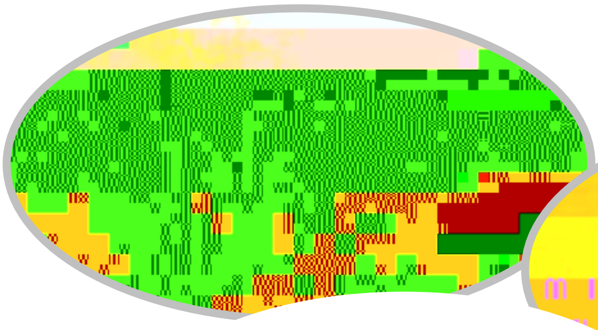
Culvert Fishway Planning and Design Guidelines

Part B – Fish Migration and Fish Species Movement Behaviour

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1 INTRODUCTION

To consider the needs for fish migration within waterways and the provisions that should be made for fish passage at road crossings and other waterway structures, road designers, waterway managers, environmental officers and scientists require general information about the migration, life cycle and movement behaviour of the freshwater fish community. Designers, managers and scientists involved in the planning, design and implementation of fish passage facilities also require information on fish movement design criteria for fish passage provisions at the structure.

These Guidelines Part B deal with fish migration and fish movement behaviour, and aim to:

- provide an outline of freshwater fish and fisheries values, fish habitat and stream zones, fish life cycles and fish migration characteristics
- categorise fish movement behaviour in terms of movement groups and movement directions, with illustrations for the Bruce Highway Corduroy Creek to Tully and University Creek prototype fishway case study projects
- identify fish movement characteristics for design in terms of fish passage design flow, design swim speeds and other movement characteristics for fish

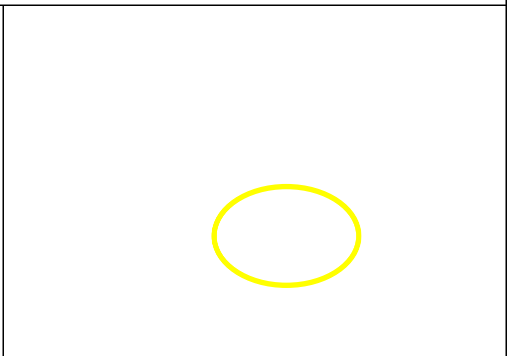
The information from Guidelines Part B is used in other parts of these Guidelines to:

- identify fish migration barriers at road crossings and other waterway structures within the various hydraulic zones of the structure, and identify fish passage options and alternative configurations to overcome particular fish migration barriers (Guidelines Part C – Fish Migration Barriers and Fish Passage Options for Road Crossings)
- categorise fish movement corridor crossings and assemble movement characteristics of the fish community for use in road corridor scale assessment (Guidelines Part D – Fish Passage Design: Road Corridor Scale) and in site scale assessment (Guidelines Part E – Fish Passage Design: Site Scale)

These Guidelines deal primarily with the Concept and Preliminary Design phases of planning and design procedures for road and other infrastructure projects. Examples of fish movement and barriers to migration at road crossings and other waterway structures are shown in Box B1.1.

Box B1.1: Native freshwater fish within University Creek in Townsville, attempting to migrate upstream at road crossings

Purple spotted gudgeon resting in shallow protected area on culvert apron slab (-/01/06) (Source: Alan Webb)



Plotosid catfish struggling through shallow water on culvert apron (-/01/04) (Source: Ross Kapitzke)

2 FRESHWATER FISH, FISH HABITAT AND MIGRATION

Information on the freshwater fish community and fish habitat areas within a catchment, and an understanding of the life cycle and migration behaviour of the fish species is vital to the provision of fish passage at road crossings and other waterway structures within the catchment. Information on diversity, abundance and distribution of the fish community for use in fish passage planning and design can generally be obtained from regional fish community data, field surveys, review of previous studies, as well as from anecdotal data for waterways in the area.

The following sections outline freshwater fish, fish habitats and fish migration, and illustrate this through information on the fish communities for the Tully Murray catchment and the University Creek catchment (Townsville) in coastal north Queensland.

