

FRESHWATER FISH HABITATS: KEY FACTORS AND METHODS TO DETERMINE THEM

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Introduction

As fish habitat generally remains hidden underwater, is somewhat foreign to humans as terrestrial beings, and can be difficult to measure, it has often been neglected in the study and management of fish species and fisheries. As with terrestrial species however, freshwater fish species are dependant on the availability of habitat, and it is the alterations to, and destruction of, this habitat which are responsible for the decline in fish species and fisheries that have been witnessed. In general, freshwater fish appear more dependant on physical habitat than their marine counterparts, as freshwater ecosystems are more confined by their surroundings and are generally under more pressure from environmental changes, due to impacts on those surroundings. Although changes to stream environments and their catchments have been well documented in only a few areas (eg. Mitchell 1990), general environmental changes have long been recognised (eg. Merrick and Schmida 1984; Lake and Marchant 1990) and the causes of these changes and threats to fishes from them extensively discussed (Cadwallader 1978; MDBC 1988; Koehn and O'Connor 1990a; Jackson *et al.* in press). It is the changes to the key habitat factors which are responsible for the general decline in fish species.

Key habitat factors

Key habitat factors essentially comprise of the water and its condition, the surrounding land which helps determine that condition, conditions that the water creates within the stream, and instream objects.

1. Water

Water is the principle component of fish habitat and whilst much public attention focuses on quality the primary concern must be the amount of water that is present.

Quantity

The amount of water determines the area of the streambed which is covered (usually measured by wetted area or wetted perimeter) and hence the amount of aquatic habitat available. The amount of habitat area does not necessarily increase proportionally with flow however, and a combination of particular habitat variables which may be deemed as important for a species may even decrease as higher flows increase water velocities (Tunbridge and Glenane 1988). Examples of such changes are given in Figures 1 and 2.

The amount of water can also determine whether particular habitats actually receive water or not, eg. overbank flooding into billabongs.

Flow regime

The timing of the amount of water in the stream determines the flow regime. This incorporates small, short-term variations, large variations (eg. floods), seasonal variations, the timing of such variations, and the rate of changes in flow.

Water velocity

In lotic ecosystems, water velocities are an important habitat factor. The habits and swimming capabilities of the species help determine the preferred water velocity. Variations in velocity, and shelters from fast velocities provided by variations in the substrate, substrate particles or other instream objects, are important in providing suitable habitat and refuges from other species. Water velocity generally decreases with depth.

Depth

Water depth can determine the amount of a particular habitat variable (eg. wood debris) which is available in the water column. Vertical space in the water column is likely to be of greater need to mid-water schooling species than benthic species. Water depth is an important factor in avoidance of terrestrial predators, and in conjunction with water velocity it determines the stream habitat type eg. pool or riffle. Depth and velocity gradients provide the major component for fish microhabitat use in many stream fish assemblages (eg. Grossman et al. 1987a, b; Angermier 1987). Depth can provide relatively stable, sheltered areas whereas shallow areas are particularly sensitive to reductions in water levels. With increasing depth, light penetration decreases and hence visibility is reduced, providing protection from predators.

Quality

Acceptable water quality is an essential prerequisite for fish habitation and each species has different tolerance levels to different water quality parameters (Koehn and O'Connor 1990b). Some of the major water quality criteria are:

a) Suspended sediment: Can kill fish at high levels, can smother eggs, cause stress and

affect feeding (Newcombe and MacDonald 1991). It can also cause invertebrate drift (Doeg and Milledge 1991) and ultimately smother substrates (Berkman and Rabeni 1987).

- b) Temperature: Often a forgotten water quality criterion, the water temperature controls the metabolic rate of the ecosystem and the fish in it. Each species has upper and lower temperature tolerance levels as well as specific requirements for activities such as spawning (Koehn and O'Connor 1990b).
- c) Dissolved oxygen: Suitable levels are essential for respiration. Stream levels can be altered by flow and temperature, and by instream structures such as riffles which assist in aeration.
- d) Salinity: Whilst high levels can preclude freshwater fish from some habitat areas (Anderson and Morison 1989), appropriate salinity levels can also be important for those species which have an estuarine or marine phase to their lifecycle.
- e) Nutrients : Whilst nutrients are an important factor in stream production, excessive nutrient loads are a major contributing factor in eutrophication.
- f) Toxins: Can cause death, stress or increased abnormalities.

There are also a large number of other chemical parameters which may influence the needs of certain fish species and to which species will have varying tolerance levels or requirements (eg. pH, calcium).

All of these water quality parameters can be affected by the amount of flow. Reduced flows can exacerbate toxic effects through reduced dilution.

Rivers and streams flow in one direction and so point source changes to the water quality have the potential to affect the system for large distances downstream.

Habitat diversity in the form of changes in depth, velocity, temperatures and other chemical parameters are all important, providing the needs of different species and lifestyles and maintaining the heterogeneity of components in the ecosystem.

