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Minutes of the Percis II working group

Determination of year-class strength in percid fishes

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1. Introduction

The main task for the working group was to identify the most important areas for future research on determination of year-class strength in percid fishes. The summaries of current knowledge should be seen only as a brief background and the reference list is restricted to only some examples on the treated matters, with priority given to papers from this symposium.

The working group verified that the processes determining year-class strength are a major topic in percid fish research. Large year-to-year fluctuations in recruitment are commonly observed and many factors have been associated with this variability. The strength and structure of a year-class is often assumed to be a result of complex interactions among abiotic and biotic variables influencing the growth and mortality of a cohort. Variability in these interacting factors causes stochastic variability in recruitment. It was concluded that only factors that are highly variable may be demonstrated to influence the year-class strength. The group agreed with the common opinion that the size of percid year-classes are decided during the first year of life. The factors influencing this were discussed under the headlines: adults, embryos, larvae and juveniles, and anthropogenic influence.

2. Adults

2.1. Current knowledge

In percids weak or no relationships between year-class strength and adult stock size have been reported. This probably reflects the reality, but when stocks are very small (e.g. due to overexploitation) there is some evidence of stock-recruitment relationships. It has been demonstrated that perch egg-strands may remain unfertilized in some years due to small cohorts of adult males, potentially influencing recruitment.

Cannibalism by older cohorts may influence year-class strength (for yellow perch, *Perca flavescens*, e.g. Forney 1971, for perch, *Perca fluviatilis,* Sumari 1971, Craig & Kipling 1983, for walleye Chevalier 1973 and Loadman *et al*. 1986, for pikeperch, *Stizostedion lucioperca,* Erm 1981). Bowlby *et al*. (1991) pointed out that there is an inverse relation between adult stock size and recruitment of two-year-old walleye (*Stizostedion vitreum*).

Ware (1975) and Hendersson and Nepszy (1994) inferred that the physical condition of spawners may be more influential on the numbers of eggs than the actual number of spawners. Furthermore, in aquaculture it has been noted that the quality and chemical composition of the eggs, especially the fat content, affect larval survival. In general, larger females produce larger eggs with better larval survival. There is also evidence that the perch egg quality is better at the end of the spawning season.

2.2. Important research

- The role of cannibalism by the adults on variability in year-class strength with special reference to the size and structural composition of habitats.
- Analyses on the relation between year-class strength and stock size from a wide spectrum of habitats and long time series.
- The influence of the physiological status of the female on the quality of embryos and subsequent survival.

3. Embryos

3.1. Current knowledge

Temperature is the dominant force behind embryonic development and survival (e.g. Saat 1996). It determines the duration of the embryonic period and the extent of vulnerability to factors causing egg mortality. Within the limits of tolerance, rapid warming produces higher survival. Slower rates lengthen incubation periods, allowing more opportunities for predation, disease, fungus, and displacement of embryos. The effect of this predation on year-class strength is poorly understood. Roseman *et al*. (1996) observed that mortality of walleye eggs is caused by slow warming rates, triggering predation, and by the removal of eggs from favourable reef locations by wind-generated water currents. Losses of spawn due to siltation caused by floods or winds and also by waves or currents, which may cast eggs ashore, have been observed (e.g. Scott & Crossman 1973, Thorpe 1977). The influence of substrate quality on survival under e.g. eutrophication has been discussed but information is scanty.

In the Baltic Sea, eggs of different populations of percids have different tolerances (e.g. Vetemaa & Saat 1996) to salinity, indicating adaptations to these brackish habitats. Fertilization and egg development of pikeperch is still possible at 10‰ (review by Klinkhardt & Winkler 1989). Laboratory experiments show that egg mortality in both yellow perch and Eurasian perch is low, below 8‰ (Ribi 1992, Victoria *et al*. 1992), and in the Baltic Sea successful spawning occurs at this salinity.

There is evidence that egg and embryo size corresponds to yolk volumes (e.g. Moodie *et al*. 1989). Larvae hatched from small eggs are smaller and have a high level of major body deformities and higher mortality rates. Differences in the mean amount of food ingested by larvae are related to egg size.

3.2. Important research

- The effect of the length of the incubation period on the size and survival of newly hatched larvae.
- The effect of predation on the mortality of embryos.
- The effect of spawning substrate quality on embryo survival.
- The effect of salinity on the distribution of spawning areas, and success of fertilization and development of eggs.

