

# Chair's introduction and overview: Environmental determinants, barriers and human interference to the movements of fish

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## Abstract

*The purpose of this paper is to provide an overview and to stimulate discussion for this workshop session. Types of fish movement include: large-scale, local, migratory, seasonal, daily, active, passive, diurnal, upstream, downstream and vertical. Some of these movements have well-understood, definite purposes, whilst others are not understood at all. Such movements can be stimulated by a range of environmental variables, which can act either alone or in combination with other variables. Many of these variables have been altered by human interference. Barriers to fish movements are often common, particularly in river systems. Barriers can be either a physical structure or a non-physical impedance such as an interruption to suitable water quality, quantity or velocity. Captures of fish are often aided by or rely on their movement. Whilst this forms a major example of human interference, such interference also takes many other forms. The effects of environmental determinants and human interference to fish movements are illustrated through examples using individual species.*

## Introduction

The patterns of movement and migratory behaviour in fish cannot be understood without consideration of their evolution and benefits to the life history of the

species (Dodson 1997). Such traits co-evolve to form adaptive strategies which provide selective advantage to a specific set of environmental conditions (Hutchings and Morris 1985). The energetic costs of migration and the efficiency of such migrations must be incorporated into any such strategies with the costs of the movement being outweighed by the evolutionary advantage. This will be determined by the length of migration, conditions faced, body size and shape, efficiency of movement, fecundity, reproductive uncertainty and egg and larval survival rates (Dodson 1997). Movement patterns are an important component in life history strategies as they provide the mechanism for accessing and utilising the resources necessary for survival (Eiler 2000).

The purpose of this paper is to provide an overview which will stimulate discussion for this workshop session.

## Types of movement

Movements can take many forms; some movements have well-understood, definite purposes, whilst others are not understood at all. Examples of some movement types are given in Table 1.

Social behaviour and interactions of the species such as territoriality, aggression and schooling can all be

**Table 1.** Types of movements and examples of why they may occur.

Movement type	Examples of movements
Large-scale	movements between spawning, feeding and nursery habitats
Local	feeding, habitat preference, territoriality, home range
Migratory	generally larger-scale, for spawning, recolonisation
Seasonal	Spawning, temperature/condition-related
Daily	local, diurnal
Regular	related to regular cues such as light
Opportunistic	feeding-related/prey abundance, flooding
Obligate	innate spawning mechanisms
Preferential	habitat selection
Active	upstream movements, unassisted
Passive	using currents or streamflows for assistance or drift
Diurnal	activity-based, predator avoidance related to light levels
Upstream	active, often spawning or recolonising
Downstream	may be passive or active, post-spawning
Vertical	may be following prey/avoiding predators, advantages to placement in the water column e.g. temperature, light
Lateral	On or off the floodplain or in and out of anabranches

major influences on movement types. Movements can avoid competition or prevent or enhance predation. Within rivers, fish can also move opportunistically into anabranches (Koehn 1997) or onto the floodplain, although Australian evidence for the latter is limited to date (Humphries *et al.* 1999). Fish movements from lakes into inflowing rivers to spawn have also been documented (Koehn 1996; Tilzey 2000).

Northcote (1978) defined migration as those movements which occur with a regular periodicity and involve a large proportion of the population. Such movements involve losing any site attachment the species has, can incur considerable energy costs and may have increased predation risks by travelling through unfamiliar localities. The benefits of these movements accrue as the habitats they move to are more suitable than the habitats they have left. Such migrations are typically for feeding or reproduction (Wootton 1992). Migrations for many species can involve diadromous movements between freshwater and marine environments

(McDowall 1988). Gross (1987) suggested that the patterns of diadromy exhibited by the world's fishes reflect the relative productivity of fresh and sea waters at the different locations. Such movements take advantage of optimal reproductive and feeding conditions for adults or larvae and can involve movements which compensate for larval drift.

Vertical movements both for following prey items and potentially obtaining preferred temperatures to maximise energetics have been outlined for southern bluefin tuna (Gunn and Young 2000).

