Chapter 17

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The Impact of Regulation and Hydrotechnical Works in River Channels on the Rheophilic Cyprinidae Fish

1. Introduction

Rivers are dynamic ecosystems that provide existence of a variety of habitats of vital importance to many plants and animals. A natural river channel is characterised by a diversified stream forms, numerous meanders, distributaries and oxbow lakes (Phot. 1). The banks are overgrown by vegetation, stabilizing them and protecting against erosion (Phot. 2). River floodplains consist of mosaics of aquatic ecosystems, including periodically flooded wetlands. They are a great place for the development of plants and animals. Environmental degradation caused by population pressure and the misguided introduction of bed chocking hydrotechnical elements led to a number of irreversible changes in aquatic ecosystems. A natural river has lost its original function and become a drainage channel, whose main objective is to drain excess water during heavy rainfall. The river channel was straightened, meanders, oxbow lakes and wetlands surrounding the river were eliminated. Fundamental components of stream ecosystems as trees and shrubs growing on the edges were cut down. Diversity of biotopes has been seriously impoverished.

Organisms especially vulnerable and susceptible to changes in aquatic ecosystems are the fish. Destruction of the river channels, regulations of the banks and loss of continuity of rivers (Humphries 2002) significantly reduced the abundance of carp fish. The various functions of rivers and economic needs, make huge emphasis on the development and transformation of rivers and their valleys. Until recently, prevailed the view that the purpose of regulating rivers was to drain as soon as possible the high waters and therefore courses should be shortened and levelled (Phot. 3). Regulations of the rivers are mainly due to rerouting (straightening) and deepening the channel with long stretches of uniform slopes and regular cross sections. As a result of such alterations, pools, wood

accumulations, side channels, other lateral habitats, clumps of trees and shrubs at the edges are reduced. Removal of riparian trees and other vegetation, in combination with artificial riverbanks security, immediately reduces the amount of organic matter, which is the basis of the food chain of all forms of aquatic life. As a result of the regulation of the river channel, stones and gravel dug out as well as the construction of bulkheads shall be destroyed in many places and places of natural spawning grounds for juvenile rheophilic fish.

Along large stretches of river valleys the diversity of primary habitat diversity is seriously destroyed. Consequently, there follows the relegation of regulated sections of the rivers many species of plants and animals, including rare, for which the riverine environment is the only place of existence. Hydro-engineering works and the sedimentation of organic matter leads to siltation of river bed, which also causes deterioration of the already greatly reduced spawning area (Jungwirth *et al.* 1993).

2. Damming and discontinuity of river channel for fish migration

Any hydraulic engineering structures can be divided into two categories: buildings do not cause water impoundment (spurs, oblong dams with crossbars or without, bands and shafts) and water damming structures (fixed and movable weirs and dams) (Phot. 4). The latter greatly hinder the movement of aquatic organisms, including the rheophilic cyprinidae fish. For rheophilic cyprinidae fish step height shall be not more than 25-30 cm and 40 cm for salmonids. Spurs mostly nourish convex edges, and dams can be mainly found on the concave shores; their job is to direct current in the desired direction (Kujawa 2008a).

A direct consequence of the dam construction is artificial body of water. The intersection of river habitat with damming (dam or weir) usually causes the disruption of biocenotic system, which reduces or eliminates completely the population of migratory species of fish due to lack of opportunities to reach up rivers to spawn (Vannote *et al.* 1980, Backiel 1985, Backiel, Bontemps 1995, Penczak 1999). It is most strongly felt by migratory species, which die in a short time depending on how large spawning areas have been cut off. The location of the barrier in the river above the main spawning grounds in the slightest degree affects the population of migratory fish. While, the location below the major spawning grounds (in the absence of good ladders) leads to the disappearance of fish stocks in a very short time (Ward, Stanford 1995). Construction of bulkheads in the area of spawning affects in a greater or smaller extent fish populations occurring there, depending on the size of the remaining spawning beneath the dam.

Damming of water in rivers causes many negative phenomena. In the former riverbed flows smaller amount of water, so it can become too hot in summer and freeze in winter which leads to total extinction of aquatic organisms.