2.1 Freshwater fish and fisheries values

Freshwater fish are defined here as those species spending all or part of their life cycle within freshwater environments. This includes species that live wholly within freshwater (e.g. Rainbowfish), species that move between marine and freshwater systems as an essential part of their spawning and growth life cycle (e.g. Barramundi), and species that live primarily in marine environments and may migrate into freshwater systems (e.g. Sea mullet).

Freshwater fish provide a range of commercial, recreational and traditional cultural values for humans, and represent significant biodiversity and conservation values for streams (Box B2.1). Species such as Sea Mullet *Mugil cephalus* are important for commercial and recreational fisheries. Jungle Perch *Kuhlia rupestris*, for example, represent important freshwater recreational fishing values, and together with other wholly-freshwater species such as Purple Spotted Gudgeon *Mogurnda adspersa*, contribute significantly to biodiversity and aquatic ecosystem functions. Many species, including Barramundi *Lates calcarifer* are important for traditional and cultural values, as well as being highly sought after for commercial and recreational purposes.

Box B2.1: Fisheries values and significance of freshwater fish

Altered stream flow through floods, and other stimuli such as water temperature change and altered photoperiod, provide cues for many freshwater fish species to migrate downstream or upstream for reproduction or habitat colonisation. The life cycle characteristics of the various fish species govern their migration behaviour, including the time of the year (season), the direction of movement (upstream or downstream), and the size of the migrating fish (adult or juvenile). Depending on the species and the life stage, migrations between habitat areas may occur at various temporal and spatial scales, ranging from river-basin scale movements of hundreds of kilometres over period of years, to local, tens-of-metres scale over days. Different fish species possess differing movement capabilities and capacities to negotiate various barriers to fish passage along the route such as adverse flow velocities and water depths at road crossings and other waterway structures.

Fish are categorised into various life cycle groups, depending on their movement between and within freshwater and marine habitats for spawning or growth (Box B2.3). This includes the potamodromous life cycle, involving movement wholly within freshwater (e.g. Rainbowfish) and the diadromous life cycle, where migration occurs between marine and freshwater habitats. The diadromous group includes catadromous – migrating downstream to spawn at sea, while growing in fresh water (e.g. Barramundi); and anadromous – migrating upstream to freshwater spawning grounds, growing mostly in saline waters (e.g. Salmon). Another group (amphidromous life cycle) includes species migrating between marine and freshwater environments (or vice versa) at some stage in their life cycle but not for the purpose of reproduction (e.g. Mullet).

Fish life cycles can be shown graphically (Box B2.3) in terms of migrations between spawning and growth habitat zones situated within the various stream zones (upland / headwater; intermediate / transfer; lowland / floodplain / freshwater wetland; estuary / coastal / tidal wetland). Anadromous species (e.g. Salmon) have downstream growth habitats in marine waters, and move upstream as adults to spawning habitats in freshwater stream zones. Juveniles disperse downstream to marine growth habitats, and adults too disperse downstream after spawning. The catadromous species (e.g. Barramundi) follow opposite movement patterns, with downstream spawning migrations by adults to marine waters, and upstream juvenile dispersal migrations to freshwater growth habitats. Potamodromous species (e.g. Sooty grunter), which move completely within freshwater systems, will follow either an upstream or a downstream migration pattern as adults to spawning habitats, with juveniles dispersing either downstream or upstream to growth habitats, depending on the particular species.

Catadromous life cycles are common in fish communities in Australia's coastal fringe river systems, where adult fish of moderate body size pass downstream to spawn and juveniles travel upstream for growth (Harris 2001). Weakly swimming early life stage catadromous fish are less able to negotiate barriers to upstream movement than adult stage anadromous species, which predominate in the Northern Hemisphere. Many headwater spawning (potamodromous and anadromous) species in Australia (e.g. Plotosid Catfish), although having the advantage of upstream migration as adults rather than juveniles, also lack the swimming capabilities of Northern Hemisphere species (e.g. Salmon). Furthermore, some of these species rely on intermittent rather than perennial streams for spawning, and are therefore very susceptible to barriers because suitable flow conditions exist for only a short period of time.

