REHABILITATION, MITIGATION AND RESTORATION OF FISH HABITAT IN REGULATED RIVERS

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Abstract

The principal factors implicated in the continuing decline of inland fisheries throughout the world are generally considered to be the reduction in quality and quantity of fish habitat conditions through the effects of land and water resource development works. In particular, river regulation through channelisation, impoundment, abstraction and other river engineering and management works often has major adverse effects on fish habitat conditions. However, a wide variety of techniques exists for restoring suitable habitat conditions in regulated rivers and improving fish abundance and diversity. For example, instream habitat improvement devices such as current deflectors and artificial cover devices can be used to re-create lost habitat features, such as the pool-riffle pattern, while artificial fishways improve habitat accessibility in impounded rivers. The provision of suitable environmental flows in regulated rivers is an essential requirement for sustaining fish habitat conditions. The use of such techniques in the rehabilitation of inland fisheries is illustrated through case-studies in the U.K., Canada and Australia.

Perturbations affecting the status of inland fisheries

Inland fisheries throughout the world are being increasingly impacted by a wide range of human activities which reduce the quality and quantity of available fish habitat and consequently adversely affect fish survival and abundance (Alabaster 1985). The major perturbations to the environment responsible for most loss and degradation of fish habitat arise from the effects of land and water resource development and river management, particularly works such as river impoundment for water supply and hydropower generation (Petts 1984). In addition, fish habitat conditions may be seriously affected by river channelisation for land drainage improvement and flood alleviation, water abstraction for crop irrigation, wetland drainage and removal of aquatic, riparian and floodplain vegetation as part of river and floodplain management (Brookes 1988). These perturbations may affect physical, chemical and biological aspects of fish habitat. In addition to such physical perturbations, inland fisheries are also affected by a wide range of other chemical and biological perturbations, including water pollution, over-exploitation and introduction of non-native species (Cowx in prep.).

Major physical perturbations to the river environment associated with impoundment and channelisation often affect both the quality and quantity of fish habitat. The construction of dams and weirs may have a wide range of effects on fish habitat, both upstream and downstream of impoundments (Petts 1984). The migratory movements of fish populations in both upstream and downstream directions are usually hindered or prevented by channel impoundment. River flow regulation by the impoundment has a variety of effects on downstream channel morphology, hydrology and water quality which may modify fish habitat conditions (Brooker 1981). River channelisation by channel dredging, widening or straightening may lead to an overall loss of available fish habitat and may severely degrade the remaining habitat. Such fundamental habitat features as channel meandering and the pool-riffle pattern may be severely modified by river channel works activities which usually lead to major reductions in overall habitat diversity (Swales 1982a).

River regulation activities such as these often produce major changes in the ecology of the aquatic environment, and fish populations may show marked declines in abundance and diversity through changes to habitat conditions, particularly reductions in the quantity and quality of physical habitat features and modifications to the natural flow regime (Petts 1984; Swales 1982a).

Fish habitat rehabilitation in regulated rivers

A wide variety of rehabilitation techniques exists for mitigating the impacts of human perturbations to the aquatic environment and fish habitat. Within the fields of river and fishery management there is a range of approaches available to improve the physical, chemical and biological aspects of fish habitat (Gore 1985). Possible measures to improve chemical or biological aspects of fish habitat may include pollution control, stocking or biomanipulation. Physical habitat restoration measures may include practices to maintain instream flows, riparian and aquatic vegetation, habitat diversity, macro-habitat features such as the pool-riffle pattern, and also preferred micro-habitat conditions (Wesche 1985). Habitat requirements of native fish show considerable variation between species and seasons, and also between age groups, which must be considered in designing habitat restoration programmes.

In the field of habitat restoration the terms mitigation, restoration, rehabilitation and amelioration are often used interchangeably and apparently arbitrarily when discussing methods for restoring fish habitat in regulated rivers. However, different approaches are available for improving fish habitat, depending on the extent of habitat degradation and whether the measures are proactive or reactive. Wherever possible it is preferable to practice impact mitigation in which the adverse effects of the perturbation are minimised using a proactive approach (analogous to 'preventative' medicine). This approach is receiving increasing attention as the preferred option in river conservation and management (see Boon *et al.* 1992). However, there are still many situations where a reactive approach to river conservation is the only option to sustain fish habitat in regulated rivers. These techniques will be considered briefly in the following discussion and illustrated with some overseas case studies.