Phot. 1. Aerial view on the River Drwęca floodplain - a part of unregulated river below Nowe Miasto Lubawskie (*photo by K. Glińska-Lewczuk*)

Phot. 2. View of part of the unregulated riverbed of the Łyna river near Cerkiewnik (*photo by K. Glińska-Lewczuk*)

Phot. 3. Adjusting stream threshold correction (*photo by R. Kujawa*)

Phot. 4. Weir on the Black Hańcza (*photo by R. Kujawa*)

At a certain section of the river, instead of flowing, well oxygenated water, appears a water reservoir with stagnant or low flow velocities. Organisms living in sections with reduced amounts of water are exposed during summer to elevated temperatures and reducing the amount of dissolved oxygen. In sections where the water level was lowered, a reduction of invertebrate fauna is noticed, and any

sharp water level rise causes the flow down the aquatic organisms. In sections dammed water velocity decreases, and decreases the ability of stream to transport sediment, which manifests itself in a gradual descent of sediment to the bottom, causing its shallowing. After a sufficiently long period of time and depending on hydrological conditions, the reservoir is partially or completely silted up.

Damming of rivers (Phot. 5) without functioning fish ladders and with mounted hydroelectric turbines causes first the death of migratory species, then the obligatory river species (rheophilic). If the flow velocity is high it creates the so-called unproductive areas below the dam. Fluctuations in water levels and pulsating discharges cause disappearance of many important fish habitats. As a result of repeated discharges of water within a month or even a day (Phot. 6), whole shoal of fish are pushed down the river. The fish swimming up the river, returning to their native places lose a lot of energy that could be used for growth or production of the gonads. The fry also suffers because of it and is relegated to shallow places where it freezes in winter. The fish staying above the impoundments (dams) (Phot. 7) are exposed to contact with the turbines, which hurt and kill them. As a result of the construction of dams there are created large local fish assemblages exposed to poaching.

Dams not only limit the movement of migratory fish and prevent them from reaching the spawning grounds, but also due to accumulation of many unfavourable factors contribute to a significant reduction in the number and range of many rheophilic fish species (Marshal, Przybylski 1996, Witkowski 1996a, b) and to find some of them are on the list of endangered species or threatened species (Witkowski 1992, Witkowski *et al.* 1999).

Phot. 5. Dam from the bottom water (*photo by R. Kujawa*)

Phot. 6. Strengthened river bed below the dam (*photo by R. Kujawa*)

Phot. 7. Reservoir above the dam (*photo by R. Kujawa*)

Among reophilic cyprinids, species particularly vulnerable to deterioration of water purity are: asp (*Aspius aspius* L.) (Phot. 8), barbel (*Barbus Barbus* L.) (Phot. 9), certa (*Vimba vimba* L.) (Phot. 10), ide (*Leuciscus idus* L.) (Phot. 11), dace (*Leuciscus leuciscus* L.) (Phot. 12), chub (*Leuciscus cephalus* L.) (Phot. 13), and common nase (*Chondrostoma nasus* L.) (Phot. 14), (Jakubowski *et al.* 1988, Penczak 1989, Penczak *et al.* 1995, 1996, Wlodek, Leather 1992, Przybylski *et al.*

1993, Leather *et al*. 1994, Witkowski, Heese 1996, Błachut, Witkowski 1997, Kujawa 2008b, Mamcarz *et al*. 2008). Asp is the only cyprinidae fish living in the Polish inland waters and it leads typical predatory lifestyle. It eats small, not exceeding a few inches, fish.

Phot. 8. Asp (*photo by R. Kujawa*)

Phot. 9. Barbel (*photo by R. Kujawa*)

Phot. 10. Certa (*photo by R. Kujawa*)

Phot. 11. Ide (*photo by R. Kujawa*)

Phot. 12. Dace (*photo by R. Kujawa*)

Phot. 13. Chub (*photo by R. Kujawa*)

Phot. 14. Common nase (*photo by R. Kujawa*)

Barbel and common nase are fish leading typical bottom lifestyle (Klimczyk-Janikowska 1973, Kujawa 2008b). They eat benthic fauna and the vegetation growing on the stones. Ide, dace and chub are "ubiquitous" and omnivores fish (Klimczyk 1965). Certa is the only trout fish and cyprinidae occurring in the Polish inland waters (Pliszka 1953, Bontemps 1960). The above-mentioned species are not of economic importance (except angling), but they are an essential component of the ichthyofauna of the rivers (Błachut 1998).