Alteration to natural fish migration behaviour at road crossings or other waterway structures may affect the fish community in the waterway in many ways, including:

- risk of injury and mortality during passage
- increased metabolic cost of passage under conditions of severe physical demand
- excessive delays in migration leading to

- concentration of fish downstream of obstruction leading to starvation, disease, and increased predation by other fish or animal prey, particularly for juveniles
- reduced species diversity and abundance
- impact on genetic diversity through isolation

Box B2.3: Fish lifecycles, waterway habitat zones and fish migration

Diadromous	Fishes that regularly migrate between fresh and salt water during a definite period of their life cycle. This includes catadromous and diadromous species.
Catadromous	Fishes that spend most of their life cycle in freshwater and which migrate to the marine environment to reproduce. The opposite is anadromous.
Anadromous	Fishes that spend much of their life in a marine environment and which migrate to freshwater as adults to reproduce. The opposite is catadromous.
Potamodromous	Fishes that make true migrations wholly in freshwater.
Amphidromous	Fishes that migrate between marine and freshwater environments (or vice versa) at some definite stage in their life cycle but not for the purpose of reproduction.

2.3 Fish species diversity, abundance and distribution

General information on the diversity, abundance and distribution of the fish community for the catchment under consideration can typically be obtained from broader scale studies of the catchment and surrounding region, and from related fish species surveys of the waterway or adjoining catchments. Fish community data compiled from these sources gives substantial information on the range of species that can be expected to inhabit waterways within the catchment, but information on the distribution of species along particular waterways is commonly far less detailed. Data from previous catchment studies and other general information on the fish community will commonly be adequate for fish passage assessment, but dedicated fish surveys of the waterway may be required in some instances where more specific information is required in relation to habitat and fauna connectivity issues for particular species or locations.

Information on freshwater fish fauna within Australia and for particular regions can be obtained from several primary references, including:

- Australian freshwater fish: Biology and management (Merrick and Schmida 1984)
- Freshwater fishes of Australia (Allen 1989)
- Field guide to the freshwater fishes of Australia (Allen et al. 2003)
- Freshwater fishes of North-eastern Australia (Pusey et al. 2004)
- Distribution and conservation status of Queensland freshwater fishes (Wager 1993)

3

Generalised interpretation of fish migration zones and fish migration calendars for the various fish movement groupings assists with identifying fish spawning or dispersal movement as adults or juveniles between the various marine and freshwater zones, and their movement during the various seasonal periods. Delineating fish migration zones (spawning / growth habitat) and movement in relation to stream zones (headwater / intermediate / lowland / estuary) allows spatial movement patterns of particular species to be mapped against the location of waterway structures or other features on the stream course in order to assist with fish passage considerations for that location. Similarly, delineation of the fish migration calendar (spawning / growth movement) in relation to seasonal periods (spring / summer / autumn / winter) allows temporal movement patterns of particular species to be mapped against seasonal hydrologic conditions in the stream, including wet season flood flows and low flow conditions.