Habitat restoration involves repairing damage caused by past activities and developments. Environmental compensation is the creation of freshwater habitats in order to compensate for anticipated adverse environmental effects of proposed developments. Habitat restoration can be either passive or active and proactive or reactive, while habitat compensation is generally active and proactive (Cairns 1990).

It is important to define the aim of habitat restoration in regulated rivers since it may not be practicable to aim to restore a stream or river to its pristine condition prior to the disturbance (Cairns 1990). A more practicable aim may be to minimise the loss and degradation of fish habitat in order to maintain a reasonably diverse and productive aquatic community. Alternatively, if the area affected contains an important recreational fishery it may be more important to aim to maximise fish density and biomass.

Habitat restoration techniques

Physical habitat improvement methodology

Fish habitat in streams and rivers lost or degraded by river channel works does recover in time as natural hydrologic processes cause the channel to readjust to the new conditions, and recovery processes restore and re-create lost habitat features. However, the natural recovery process is necessarily a long-term process and fish habitat in channelised rivers may take many years to recover to a level similar to the pre-impact conditions (Swales 1982a). However, the natural recovery process can be accelerated considerably through the use of remedial artifical habitat improvement devices which can be used to improve and modify habitat features. Such active measures are generally preferable from an environmental perspective since the goal of habitat restoration is achieved in a shorter time than it would by relying solely on passive natural recovery processes. In severely degraded streams, natural morphological and biological recovery may be a very slow process, typically requiring 10-100 years (Swales 1982a).

Structures such as low dams, current deflectors and artificial cover devices have been used for many years to improve habitat conditions for recreationally important species of trout and salmon in the streams and rivers of North America and Europe (Wesche 1985). However, these devices are now receiving increasing use and attention as a means of restoring lost or degraded fish habitat in regulated rivers (see review in Swales 1989). An increasing number of studies have documented the successful use of these devices in restoring fish habitat in rivers which have been channelised, impounded or otherwise impacted by river channel works activities. As a result, it has often been possible to partially restore the diversity and abundance of fish populations in impacted areas of stream or river (e.g. Swales and O'Hara 1983).

Artificial fishways

In addition to habitat improvement techniques, there is also a wide range of techniques available to improve the accessibility of suitable habitat areas. The construction of dams and weirs often considerably limits the availability of suitable habitat areas. However, there is now a well developed field concerned with the design and construction of artificial fishways in dams and weirs which allow the upstream and downstream movements of fish. Most fishways take the form of artificial 'fish-ladders' or other fish-passes which provide a free passageway between the lower and upper areas of the impoundment. Most fish-passes have been constructed for recreationally and commercially important fishes, particularly salmonid species of salmon and trout, in the impounded rivers of the northern hemisphere. In the Murray-Darling River in south-east Australia, however, fish-passes installed in several weirs to improve the passage of native fish species have been shown to be effective in allowing fish movements in the river (Mallen-Cooper 1989).

Environmental stream flows

The impoundment of streams and rivers using dams and weirs, together with water abstraction for crop irrigation, has the effect of regulating the natural river flow to produce a hydraulic flow regime which is considerably removed from the natural flow regime before river regulation (Petts 1984). An important aspect of the restoration of fish habitat conditions in regulated rivers is the assessment of suitable instream flows for fish and other biota. Instream flows provided for environmental reasons, designed to enhance or maintain the habitat for riparian and aquatic life, are often referred to as environmental flows (Gordon *et al.* 1992). A wide range of techniques have been developed to assess the suitability of stream flows for the survival of fish and other biota (see reviews in Kinhill 1988; Gordon *et al.* 1992).

The available techniques fall into three major categories.

(1) *Historical discharge methods*
These are based largely on historical flow records and use a fixed proportion of flow to provide environmental stream flow recommendations. They are also referred to as 'rule of thumb' methods since they do not involve the collection of field data, e.g. Tennant or Montana method (Tennant 1976).

(2) *Transect or hydraulic rating methods*
These involve the collection of field data at one or more transects in a stream reach and the development of relationships between discharge and other physical habitat variables (e.g. Stalnaker 1980).

(3) *Instream habitat simulation methods*
These consider not only how physical habitat changes with streamflow but combine this information with the habitat preferences of a given species to determine the amount of habitat available over a range of stream flows e.g. Instream Flow Incremental Methodology (IFIM) (Bovee 1982).