The fish usually occur in specific habitats (Starmach 1956, Rolik 1971, Copp 1989, 1992, Karr 1991, Keckeis 2001, Schiemer *et al.* 2001). They mostly prefer cool flowing water with high content of dissolved oxygen. They can also exist in artificial dam reservoirs and in flow-through reservoirs. During the reproduction, however, the fish flow into rivers or sections of streams where there are suitable conditions for spawning. Their reproduction usually takes place in rivers with pebble and gravel bottom and a very good oxygen conditions. They belong to a lithophylic or litho-phytophylic reproductive group (Balon 1975, 1981, Mann 1996).

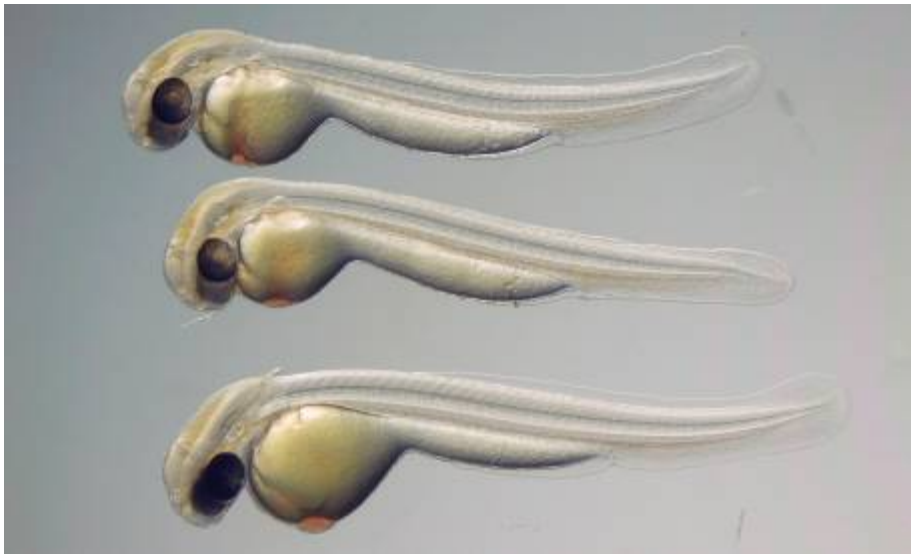
The eggs of all species are more or less sticky, so it can stick to the substrate (Phot. 15), which for most species are stones, gravel and other objects lying on the bottom. In the case of eggs, ide and dace also plants can be a substrate. The earliest to breed in natural conditions of the above species of fish, because already in late March – April, are asp and dace, but join at the latest (June), barbel and certa (Kokurewicz 1971, Hancock *et al.* 1976, Mann 1996). Incubation of eggs, depending on the species and water temperature, can last from several days to almost a month (Kujawa 1998, 2004). It is then exposed to all kinds of water

pollution, especially to the silting. Sedimentation of fine particles of silt, is a major threat to fish eggs in spawning on gravel, rocky or sandy bottom. Eggs covered with suspension die due to lack of oxygen or due to mold contamination (eg *Saprolegnia sp.*). Also, covered tightly with fine sediment of the porous system in the bottom of the river or stream leads to sterility of life in this biotope in which there live numerous organisms, which are among others fish food. As a result of sedimentation of fine silt particles also decreases the degree of self-cleaning of the river, and thus organic matter decomposition processes proceed more slowly.

Phot. 15. Ide eggs on a substrate (*photo by R. Kujawa*)

Rheophilic cyprinidae larvae (Phot. 16) lie for a long time after hatching among the stones, resorbing stocks of large yolk bags (Kryžanovskij 1949, Keckeis, Schiemer 2001), and then air-filled swim bladder, they are passively taken by the stream of river, on the shallows and backwaters where there are suitable conditions for feeding (Reichard *et al.* 2001).