2. Surrounding habitat

Catchment

Catchment management has a major influence on the water quality of the stream and also influences the quantity of water available. Run-off is affected by activities such as urbanisation, drainage, deforestation and reforestation. Any activity in the catchment has the potential to affect the stream water.

Banks

The bank is important as it forms the perimeter of the stream, is the boundary between the water and the land, forms the stream channel and keeps the water within the stream. This helps determine water depth and velocities, available habitat and habitat variation.

Riparian zone

This vegetation zone is essential to the well-being of aquatic ecosystems and has continual interactions with the stream. It acts as a buffer between the surrounding activities and the stream, filters runoff, provides shade and inputs of organic material. In upland streams these inputs provide the major energy source in the form of leaves, bark etc, and much of the instream habitat (snags, logs, branches) originates from this zone. The root systems of this vegetation also play a major role in erosion prevention.

Shade

This can be particularly important to those fish species which avoid sunlight or wish to escape predators and is also a factor in the prevention of algal blooms.

3. Instream habitat

Instream objects are important in providing structure to the underwater habitat. They provide shelter from water velocity and sunlight,

orientation points around which a territory or habitat area can be based, spawning sites, and areas in which to hide from predators or hide in wait for prey. Such objects fall into three main categories:

- a) **Substrate:** Substrate particles provide important refuge areas for small fish and juveniles whilst substrate undulations provide particular habitat areas through variation in depth.
- b) **Wood debris:** Fallen trees, branches, logs, (all usually referred to as snags), and associated organic debris, form a major component of instream habitat, especially in lowland rivers. In addition to providing the advantages mentioned for instream objects they cause variations in flow and depth, provide habitat areas and spawning sites for species such as freshwater blackfish *Gadopsis marmoratus* (Koehn 1986; Koehn *et al.* in press; Jackson 1978), and attachment sites for invertebrates (O'Connor 1991).
- c) **Aquatic plants:** Provide habitat and spawning sites for fish and attachment sites for invertebrates, bed and bank stability and shade.

As each species has its own particular habitat needs, and these may change throughout its lifecycle, a diversity of habitat is essential to provide these needs. This diversity is provided in part, by a diversity of other attributes such as flows.

Access to habitats

For available habitat to be of use it is essential that fish species have access to it. Harris (1984) calculated that about 50% of available habitats in south-eastern New South Wales and far eastern Victoria was not available to migratory species. As about 70% of the fish species in these coastal drainages need to migrate between freshwater and the estuaries or the sea at some stage of their lifecycles (Koehn and O'Connor 1990a), barriers to fish passage mean that a large

proportion of the available habitat may not be available to the majority of fish species in this region. Such barriers can be formed by major structures such as dams, weirs, retarding basins, etc, or even by less obvious structures such as poorly designed culverts and road crossings. In addition to species which are known to make large scale migrations, all species need to be able to move freely within the stream in order to recolonise and find suitable habitat areas, mates etc, and there are many species for which movement needs are completely unknown. Serious attention needs to be given to redressing the problems of barriers to fish passage as a habitat issue.

Other influencing factors

There are several other biotic factors such as introduced species, diseases and food supply which can have a major influence on fish populations, and although they can often act independently of the habitat available, their effects can be influenced by it. For example, introduced species with wide habitat tolerances such as carp *Cyprinus carpio* may be advantaged over native species which have particular requirements where those requirements have been degraded. Additional stress caused by suboptimal habitats may assist diseases, and lack of food supply could well reflect general stream habitat degradation. Such factors are well canvassed in other publications (Pollard 1989; Morison 1989; Hynes 1970).

Methodologies to determine habitat linkages

There is still an urgent need for appropriate basic biological information on freshwater fish. A collation of all biological information on Victorian native freshwater fish (Koehn and O'Connor 1990b), shows that there are many gaps in our knowledge base. In order to manage any species or ecosystem properly, knowledge of the ecology of the organisms is essential.

With a limited number of researchers and funds, it is imperative that the best use be made of the resources available to provide the best information for managers. This means that before a study is undertaken the most effective method of research must be determined. The first question that must be asked is: What is the required outcome? What is the information needed for? What is the question that we are going to try to answer? Then, subsequent questions such as: What degree of resolution do we need to answer the question? Is a yes/no answer enough or do we need further details?; what degree of scientific rigour do we need to achieve?; what are the parameters that need to be measured?; what parameters can be managed?

These will assist in determining the method best suited to answering the question at hand.

Methods

Multiple parameter studies

- Wide-scale studies measuring habitat characteristics at several rivers within a region and correlating them with fish distributions and numbers at those sites (eg. Davies 1989).
- Localised studies using instream sections where habitat characteristics are measured and correlated against fish numbers (eg. Koehn 1986; Koehn *et al.* in press).
- Fish position studies which use the instream locations of individual fish determined by site of capture, observation, radiotracking, etc. (see Grossman and Freeman 1987; Tyus *et al.* 1984). This type of study is often used to determine frequency of use curves and habitat suitability models (eg. Terrell 1984).

