribution of fish larvae in turbid water has been reported to reduce cannibalism in walleye larvae (Loadman et al. 1989). In another study on walleye cannibalism was not affected by turbidity though (Rieger and Summerfelt 1997). Consequently the mechanisms associated to cannibalistic behavior and turbidity is not clear.

By staining otoliths of pikeperch larvae early in life it is possible at a later time to estimate individual larval growth prior to the time of capture. Estimation of prior growth of pikeperch larvae revealed that cannibals that were among the largest of fish in a batch at day 35 post hatch also had been among the largest fish on day 14. Non cannibalistic individuals with only *Artemia* in their guts of the same size on day 35 had also been among the largest fish in the batch on day 14 (Steenfeldt et al. 2010). It was concluded that cannibals are among the largest fish from early larval life (day 14 post hatch), but that non cannibals of the same size at day 14 post hatch can grow at similar rates till day 35 post hatch. Size of prey fish in cannibal stomachs could also be estimated based on otolith size, and were found to be $65.4 \pm 6.7\%$ of cannibal length. Since cannibals are significantly larger than their prey, grading of early stage fish may help ameliorate cannibalism.

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