

Fishways as tools for monitoring movement patterns of large fish populations

Ivor Stuart

Department of Natural Resources and Environment
123 Brown Street, Heidelberg VIC 3084

Abstract

The recent advent of effective fishways has presented researchers with an important opportunity to not only monitor large-scale fish movements, but to also quantify other more subtle behavioural habits exhibited by native fish. Traditional count data are useful to determine the effectiveness of a fishway and assess long-term changes in the abundance and species composition of migratory fish populations. However, several emerging technologies will potentially further develop this research. For example, the entrance of a fishway is a very useful site for remote scanning of fish previously tagged with active or passive external/internal tags. Such technology is now commonly used and is advantageous because there is no requirement for continued handling of migrating fish. Hence, long-term data, such as fish home range and timing of spawning movements, can be reliably collected. Several case studies will be presented outlining the current technologies and methods used for monitoring of large migratory fish communities in fishways, their advantages and possible limitations.

Introduction

This century about 150 fishways have been constructed on many of the coastal and inland rivers of eastern Australia. Over 50% of these have been built in the last 10-15 years, including approximately 18 rock ramp, 22 vertical slot and 4 lock-type fishways. Many others are planned. Towards the latter part of the century the impetus for new fishway research and

construction has largely been a decline in the distribution and abundance of native fish species (Cadwallader 1978). Hence, most fishways built since the late 1980s incorporate standard design criteria which aid successful passage of a wide size range of native fish (Mallen-Cooper 1999). Indeed, fishways are likely to have an important role in maintaining and restoring biodiversity of whole fish communities (Stuart and Mallen-Cooper 1999). However, although most river regulation agencies support multi-million dollar fishway programmes, few of these new facilities have been subject to intensive monitoring. Consequently, there have been limited opportunities to provide effective design feedback to engineers and no cost/benefit analyses have been available to the licensee or general public. This paucity of monitoring, particularly of new "generic" facilities, also exacerbates the lack of clearly specified performance and operating objectives presented to the fishway operators. Unless monitoring programmes continue there is a risk that serious individual design flaws will be undetected, or at least remain unrectified and the current momentum to provide for fish passage may be diminished (Jackson 1997).

A shared and somewhat surprising finding among almost all of the more recent fishway monitoring projects has been the high diversity and abundance of fish captured migrating. In sub-tropical river systems, 34 fish species have been captured entering a single fishway and, during peak periods of movement, up to 4 500 fish per day (Stuart and Berghuis 1999). Large-scale fish migrations are not only restricted to northern

rivers. They have been documented in several temperate rivers of south-eastern Australia (O'Brien 1997; Mallen-Cooper 1999). Monitoring these movements within fishways has traditionally consisted of trapping and counting fish at several points, usually at the top and bottom. However, most fishways have been built with little understanding of fish attraction. For example, there are few data on how fish approach barriers, their ability to quickly detect a fishway entrance particularly during high flows, the consequent extent of temporal delays and their behaviour immediately before entering the facility. Collection of these data may be essential to optimise fish passage. To this end the use of other monitoring techniques such as underwater video surveillance of fishway entrances and radio telemetry devices is also discussed. The specific aims of this review are to outline the current techniques for monitoring large migratory fish populations and briefly discuss some future research directions using existing technology.

Methods of evaluating fishways

Evaluation of fishways is almost always dependent on an accurate assessment of the number of fish successfully utilising the facility. This has usually been carried out by sampling migrating fish at fixed points within the facility. The top of the fishway has been used in many studies to trap fish and this has revealed information on the movement habits and general effectiveness of the fishway (Kowarsky and Ross 1981; Russell 1991). However, the arrangement of the fishway entrance, hydraulic conditions within the pools and the differing swimming ability of fish species and size classes can confound such data. Consequently, other projects have sought to provide a more robust measure of effectiveness by sampling at several locations, usually at the top and bottom (Mallen-Cooper *et al.* 1995). These independent data can yield considerable information on population size, life stages migrating and passage efficiency; other experiments can also be employed to monitor fish behaviour and physiological abilities. Nevertheless, these methods require handling of all target and non-target fish and collection of as much data as possible,

over a wide range of flows and seasons. Occasionally, monitoring may be limited by small sample sizes and conversely during peak periods of movement very large numbers of fish may enter the fishway, thus placing an additional strain on field workers and on the safe release of fragile fish species. In addition, some studies have included sampling in the river below a barrier to determine population size and whether there are accumulations of fish (Marsden *et al.* 1997). These methods may also be used to infer fish migration through changes in abundance before and after fishway installation (Mallen-Cooper 1999) together with mark-recapture techniques (Gwartney 1969). However, the requirement for large numbers of fish and appropriate choice of the sample sites may limit the success of these experiments.

