CLARE WEIR

FISH PASSAGE STUDY

PRE-CONSTRUCTION REPORT

MAY 2001

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"It will be interesting to note the effect of the new Clare Weir on barramundi numbers"

S.H. Midgley 1977

TABLE OF CONTENTS

Introduction

Background

The potential for rehabilitating fish passage at Clare Weir was raised in 1995 at a regional level by the then Department of Primary Industries, Resource Management Group (now Department of Natural Resources). At this time advice was sought from DPI fisheries biologists and the Fishway Co-ordinating Committee and it was agreed to hold a site inspection and discussion by an expert panel of fisheries biologists, engineers and resource managers. The expert panel identified the need for data on fish movement requirements at the weir and it was agreed that this data should be collected. At the same time as further fisheries data was being collected, a paper on engineering design options and costing was also prepared and together these were expanded to form a feasibility study.

The Fishway Co-ordinating Committee considered information and recommendations from this study in 1997. The committee determined that further fisheries data was needed, which included fish movements on varying flows and the necessary operating range of the fishway, the confounding effects of downstream barriers on fish movement up to the weir and the location and number of entrances the fishway required. Consequently, a decision on the fishway design was deferred until this information became available.

When funding was secured for the statewide Fish Communities and Fishway Monitoring Project by DNR and DPI in September 1997, collection of data on fish movement in the Burdekin System and fish accumulations at Clare Weir was identified as a priority area for the Northern Fishway Team.

This course of action has evolved further into the pre-construction fishway design process. As part of this process, Sunwater (the latest incarnation of the body charged with building the fishway) have contracted the Department of Primary Industries, Queensland Fisheries Service to provide information on fish communities of the Burdekin River and the effect that Clare Weir has had on these communities. This information is provided to Sunwater to ensure that an appropriate fishway is built on Clare Weir.

The DPI Northern Fish Community and Fishway Monitoring Team have undertaken a literature review of all available information on fish communities of the Burdekin River. Anecdotal evidenced suggested that Clare Weir has had a deleterious effect on the fish communities of the Burdekin River, with anglers complaining of large declines of certain species above the weir (Pers. Comm. Burdekin Fish Stocking Association (BRFSA)). Short-term broad-based fish community sampling was also undertaken, to complement the literature review, as there is a definite lack of information concerning the freshwater fish communities of the Burdekin River. Information has been collated on life cycles and specific migration requirements of fish found in the Burdekin River, to help determine the type, location and operational characteristics of any fishway built at Clare Weir. In addition to the literature review and broad-scale fish community sampling, targeted sampling was undertaken below Clare Weir to identify zones of fish aggregation under various flow conditions.

This data, together with information regarding stream hydrology and current weir design, allows recommendations for fishway design and operating requirements. This design takes into account that the weir is an existing structure and that this is a retrofitting exercise. Hence, such options for the siting and operation of the fishway are restricted and may be less than optimal.

Burdekin River

The Burdekin River catchment is the second largest coastal catchment in Queensland, covering an area of 129,860km^2 (Figure 2). The basin stretches from Alpha in the south, 600km northwards to the Valley of Lagoons, inland from Ingham.

The main channel of the Burdekin River originates in the Great Dividing Range north of the Valley of Lagoons, from where it meanders southwards to Charters Towers, east through Burdekin Falls Dam and then north to Ayr where it enters the Coral Sea in Upstart Bay. A major sub-system of the Burdekin River, the Belyando/Suttor River System, brings water from the south and west into the Burdekin River upstream from Burdekin Falls Dam.

The basin is located inland from the coastal escarpment, with the majority of the catchment situated in the Central Highlands. Only a relatively small portion of the catchment is located on the coastal plain, where an extensive flood plain and delta system has formed (Figure 1).

Figure 1. The lower Burdekin River traverses the extensive cane fields of the coastal plain.

The Burdekin River basin has a generally sub-humid tropical savannah climate, with some of the driest conditions in tropical North Queensland (Fleming 1981). Normally, the coastal areas have between 800 and 1000mm of rain per year, mostly concentrated within the period of the wet season. The upper reaches of the system have greatly reduced rainfall from the coastal areas with less than 700mm received throughout the year (Fleming 1981).

Throughout the catchment, evaporation rates far exceed annual rainfall and consequently, streams of the Burdekin system have highly variable flows (Fleming 1981). As an example, in April 1958, the Burdekin River had a peak discharge of 3,096,000Ml/day at Clare Weir; this is the highest recorded flow within this system. Contrasting to this, just seven months later the river ceased to flow. The lower Burdekin River ceases to flow on average once every 2 years, usually in the period from October to November. Other streams in the system have been known to run dry for a number of years.