Box B3.1: Fish movement groups: Life-cycle stage, movement direction, fish maturity and size, waterway habitat zones	
Group C1 - Catadromous species, marine to upland habitats	Fishes migrating downstream as adults from freshwater habitats to spawn in estuarine / marine waters, and migrating upstream as juveniles for growth in lowland to upland freshwater habitats.
Group C2 – Catadromous species, marine to lowland habitats	Fishes migrating downstream as adults from lowland freshwater habitats to spawn in estuarine / marine waters, and migrating upstream as juveniles for growth in lowland freshwater habitats.
Group P1 – Potamodromous species, upland spawning	Fishes migrating upstream as adults from lowland waters to spawn in upland waters, and migrating downstream as juveniles for growth in lowland freshwater habitats.
Group P2 – Potamodromous species, lowland spawning	Fishes migrating downstream as adults from upland waters to spawn in lowland waters, and migrating upstream as juveniles for growth in upland habitats.
Group P3 – Potamodromous species, local spawning, lowland to upland habitats	Fishes spawning and growing in local stream and wetland habitats, with no substantial broad scale spawning migration, but migrating upstream and downstream to other habitats as adults and juveniles.
Group P4 – Potamodromous species, local spawning, lowland habitats	Fishes spawning and growing in local lowland stream and wetland habitats, with no substantial broad scale spawning migration, but migrating to adjacent lowland habitats as adults and juveniles.
Group M1 – Amphidromous (freshwater vagrant) species	Marine fishes spawning and growing in estuarine / marine waters, and migrating to and from estuary and lowland freshwater habitats on an occasional basis, rather than for the purpose of reproduction.

The movement group classification and spatial and temporal movement characterisation are illustrated below for the fish community of the Tully Murray catchment. Fish species lists, movement grouping, and generalised species size and swimming ability data for these fish are presented here and are referred to in Guidelines Part D – Fish Passage Design: Road Corridor Scale. Generalised movement information for the Tully Murray fish community has been synthesised and adapted form various key references on fish community and behaviour characteristics for these species, including Allen et al. (2003), Cotterell (1998), Herbert and Peeters (1995), and Pusey et al. (2004). The applicability of this information to other fish communities in other regions or catchments should be checked before use elsewhere.

Fish species within Group C1 – Catadromous species, marine to upland habitats spawn in estuarine / marine waters and typically grow in lowland to upland freshwater habitats (Box B3.1). Spawning adults migrate downstream from freshwater to marine waters, whilst juveniles and adults disperse upstream from estuary to freshwater habitats after spawning. Generalised temporal information on movement for the fish community of the Tully Murray catchment indicates that adult downstream spawning migration typically occurs in spring to autumn (Nov – May), in association with increased stream flows, temperature and photoperiod. Juvenile upstream dispersal migration typically occurs during summer (Dec – April), particularly during wet season stream flow, whilst adult upstream dispersal migration after spawning typically occurs in association with floods.

In contrast, fish species within Group C2 – Catadromous species, marine to lowland habitats spawn in estuarine / marine waters but typically grow in lowland rather than upland freshwater habitats (Box B3.1). Adult downstream spawning migration, and upstream dispersal migration of juveniles and adults occurs between freshwater and marine waters, but the freshwater range is typically confined to lowland habitats compared with lowland and upland habitats for Group C1. Life stages, migration timing, and cues for movement for the Tully Murray fish community remain much the same in the generalised migration calendars for Group C2 and Group C1, the differences confined to the reduced spatial extent of movement to and from freshwater habitats for Group C2 compared with Group C1.

Potamodromous species Group P1 – Potamodromous species, upland spawning and Group P2 – Potamodromous species, lowland spawning are complementary opposites in terms of upland and lowland locations of spawning and growth zones, and upstream and downstream spawning and dispersal migration directions for adults and juveniles between freshwater habitats (Box B3.1). Group P1 species migrate upstream from lowland waters to spawn, whilst juveniles and adults disperse downstream from upland to lowland freshwater habitats after spawning. For the Tully Murray catchment, adult upstream spawning migration typically occurs during wet season stream flow (Nov – Mar), whilst juvenile and adult downstream dispersal migration after spawning also occur during the wet season stream flow periods (Dec – April). Group P2 species migrate downstream from upland to lowland waters to spawn, whilst juveniles and adults disperse upstream from lowland to upland freshwater habitats after spawning. Adult downstream spawning migration typically occurs in spring and summer (Aug – Mar), associated with increased stream flows, temperature and photoperiod, whilst juvenile and adult upstream dispersal migration after spawning occurs during summer and autumn (Mar – May), often associated with low stream flows.