In case of change the environmental conditions due to the accumulation of water in rivers it comes to qualitative changes in the assemblages of organisms living there. Rheophilic fish belong to the organisms that respond quickly to deteriorating environmental conditions, so that their number is drastically reduced (Mamcarz 2008). The deterioration of environmental conditions of rivers and reservoirs is also influenced by discharged pollutants. Although the last discharges of untreated industrial and household sewage have been limited, the areal pollution has increased (flowing from intensively fertilised fields) and it is much more difficult to control. All this has contributed to strong water eutrophication (Penczak *et al.* 1992, 1998, Penczak, Koszalińska 1993).



Phot. 16. Ide and asp larvae (below) during yolk bag resorption (*photo by R. Kujawa*)

As a result of increased trophic waters, a large number of rheophilic fish species cannot find the right conditions for development. As a result of a strong degradation of habitats comes to a drop in the number of species and to unfavourable changes in the structure of fish assemblages. The oxygen deficits lead to the extinction of many species of fish and other rheophilic organisms. Rheophilic cyprinidae fish, like salmonids, are less resistant to deficits of dissolved oxygen in water, because their breathing apparatus is characterised by a relatively small surface absorption. In aquatic habitat strongly modified by hydro structures these fish occasionally join to spawn. Eggs laid in these conditions often die in a short time. Disappearance of these species may be a signal of unfavourable changes in the environment affecting the biological balance (Karr 1991, Schiemer *et al.* 2001, 2003).

3. Fish consequences of human induced discontinuity of river channels

Partitioning of rivers unable migratory fish to take reproductive migration between marine and inland waters, access to breeding sites, usually located in the middle and upper reaches of rivers. As a result of disturbances in the continuity of the river channels, decreases the number of non-migratory rheophilic cyprinidae fish of lithophylic (barbel, common nase, chub and asp) and even phyto-lithophylic reproductive groups (ide and dace). Nevertheless, the number of limnophylic phyto- lithophyles increases (bream – *Abramis brama* L.), or fish groups not having a clear preference for the type of water (roach – *Rutilus rutilus* L.) and perch (*Perca fluviatilis* L.). They migrate to lotic sections and soon take the dominating positions in rivers over the rheophilic species (Mann, Bass 1997).

The species which prefer standing waters (stagnofile fish) maintain or increase their numbers. Sections of rivers where water is dammed stop being the area of salmonids and change into the region of the carp fish. Those conditions reduce the living space of many fish species which prefer clean water, fast flowing and relatively constant water temperature conditions.

Hydrotechnical building of rivers and watercourses regulations led to the interruption of migration routes of rheophilic fish species and loss of spawning grounds. As a result of those activities, a decrease in their numbers and even extermination of entire populations took place. Currently, the action shall be taken to reverse negative changes that have occurred in the environments of flowing waters and restore them the high natural values. A special role is attributed to ichtyofauna, because the quantitative assemblage structure of the fish is regarded as the best biological indicator of the health of aquatic ecosystems. In the image of ichthyofauna there are reflected not only momentary, accidental events, but re also recorded hard to see it in the short term changes taking place in the multi-scale. The shape of the bands of ichthyofauna inhabiting the river determines the impact of many different factors. In the year-scale particularly drastic consequences is partitioning of rivers, interrupting the continuity of ecosystems. Another threat to the fish are small hydropower plants, and especially their turbines. Even bars installed at the inlet (working channel) do not fully protect the fish from damage by the turbine. The provision of the application before the inlet to the turbine grid mesh of 20 mm can only to a certain extent, minimise the loss of fish.

In recent years there are taken steps to reinstate the species in the area of their former occurrence (Sych 1996). Restitution actions aimed at restoring the migration routes and free access to spawning grounds, protecting the survived wild spawning population, protection of breeding and rearing their young generations, strengthening and rebuilding these populations through stocking fish raised in controlled conditions and protect the biodiversity of the population (Kujawa 2004, Feldman 2008). In order to allow migratory fish spawning movements over a damming structure, there are built a variety of kinds of ladders. Numerous ladders built in recent years, however, show a defect in the design and location and thus they do not fulfil their task.

The condition for recovery of endangered fish populations, their restitution, in addition to the quality of water – rivers are also streamlining – ecological restoration or openness of rivers. In industrialised countries, where almost all the rivers were regulated, it is not only restoration of the main river channel, but also its tributaries. There, fish usually have their spawning and juvenile development areas. The key task in this situation is to maintain river channels passable for spawning of rheophilic fish and development of rheophilic benthic fauna.

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