4. Larvae and juveniles

4.1. Current knowledge

Many studies have demonstrated that temperature has a direct influence on larval survival in percids, and that the range of optimal survival is narrower, the younger the fish (e.g. Hokanson 1977). In field studies sharp temperature drops have been found to increase mortality. The onset of exogenous feeding is a critical phase since even short-time starvation may cause mortality. For visually feeding larvae it is plausible that the longer the night, the larger the risk. Different life stages and species react differently to changes in the light conditions created by e.g. turbidity. This has consequences for their distribution as well as their prey-capture efficiency, ultimately affecting consumption and mortality from predation. Although larval mortality is very high, no finite conclusions on the relationship between larval survival/abundance and year-class strength have been made for percids.

Predation is suggested to be influential in structuring year-class strength by limiting survival during the larval and juvenile periods (e.g. Persson *et al.* 1988, Karås 1996, Radke & Eckmann 1996). Metamorphosis to the juvenile stage must be a period of high mortality (Madenjian & Carpenter 1991, Jensen 1992) since large shifts occur in diet, habitat use and growth rate. The potential for predation decreases with increased growth during vulnerable periods; during the first year of life, survival is thus positively related to growth. Since the growth rate often is positively related to temperature in percids, that is true also for survival (e.g. Koonce *et al.* 1977, Madenjian & Carpenter 1991, Lehtonen & Lappalainen 1995). At least in perch, day-length has profound effects on food consumption and consequently growth. Starvation caused by poor light conditions during the short winter days has been demonstrated to have a potential to induce mortality. The smallest individuals, which have the smallest energy reserves, are most vulnerable (e.g. Toneys & Coble 1980). Based on the dependence of growth on temperature and day-length for perch (Karås & Thoresson 1992), an index of year-class strength has been formulated, which proved to have good predictive power for Baltic populations (Böhling *et al.* 1991).

4.2. Important research

— Develop explicit relationships between mortality and body size, and carry out sensitivity analyses to determine which parameters are most important for changes in size-specific survival.
— The importance of metamorphosis as a critical stage for year-class determination.
— The significance of predation for the recruitment process, also identifying important predators.
— The relative influence of abiotic and density-dependent factors on recruitment at the outer limits of the range of the species as compared with the conditions near the center of distribution.
— Effects of trophic interactions on year-class strength.
— Effects of water transparency and colour on distribution, consumption, and predation.
— The influence of variations in ice and snow cover on consumption and mortality.

5. Anthropogenic influence

5.1. Current knowledge

Early life stages are generally most sensitive to environmental disturbances. The main human impacts on percid recruitment are caused by acidification, eutrophication, industrial effluents and physical disturbances in migratory routes and recruitment areas. Environmental disturbances often break the natural pattern of year-class variation and generally affect earlier stages than those decisive in the normal process.

Acidification has mainly affected oligotrophic lakes in the northern parts of Europe and North America. Perch and yellow perch are the dominating species in most of these lakes, while the Stizostedion species are rare. Ruffe is common in especially deep lakes. The perches are known to be less sensitive towards the toxic effects of acidity and metals dissolved in a low pH than most other species, including ruffe. Lower competition makes moderate acidification beneficial for perch in lakes with cyprinids or arctic charr (*Salvelinus alpinus*), but the mechanisms behind their interactions are not fully understood. However, negative effects of acidification also on perch are indicated by a positive response when liming lakes without other fish species (Nyberg *et al.* 1986).

A moderate eutrophication is known to increase stocks of percids, while only ruffe and pikeperch are favoured in late stages of the process (e.g. Leach *et al.* 1977). North American percids are generally more sensitive than Eurasian species to eutrophic conditions (e.g. Leach *et al.* 1977, Colby & Lehtonen 1994). Even if the effects of eutrophication are described in numerous cases, the underlying mechanisms are poorly understood.

The effects of industrial effluents on the recruitment of percids have been documented and analyzed mainly in areas influenced by cooling water and pulp and paper production. As could be anticipated from the positive relationship between first-year survival and temperature, heating generally favours recruitment of perch (Karås 1996), while pulp mill effluents generally depress it (e.g. Sandström *et al.* 1991).

Toxic substances may cause delay of sexual maturation, lower embryo quality and reduced larval survival in perch (Sandström 1994). Wood sterols of oestrogenic character are at least partly thought to be responsible. Oestrogenic compounds are found in a variety of industrial discharges as well as in effluents from sewage plants. Their effects on fish reproduction are, however, still virtually unknown.

5.2. Suggested research

— The influence of the light conditions in eutrophic waters on the foraging by and predation on percids during the first year of life and its effects on the recruitment process.
— The influence of acidification on the interrelations between percids during their first year of life and their food organisms and competitors.
— Effects of oestrogenic substances on percid reproduction.

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