Potamodromous species Group P3 – Potamodromous species, local spawning, lowland to upland habitats and Group P4 – Potamodromous species, local spawning, lowland habitats are wholly freshwater fish that display no substantial broad scale spawning migration (Box B3.1). Group P3 species typically spawn and grow locally in streams and wetlands from lowland to upland waters, whilst juveniles and adults of some species in this group disperse upstream or downstream to other habitats after spawning. For the Tully Murray catchment, spawning typically occurs in stable low flow conditions in winter, spring and early summer (July – Dec), associated with increased temperature and photoperiod, whilst local juvenile and adult dispersal movement after spawning is often associated with increased stream flows (Mar – May). Group P4 species differ from Group P3 in that spawning and growth is typically restricted to lowland waters only, and juveniles and adults disperse locally within adjacent lowland habitats after spawning. As for Group P4, spawning typically occurs in stable low flow conditions in winter, spring and early summer (July – Dec), associated with increased temperature and photoperiod, and localised dispersal movement after spawning is often associated with increased stream flows (Mar – May).

Group M1 – Amphidromous (freshwater vagrant) species are marine fishes spawning and growing in estuarine / marine waters, and migrating to and from estuary and lowland freshwater habitats on an occasional basis, other than for the purpose of reproduction (Box B3.1). No adult spawning migration to freshwater habitats takes place, whilst juveniles disperse upstream from estuary to lowland waters and adults disperse between estuary and lowland waters in a facultative manner (not obligatory for life cycle of the species). Juvenile and adult dispersal movement between estuary and lowland waters is often associated with increased stream flow.

Box B3.3: Generalised fish movement direction for fish movement groups: Migration nature, movement direction, fish maturity and size, life-cycle stage, and including migration timing and flow for fish species of the Tully Murray catchment (Source: Kapitzke 2006a)

Fish movement group	Upstream movement - obligatory			Downstream movement - obligatory			Localised movement ALS / JLD / ALD / LFM
	Adult spawning AUS	Juvenile dispersal JUD	Adult dispersal AUD	Adult spawning ADS	Juvenile dispersal JDD	Adult dispersal ADD	
Group C1 - Catadromous species, marine to upland habitats		q^{F}	q	q^{F}			
Group C2 – Catadromous species, marine to lowland habitats		q^{F}	q	$q^{L/F}$			
Group P1 – Potamodromous species upland spawning	$q^{L/F}$				q^{F}	q^{F}	
Group P2 – Potamodromous species lowland spawning		$q^{L/F}$	q^{*}	$q^{L/F}$			
[redacted]	(q^{L})	q^{*}	q^{*}				ALS / JLD / ALD $^{L/F}$

[redacted]

3.4 Swim characteristics of fish movement capability groups

Swim characteristics and capabilities of fish attempting to negotiate a barrier at a waterway structure depend on the fish species, fish maturity and size (adult / juvenile), and the swim mode adopted (burst / prolonged / sustained). Only limited information is available about the swim capabilities of particular species of Australian fish to negotiate various hydraulic conditions (velocity, water surface drop, turbulence). Fish swim capabilities can be established from:

- information that may be available in the literature for the particular species
- generalised capabilities related to fish groupings of similar body type, size and maturity
- default relationships between swim speed and body length (or some other surrogate)

A combination of these approaches is outlined here, and estimates of fish swim speeds are presented for illustration using data for the Tully Murray fish community compiled in Section 3.3. The fish swim speed data presented here is based on limited quantitative information, and is a conservatively low estimate of likely fish swim capability for many of the species. The applicability of this information to fish communities in regions or catchments other than for the Tully Murray should be checked before use elsewhere.

The method for establishing generalised swim capabilities for groups of fish uses the fish movement directions and timings for the fish community identified above, and establishes fish movement capability groupings for species within critical movement direction categories. The compilation of fish movement direction and timing data for the fish community (Box B3.5) shows upstream, downstream or localised movement under various flow conditions, and is used in conjunction with the listing of fish movement groups for the fish community (see Box B3.1) to determine those species facing the most adverse upstream movement conditions. In terms of fish movement in a waterway and fish passage past a potential waterway barrier, the most critical fish movement directions identified in Section 3.2 are upstream against the stream flow – adult upstream spawning migration (AUS) and juvenile upstream dispersal migration (JUD).