Along the main channel of the Burdekin River there are a number of barriers to fish migration. These include weirs, dams and temporary sand dams. In the lower Burdekin River sand dams are pushed into place across the riverbed each dry season to impound water for irrigation. These structures are washed away by the first floods of the wet season. A number of permanent weirs and dams are also found on the main channel of the Burdekin River, these include:

- The Rocks Weir – a small weir (1.0m) at 40km AMTD, impounding water for irrigation during the dry season (bypassed during the wet season).
- Clare Weir –7.0m high at 50.3km AMTD, used for irrigation supply.
- Blue Valley Weir – 2-3m high at 118km AMTD, largely redundant to current operations.
- Gorge Weir – 6.0m high at 130km AMTD, largely redundant to current operations.
- Burdekin Falls Dam – 32m high at 160km AMTD, water supply for downstream irrigation.
- Charters Towers Weir 6.0m high at 470km AMTD, water supply weir for Charters Towers.

The Bowen and Broken Rivers also have a permanent weir and large dam, these are

- Collinsville Weir – 5.0m high at 210km AMTD, water supply for Collinsville.
- Eungella Dam – 40m high at 350km AMTD, water supply for downstream irrigation.

It should be noted that river regulation has also altered flow conditions within the Burdekin River to the probable detriment of migratory fishes. The Burdekin system has become an increasingly regulated system with the installation of numerous barriers between its upper tributary streams and its confluence with the sea to aid the off take of irrigation water. The impact of altering these flows on the diversity and abundance of migratory fishes may be substantial. As noted by Welcomme (1985), reductions in faunal diversity have often been associated with the regulation of floodplain rivers.

Figure 2. Location of the Burdekin River System in North Central Queensland.

Clare Weir

Completed in 1980, Clare Weir (Figure 3) is located on the main channel of the Burdekin River 50.3km from the estuary and is the second (but most significant) permanent weir upstream from the estuary. The weir is a mass concrete structure 5.2m high and 350m wide, which supports 1.8m high hydraulically operated steel gates. The total capacity of the storage created by this weir is 15,500 Mega litres (Barry 1997). The upper deck of the weir also supports a rail system used by the gantry crane that operates the hydraulic gates. The rail system runs across the weir from the crane storage area at the top of the right-bank to the top of the left bank.

The size of the weir limits the frequency of drown-out and the weir requires a flow of 500,000Ml/day to provide fish passage past the weir. This flow level occurs less than 1.5 percent of the time. Only 100 days in the past 21 years since construction has drown-out allowed for fish passage past the weir.

A submerged orifice pool type fishway (a Northern Hemisphere salmonid design) was constructed at the same time as the weir. This fishway has a slope of 1:10 and falls between each cell of 400mm, consequently velocities of between 1.3m/s and 2.4m/s occur through the orifices (Barry 1997), which are unsuitable for native fish. The design is further compromised as it has a fully enclosed concrete roof, which makes the fishway very dark and difficult to maintain (removal of debris etc.).

Figure 3. Clare Weir, focus of the current study. The existing ineffectual fishway extends from left to right against the bank in the foreground.

In terms of provision of fish passage at Clare Weir, it is apparent that the design of the existing fishway installation is flawed. Barry (1997) suggested shortcomings of the existing fishway included unacceptably high velocities within the fishway, turbulence at the entrance during certain flows, dark and covered conditions within the structure and siltation after high flows. In view of this overall ineffectiveness, it is highly probable that the existing fishway structure would have little impact in reducing the negative impacts that Clare Weir is causing on migratory fishes in the Burdekin River. Seasonal flooding causing total drowning of the weir is the only other feasible opportunity for upstream fish migration. However, as outlined by Gehrke (1995), the effectiveness of drowning weirs in restoring riverine connectivity is very limited due to the lower frequency and shorter duration of floods, and high velocities associated with flooding. Furthermore, ability to negotiate barriers at peak flows may be limited to a very select suite of fish species.

Previous Fisheries Studies

The first recorded fish community study in the Burdekin River System was conducted by S.H. Midgley in 1977 (Midgley 1977). This broad-scale survey concentrated on the general fish communities of the Upper Burdekin River system, with only one site on the Burdekin River below Burdekin Falls Dam. This site was located downstream from the Gorge Weir at AMTD 128km. James Cook University has conducted a number of studies throughout the catchment. They include a study of the fish communities of the Burdekin River, conducted from 1989-1992. This study again only had one site in the lower Burdekin River, a site near Dalbeg (Pusey et. al. 1998). Although these studies have identified species of fish found at these sites they have produced little information as to the impacts of Clare Weir on the fish communities of the Burdekin River System.

Between 1995 and 1997, DPI undertook sampling at four sites in and below Clare Weir to determine when and under what conditions fish passage would be required at Clare Weir (Hogan et al 1997). This study also made recommendation on the location of the fishway entrance, based on aggregations of fish downstream of the weir. After considering the data from this sampling, the Fishway Co-ordinating Committee requested the collection of additional data on fish movement, fish aggregation and differences between fish communities up and downstream of Clare Weir which has led to the existing study.