All of these methods measure a range of habitat parameters and correlate fish numbers against these parameters using regression analysis, principle components analysis, etc. (Zar 1984; Digby and Kempton 1987).

Single parameter studies

These determine the importance of only one parameter and may often be undertaken as experimental studies in the field or laboratory, eg. LC₅₀, tolerance tests (Bacher and O'Brien 1988).

Single aspect studies

Study one particular aspect of the fish and determine the requirements for that aspect eg. the spawning of freshwater blackfish *G. marmoratus* (Jackson 1978).

Observations

Field or laboratory observations may provide answers to simple questions such as the nature of the species, and may give a good indication as to the direction that the study should take, and the methods to be used (Eldon 1969).

Distributional data

May give general information on the areas that the species inhabits and may be used in conjunction with other data to indicate areas of usage (eg. altitude ranges, barriers overcome).

Monitoring

Widespread monitoring undertaken for other purposes may not ideally be suited to obtaining direct habitat linkages. Such monitoring can however provide baseline data for the future and may indicate trends of populations. Monitoring of this type needs to be planned carefully to obtain maximum benefit from expenditure.

Monitoring the outcome of a particular event can provide direct information as to the effect on fish populations. There is an inherent possibility, however, that events requiring long-term monitoring (eg. timber harvesting) may not occur, funding may not be forthcoming (see Koehn *et al.* 1992), or that natural variation or chance events may cloud results.

Adaptive management

Manipulation of a 'natural' situation and monitoring of the effects can provide information on habitat requirements, for example, the placement of rocks in the Ovens River substantially increased the population of two-spined blackfish present (Koehn 1987).

In many cases several of these methods may have to be used together with physiological information to piece together the full picture of the requirements of the species. It should be remembered that this paper refers to management-oriented research that will provide appropriate answers to management in a time and cost effective manner. Academic theories and the study of freshwater processes remain important in the overall understanding of freshwater ecosystems and should always be considered when research is being designed and undertaken.

Constraints

When undertaking such research, apart from constraints imposed by resources, there are always constraints imposed by natural conditions which need to be taken into consideration. Some of these relevant to freshwater studies are: finding appropriate natural or relatively undisturbed habitats for study sites; obtaining sufficient fish numbers to be statistically viable; the effects of other (possibly introduced) fish species present; limitations imposed by the endangered or inaccessible nature of the species; barriers to fish passage downstream; fishing (legal and illegal); chance events (eg. a toxic spill, landslides); different life stages of the species or different habitats used at different times (eg. at night or during spawning); access to sites; the availability of efficient capture methods; river type; seasonal weather; or site conditions.

Concluding remarks

It is important that research conducted on the habitat requirements of freshwater fish species is directed toward the better management of those habitats. It is the alteration to their habitats that has caused the decline of most species and in most cases continues to be of threat (see Jackson *et al.* in press). These threats need to be addressed in terms of both research and management to prevent further declines in freshwater fish stocks. A positive step toward this is the

fish management plan for the Murray-Darling Basin (Lawrence 1991) which recognises and addresses many of these problems in that region, and similar plans for management and research are needed for other river basins.

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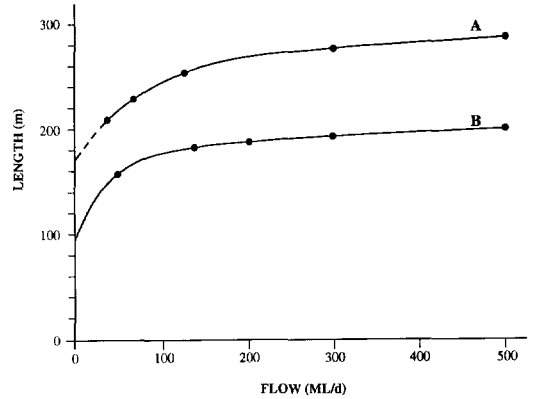


Figure 1. Length of wetted perimeter related to flow, measured across transects at two sites (A & B) on the Gellibrand river, Victoria. (from Tunbridge and Glenane 1988).

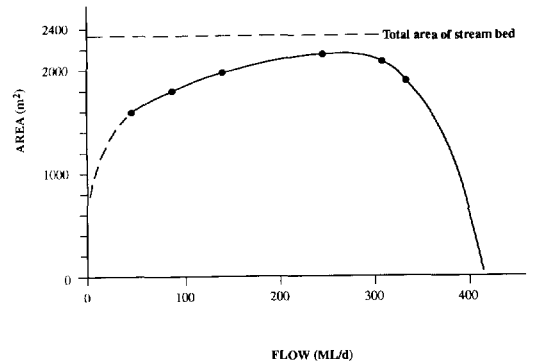


Figure 2. 'Rearing habitat' for freshwater blackfish *Gadopsis marmoratus* (defined as water with a depth >45cm and velocity < 30cm/sec) at a range of flows at the Mt. McKenzie section of the Gellibrand river, Victoria. (from Tunbridge and Glenane 1988).