Information on fish movement capabilities for species moving in these critical directions is extracted from fish movement data available for these species or other species within the fish movement capability group for the fish community. As an illustration for the Tully Murray catchment, the critical information on fish movement capabilities for these movement directions has been extracted from fish movement groups for the Tully Murray fish community, and categorisation of fish movement directions and timings for the fish (see Section 3.3). Swimming ability and other aspects of movement capabilities of this fish community are presented below in terms of flow conditions, migration timing and common length of the fish (Box B3.6).

To assist with categorisation of fish swim speeds to be used for road crossing or other waterway structure design, several fish movement capability groupings can be adopted within the critical fish movement direction categories AUS and JUD. The Tully Murray fish community data (based on Kapitzke 2006a) includes available quantitative and qualitative information on fish movement capabilities for each of the groups (Box B3.6). Movement capability groupings (AUS1, AUS2, JUD1…) are based on families and common length range for the fish species, and may comprise species from several fish movement groups (C1, C2, P1…). For example, Group AUS1 comprises Eel tailed catfish of 15 – 25 cm common adult length, Group JUD6 comprises a number of similar species (Cardinalfishes / Glass perchlets / Gobies / Gudgeon) less than 10 cm common adult length, and Group JUD3 comprises Flagtails / Herring of 20 - 25 cm common adult length.

Box B3.6: Fish movement capability groupingMurr8 rf 16.commun008

Box B3.7: Nominal fish swim speeds for Tully-Murray fish community – upstream movement[1] (Source: Kapitzke 2006a)

Fish movement capability group	Common length of fish	Prolonged speed – nominal (20 sec to 200 min duration)	Burst speed – nominal (5 sec to 20 sec duration)	Comment
AUS – Adult upstream spawning migration (fish movement groups P1, P3)				
Medium size fish species – adults				
Group AUS1 – Eel-tailed Catfish	adults 15 cm - 25 cm	0.45 m/s to 0.75 m/s	0.9 m/s to 1.5 m/s	3 BL/s used for prolonged swim speed (default value) 2 x prolonged speed used for burst swim speed (notional value)
Group AUS2 – Grunters	adults 15 cm - 25 cm			
Small size fish species – adults				
Group AUS3 – Rainbowfish	adults < 10 cm	0.25 m/s	0.5 m/s	3 BL/s used for prolonged swim speed (default value) 2 x prolonged speed used for burst swim speed (notional value)
JUD – Juvenile upstream dispersal migration (fish movement groups C1, C2, P2, P3, P4)				
Medium - large size fish species – juveniles				
Group JUD1 – Eels	adults 60 cm - 100 cm (juveniles to 30 cm)	0.3 m/s to 1.0 m/s	up to 1.4 m/s	prolonged and burst swim speeds based on data for juvenile eels, barramundi and jungle perch (see Box 3.6)
Group JUD2 – Giant Herring / Sea bass	adults 50 cm - 120 cm (juveniles to 30 cm)			
Group JUD3 – Flagtails / Herring	adults 20 cm - 25 cm (juveniles to 10 cm)			
Small size fish species – juveniles				
Group JUD4 – Hardyheads / misc. species	adults < 20 cm (juveniles to 10 cm)	0.1 m/s to 0.3 m/s	0.2 m/s to 0.6 m/s	3 BL/s used for prolonged swim speed (default value) 2 x prolonged speed used for burst swim speed (notional value)
Group JUD5 – Gobies / Grunters / Gudgeons	adults 10 cm - 20 cm (juveniles to 10 cm)			
Group JUD6 – Cardinalfishes / Glass perchlets / Gobies / Gudgeon	adults < 10 cm (juveniles to 5 cm)			
Notes	1 The fish swim speed data presented here is based on limited quantitative information, and is a conservatively low estimate of likely fish swim capability for many of the species			

fauna connectivity / fish passage goals adopted for the project. At the conservative end of the scale, fish passage facilities would aim to provide for 100 % effectiveness in passage for the complete native fish community over the full range of flow conditions for which fish passage is available in the natural waterway condition. A more restrictive approach with reduced fish passage effectiveness would aim to provide passage for a reduced diversity of fish species, life stage and maturity, and / or a reduced range of flow conditions. This would overcome a total fish migration barrier at the crossing, but would retain partial or temporal barrier status.