Case studies

a. Habitat restoration in a channelised river

Many lowland rivers in the United Kingdom are subject to periodic river engineering and management works aimed at increasing channel hydraulic capacity and modifying flow conditions to improve land drainage and alleviate flooding. River channel works such as channel realignment, bank regrading and vegetation clearance, dredging of the river bed and clearing of aquatic weeds and other instream material are frequently undertaken over large sections of lowland river by river management authorities. Such works may have severe effects on the quality and quantity of fish habitat and on river ecosystem processes (Swales 1982a). As a result, channelised rivers generally experience major declines in fish abundance and diversity as a response to the loss of major habitat features such as the pool-riffle pattern and the overall decline in habitat diversity (Swales 1982a; 1989).

Although habitat conditions in channelised rivers will improve in time through river recovery processes, studies have shown that natural recovery is a long-term process. As part of an experimental study, attempts were made to accelerate the natural recovery process in a channelised river in north-west England using artificial habitat improvement devices. The responses of the fish community to the habitat changes associated with the installation of these devices was assessed. Habitat improvement devices in the form of low weirs, current deflectors and artificial cover structures were installed in a channelised area of river and were found to be effective in improving fish habitat conditions (Swales 1982b). The low dams and current deflectors were found to be effective in recreating habitat features such as the pool-riffle pattern, while the cover structures simulated areas of shelter normally associated with river banks.

Fish populations in the study section were monitored before and after the installation of the improvement devices and the population density and biomass of the main fish species were estimated by electrofishing. Following habitat improvement, the population densities of dace and chub, the two main species present, increased by 75% and 37% respectively, while population biomass increased by 31% and 25% (Swales and O'Hara 1983). Distribution mapping studies revealed considerable fish relocation following habitat improvement, with large concentrations of fish being recorded in the vicinity of the improvement structures (Figure 1). It was concluded that the improvement programme was successful in partially mitigating the adverse effects on the fishery of previous land drainage works.

b. Restoration of off-channel habitats

The streams and rivers of British Columbia, Canada, are major producers of anadromous species of salmonid such as rainbow trout (*Oncorhynchus mykiss*), coho salmon (*O.kisutch*) and chinook salmon (*O.tshawytscha*). Such species typically rear in freshwaters for several years before migrating to the ocean for adult maturation and development. Recent studies in the rivers of British Columbia have shown that different species of juvenile salmonid show considerable variation in their habitat preferences and utilisation. In addition, salmonid species show major seasonal differences in habitat preferences. For example, in summer, juvenile coho salmon generally prefer pool habitats with abundant cover, but in autumn and early winter, populations migrate from their summer rearing areas into tributaries, back-channels, sloughs, ponds and lakes in which they overwinter (Swales *et al.* 1986; 1988).

In the Coldwater River, a tributary of the Fraser River in interior British Columbia, juvenile coho salmon and other salmonid species were found to utilise off-channel habitats, particularly shallow floodplain ponds, as their preferred overwintering areas (Swales *et al.* 1986; Swales and Levings 1989). The ponds were found to contain high population densities of overwintering coho salmon (up to 4,000 per hectare) and growth in the ponds appeared to be faster than in main channel habitats. Habitat conditions in the ponds were less extreme than in the main stream channel. Off-channel ponds appeared to play a valuable role in the life cycle of coho salmon and other juvenile salmonids (Swales and Levings 1989).

As a result of road construction works along the valley of the Coldwater River, the stream channel was diverted and it was found necessary to drain several off-channel ponds. As a consequence of the policy of 'no net loss' of fish habitat operated by the Department of Fisheries and Oceans in Canada it was required that equivalent habitat be created by the developers to compensate for the loss of stream channel and pond rearing habitat. As a result, several artificial off-channel ponds were constructed and connected to the realigned stream channel to provide an equivalent area of rearing habitat for juvenile salmonids. Monitoring of the ponds shortly after construction showed that juvenile salmonid species were using the ponds as overwintering habitats and that the ponds were successful in partially compensating for the lost natural habitats (Swales *et al.* 1986).

c. Environmental streamflow assessment

The flow of many streams and rivers in the Murray-Darling river basin in south-east Australia is regulated by dams or weirs constructed for water supply, navigation or hydro-power generation. Approximately 75% of all the irrigated land in Australia is contained within the Murray-Darling basin and numerous storage impoundments have been constructed in the headwaters of eastern tributaries of the Darling River. Water supply for irrigation has resulted in major changes to the hydrologic flow regime of most of the rivers in the basin. Flow regulation is thought to be one of the principal factors implicated in recent declines in native fish populations in the Murray-Darling basin (Cadwallader 1986; Lloyd *et al.* 1991).