Several new technologies have been developed for fisheries ecological research, which may be adapted to minimise these problems. For example, time-lapse video and visual observation were used to record salmon passage at a fishway in North America (Hatch *et al.* 1994). The authors concluded that the system was accurate and cost-effective, but possible limitations to the technique are a need for relatively clear water and a considerable amount of image processing time (Hatch *et al.* 1998). Irvine *et al.* (1991) used image recognition software to automate fish counts and in Australia the development of another automatic system was also recently reported (Owen and Harris 1998). The latter study found that the underwater camera and imaging software system were highly accurate using simulated data, but that problems relating to turbidity and tracking of large fish numbers were likely to arise during a field study. Furthermore, video technology is usually dependent on strong lighting, which can alter fish behaviour and diel movement patterns (Hadderingh *et al.* 1999).

Radio telemetry has been successfully used for tracking the movements of several temperate and sub-tropical native fish species (Koehn and Nicol 1998; Kind and Brooks 1999), but this technology has not been specifically employed to evaluate fishways. Conversely, in North America researchers have used

radio tags to study the movements of migrating fish as they attempt to locate fishway entrances (Barry and Kynard 1986; Vogel *et al.* 1990) and their behaviour within (Theiss and Kynard 1997). These individual radio signals can provide important information on how fish approach weirs, possible distraction to spillways during high flow, their success at quickly detecting a fishway entrance and their behaviour once inside the facility. To date similar data have not been collected in Australia. Interestingly, automatic datalogging receivers coupled to a satellite uplink have allowed remote collection, processing and transfer of riverine fish movement data (Eiler 1995). The disadvantages of these methods are the initial cost of the equipment, consequent limitation to the number of tagged fish, restriction of tagging to larger size classes and post-handling behavioural changes.

In the mid 1980s passive integrated transponder (PIT) tags were developed which have several advantages over radio tags. These include relatively low cost (A\$ 7-8), unlimited life expectancy, and the ability to be used in both small and large fish (Prentice *et al.* 1990). PIT tags have been used to monitor the movements of fish in experimental fishways (Castro-Santos *et al.* 1996), where high detection efficiencies have been reported. Antennae can be built into the fishway (e.g. around a vertical slot) and automatic reading and logging of tagged fish, their location, passage efficiency and time of arrival recorded. However, the range of detection of the tags is limited to approximately 60 cm, hence antennae arrays must be carefully positioned or specially made reader tunnels employed. The system seems only to be otherwise deficient if large numbers of tagged fish enter the detection zone simultaneously (Castro-Santos *et al.* 1996). A combination of the methods outlined above is likely to be important in further elucidating the behavioural patterns of migrating fish and of their ability to find a fishway entrance during high flow events.

Conclusion

Ongoing performance monitoring should complement the increased interest in fishway construction. A lack

of objective monitoring may result in a real risk of site-specific design or operation flaws and consequent delays to migrating fish. More importantly, without monitoring the lessons gained from each site cannot be integrated into future constructions (Cada and Sale 1993). Clearly, quantification of the number of fish approaching the facility, their ability to detect the fishway entrance and length of delays is important for fishway design, particularly at sites where the river channel is wide or hydraulic conditions during overtopping events prevent or distract fish from finding the fishway entrance. Radio telemetry and PIT tag technology will be integral in answering these questions and may provide important evidence of the need for a fishway on both river banks. Additional benefits of fishway evaluations include long-term population monitoring and positive promotion of results toward public support for other river restoration projects (Bennett 1997). Proving the success of fishways should not be the sole province of government agencies, but also of the water authorities and design agencies. Only then can clear and measurable fishway performance goals be achieved.

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