The adopted fish passage effectiveness and design criteria for particular waterway structures

condition relates to the limiting flow stimulating fish movement between habitat areas, and providing low flow connectivity within waterway channels. Maximum and minimum design flow conditions are also constrained by practical limitations in configuration of fishways to effectively provide fish passage at the structure.

A variety of methods are used internationally and within Australia for defining the range of fish passage design flows for waterway structures, but these are generally not directly transferable to fish passage design for road crossings or other waterway structures in Queensland. In northern America, where fish passage requirements have historically been focussed on providing for migration of strong-swimming salmon to upstream spawning habitats, relationships between biological and hydrological variables were examined to establish the characteristic stream discharge that would produce an acceptable delay in migration for particular species. In Canada, the three-day 10-year ARI discharge is used, which corresponds to the stream discharge that is exceeded for no more than 3 days in the 10 year ARI flood.

The technique for defining fish passage design flow for weirs in southern Australian streams provides for fishway operation for 95% of flow until drown-out of the weir (Mallen-Cooper 2000). Although meaningful for large rivers with slowly rising and falling flow conditions, this approach is not applicable to Queensland waterways where highly variable streamflow characteristics may mean that fishways operating for 5% of time may miss a substantial period of flow in some waterways, and are unlikely to encompass short duration flow events or intermittent stream flow conditions that represent a limited window of time for fish passage.

4.3 Design swim speeds and other fish movement characteristics

Swimming performance and movement behaviour in response to flow are key elements governing fish passage. Swimming capabilities vary with fish species and swimming mode, and with body morphology, fish length, water temperature and other variables. Australian freshwater fish species migrate mostly in response to flow stimulation, and they are relatively poor swimmers compared with northern hemisphere species. They have poor jumping abilities to overcome water surface drops and they are readily obstructed by rapids and small waterfalls. Many Australian fish move upstream as juveniles, thereby making passage through waterway barriers more difficult as they attempt to combat difficult flow conditions.

Fish swim speed data are commonly established from eco-hydraulics flumes where fish move in a non-volitional manner under controlled flow conditions. This often underestimates swim behaviour in a stream or through a waterway structure in the field, where fish move in a volitional manner in response to flow or other triggers. Most published data on swimming ability of fish relates to species from the northern hemisphere, and data on swim speed, jumping ability, minimum water depth requirements, and tolerance to turbulence are lacking for most Australian native fish species. With the exception of barramundi, golden perch, Australian bass, silver perch, sooty grunter and sea mullet, the available swim speed data often relates to sustained speeds with little known about burst speeds and endurance levels (Hajkowicz and Kerby 1992).

The design swim speed for the waterway structure should be based on the swim capabilities of the target fish species under the relevant swim mode (burst or prolonged swimming). Fish swim speed information such as that presented for the Murray fish community (Box B3.7), or other more specific data for particular species, life cycle stage and maturity can be used where available. An envelope is usually applied to the fish swimming capabilities for the various groups of fish species, life stages and maturity and for the particular swimming modes. Closer examination of design criteria and selection of priority species for passage may be warranted at particular structures and for particular situations.

For a conservative approach where no other swim speed data are available, the criteria suggested by Cotterell (1998) is to use a prolonged swim speed of 0.3 m/s or less to allow for migration of all native species. Mallen-Cooper (2001) advocates a default prolonged swimming speed value of 3 body lengths (length of fish) per second (BL/s), with design swim speeds of 0.15 m/s for fish less than 80 mm in length, and 0.75 m/s for fish greater than 250 mm in length.

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