A wide range of methodologies exists for the assessment of the instream flow requirements of fish and other biota in regulated rivers (Gordon *et al.* 1992). However, most of these have been developed and tested overseas and may not be suitable for use in Australian rivers, where the streamflow regime is generally more unpredictable and variable than in most other countries. There is a need for the development of a reliable and simple method for recommending minimum instream flows to protect aquatic life in Australian streams and rivers which is inexpensive, easy to perform and requires little or no field investigation (Orth and Leonard 1990).

In New South Wales, the Department of Fisheries and the Department of Water Resources are currently investigating the use of an alternative approach based on the use of 'expert-panels' to assess streamflow suitability for fish populations and river ecosystem processes. In this approach, expert-panels are set up consisting of specialists in the fields of fish biology, river invertebrate ecology and fluvial geomorphology. The flow regime below storages is experimentally manipulated and a range of discharges released from the storage. The expert-panel is then asked to score the suitability of each flow release as an environmental flow in which native fish are the primary indicators of environmental quality. Preliminary results of the study suggest that the expert-panel approach potentially has a valid and important role to play in environmental streamflow assessments (Swales *et al.* in prep).

In general there was a consistent trend at all storages for the expert-panels to prefer the lowest discharge releases as summer flows, the highest discharge releases as winter flows, and intermediate discharges as spring and autumn flows. The expert-panel approach, despite some limitations and drawbacks, is thought to be potentially a useful tool in instream flow studies for assessing suitable environmental flows in regulated rivers.

Conclusions

Although river management and engineering works such as channelisation and impoundment can have wide-ranging adverse effects on inland fisheries through reductions in the quality and quantity of fish habitat, it is nonetheless often possible to restore and rehabilitate the river environment to mitigate the impacts of river channel works on fish populations. Wherever possible, however, it is still generally preferable to be proactive rather than reactive and to implement preventative measures to minimise the adverse effects of river modifications on fish habitat conditions. In the final analysis, fisheries in regulated rivers can only be sustained by taking measures which sustain fish habitat.

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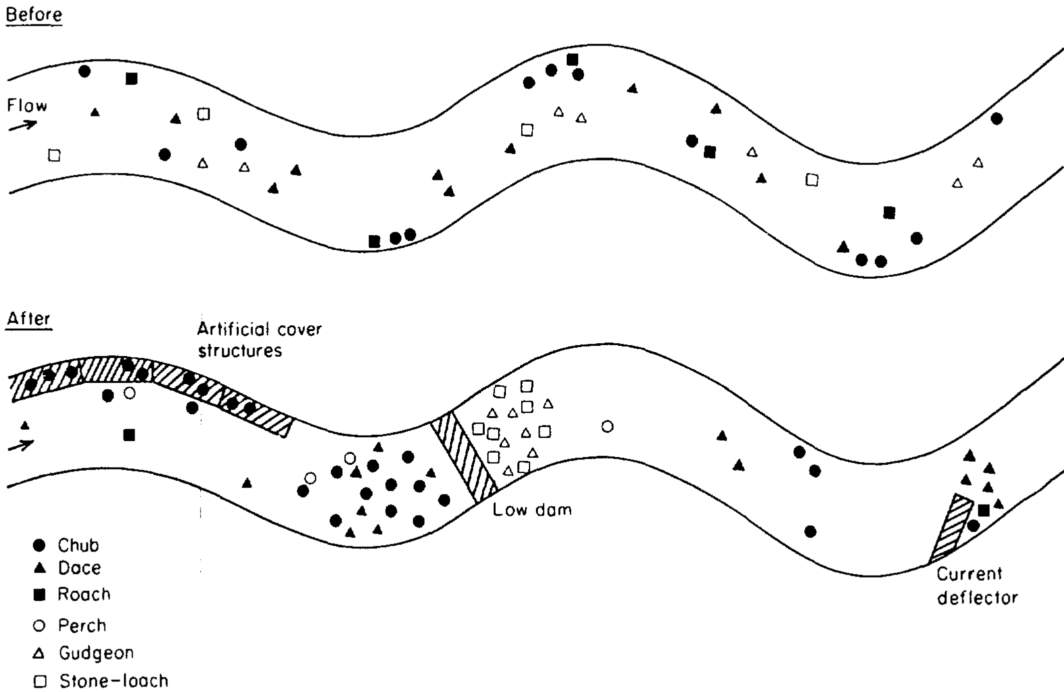

Figure 1. Fish distribution and abundance before and after habitat improvement (from Swales and O'Hara 1983).