### **Environmental determinants**

Movements can be stimulated by a range of environmental variables, which can act either alone or in combination with other variables as outlined in Table 2.

Often these environmental variables have secondary influences which can also influence movements. For

**Table 2.** Environmental determinants for movement and examples of species to which they may apply.

Determinant	Example
Moon phase	Glass eels (McKinnon <i>et al.</i> 2000)
Light	Southern bluefin tuna (Gunn and Young 2000)
Streamflows	Murray cod (Koehn and Nicol 1998)
Currents	Plaice (Arnold 1981), southern bluefin tuna (Gunn and Young 2000)
Tides	Glass eels (McKinnon <i>et al.</i> 2000)
Water temperatures	Southern bluefin tuna (Gunn and Young 2000), carp (Mallen-Cooper <i>et al.</i> 1995), brown trout (Tilzey 2000)
Season	Murray cod, trout cod (Koehn and Nicol 1998), silver perch, carp (Mallen-Cooper <i>et al.</i> 1995; McKinnon 1997)

example, light levels caused by moon phase can illuminate prey, or flooding can cause an influx of prey. Many environmental variables have been altered by human interference, especially in river systems (Koehn and O'Connor 1990) but their effects on movement have usually not been quantified.

### Barriers

One of the issues of human interference to fish movements that is specific to river systems is barriers. Physical barriers and solutions to them have been reviewed by O'Brien (2000) and include both large (e.g. dam walls) and small (e.g. culverts) structures. There are over 3 600 barriers to fish movement in the Murray-Darling Basin alone (Murray-Darling Basin Commission in prep). Harris (1984a, 1984b) calculated from a study in south-eastern Australia that about half the potential fish habitat in coastal rivers was not available to migratory species due to blockages by barriers. In general, about seventy percent of fish species in these rivers require migrations to complete their natural life cycles (Koehn and O'Connor 1990), so barriers can affect the majority of the fish fauna, particularly in coastal rivers. Barriers have also been recognised as a major threat to totally freshwater species (Koehn and O'Connor 1990).

Whilst most attention to movement barriers has been for fish passage to allow upstream movements, downstream movements are also important. Examples

of downstream movements of adult fish have now been provided for species such as Australian bass (Harris 1986), common galaxias (Frankenberg 1966), Murray cod (Koehn 1997), golden perch (Koehn and Nicol 1998; McKinnon 1997) and carp (Koehn and Nicol 1998), the latter three species being restricted wholly to freshwater environments.

Barriers to movement which are harder to detect are those of a non-physical nature. Such barriers can be created by: thermal, saline or other water quality changes; interruption to continuous habitats; high or unsuitable water velocities; and shallow water. These barriers, as with some physical barriers, may not be total in their nature but may affect only a portion of the population or may act for only a certain period.

The impact of movement barriers on population fragmentation of, and the restrictions to, genetic mixing have not been quantified for river populations.

### Human interference

Many captures of fish are aided by or rely on their movements and migratory habits, making these migratory species particularly vulnerable to capture. Many of the world's most important commercial species are migratory fishes. In 1978, 24 of the 25 marine species which gave the highest yields were migratory species (Harden Jones 1981). Targeting migratory stocks often means targeting spawning

migrations, which means not only reducing the existing numbers but also preventing potential recruitment.

Fowler (2000) has recommended management policies to protect King George whiting populations to allow escapement through a 'gauntlet' fishery of both commercial and recreational fishers in South Australia. Several States have closed seasons for Murray cod to protect them from capture during spawning season movements.

## Conclusion

We need to understand the movements of fish species in order to apply adequate management regimes. The movements of fish need to be considered in relation to their purpose in the lifecycle of the species and their evolutionary benefit. The benefits of movements need to be considered to understand the dynamics of fish populations. The swimming speeds and ability to migrate are not known for most species, nor are the cues to movements. Understanding the reasons and cues for movement is the first step in providing management which can allow those movements to continue (e.g. providing flooding). Understanding swimming abilities can assist in the design of more efficient fishways to alleviate the problems caused by barriers. The protection of many migratory species is essential for regulating their capture by both commercial and recreational fishers.

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