Fish Species of the Burdekin River

40 species of fish have been identified from the freshwater reaches of the Burdekin River (Table 2) (Midgley 1977, Hogan *et al*. 1997, Pusey *et al*. 1998), of which 28 species were captured during this study. The number of species present is low by world standards (Bishop and Forbes 1991, Pusey et. al. 1998), but is consistent with species richness in other eastern Australian sub-tropical rivers (Pusey *et al*. 1998). Species found in the Burdekin River include two endemic species: one species of neosilurid catfish (*Neosilurus mollespiculum*) (Allen and Feinberg 1998) and the small-headed grunter (*Scortum parviceps*) (Merrick and Schmida 1984). Barramundi populations in the Burdekin Basin are from one of seven genetically distinct stocks throughout Queensland (Shaklee *et al*. 1993).

At least 24 known migratory fish species require passage past Clare Weir (Table 2). The size range of these fish varies greatly. Adults of a number of larger fish species found in this system, including bull shark (Figure 4), barramundi (Figure 5), sleepy cod, fork-tailed catfish, striped mullet, oxeye herring, freshwater longtom and long-finned eels, have been recorded migrating in other river systems (Stuart and Berghuis 1997). These species range in size from 35 cm to 200 cm. Small fish in the Burdekin that are known to migrate include olive perchlet, bony bream, rainbowfish and empire gudgeons which can be as small as 10mm when they are migrating, but mostly range from 20-150mm long (Stuart 1999). Juveniles of many species also migrate, with juvenile phases of species such as mullet, barramundi, mangrove jack, sooty grunter, olive perchlets and eels migrating varying distance upstream to access freshwater habitats. These juvenile fish are particularly vulnerable as they have a greatly reduced swimming ability and are unable to negotiate even small barriers.

Stocking of fish has also occurred in the system, due to the perceived decline in fish numbers in the Burdekin River, especially in the waters above Clare Weir. Barramundi are the main species to have been stocked into the Burdekin River system, as they are a highly prized angling species that are greatly affected by barriers to migration. Stocking has occurred in two areas below Burdekin Falls Dam as well as within the waters of the dam (Table 1). These stocking have been undertaken since 1988, when the first stocking of barramundi into the waters of Clare Weir occurred. In total 592,924 barramundi have been stocked into the system as part of the DPI stocking program.

Table 1 Barramundi stockings in the Burdekin River System, 1988 – 2001 (DPI Stocking database).

Year	Clare Weir	Bowen River Weir	Burdekin Falls Dam
1988/1989	6000		
1989/1990	400		
1990/1991	48 000		15 000
1991/1992	90 000		60 000
1992/1993			
1993/1994			
1994/1995			45 000
1995/1996	1 000		20 000
1996/1997			99 000
1997/1998	3 000		100 000
1998/1999	25524	40 000	
1999/2000		16 000	
2000/2001		24 000	
Total	**173 924**	**80 000**	**339 000**

Table 2 Migration patterns of the freshwater fish of the Burdekin River, Queensland, adapted from Allen 1989, Merrick and Schmida 1984, McDowall 1996, ASFB 1999 and Stuart 1999.

SPECIES	Seasonal Movements				Flows		
DIADROMOUS	Sum.	Aut.	Win.	Spr.	Low	Mod.	High
long-finned eel *Anguilla reinhardtii* [Anguillidae] ©	✔	✔	✓	✔	✓	✓	✔
South-Pacific eel *Anguilla obscura* [Anguillidae] ©	✔	?	?	✔	✓	✓	✔
bullrout *Notesthes robusta* [Scorpaenidae]	✓		✔	✔	✔	✓	
barramundi *Lates calcarifer* [Centropomidae] ©®	✔	✓	✓	✔	✔	✓	
bull shark *Carcharhinus leucas* [Carcharhinidae] ®	?	?	?	?	?	?	?
mangrove jack *Lutjanus argentimaculatus* [lutjanidae] ®	✓	✓	?	?	✓	?	?
fork-tailed catfish *Arius graeffei* [Ariidae] ®	✔	✔	✔	✔	✔	✔	✔
salmon catfish *Arius leptaspis* [Ariidae] ®	✔	✔	✔	✔	✔	✔	✔
striped mullet *Mugil cephalus* [Mugilidae] ©®	✔	✓	✔	✔	✔	✔	✓
oxeye herring *Megalops cyprinoids* [Megalopidae] ®	✓	✔	✓	✓	✔	✓	?
freshwater longtom *Strongylura kreftii* [Belonidae]	✓	✓		?	✓	✓	?
striped butterfish *Selenotoca multifasciata* [Scatophagidae]	?	?	?	?	?	?	?
dusky flathead *Platycephalus fuscus* [Platycephalidae]	?	?	?	?	?	?	?
threadfin silverbiddy *Gerres filamentosus* [Gerreidae]	?	?	?	?	?	?	?
silverbiddy *Gerres subfasciatus* [Gerreidae]	?	?	?	?	?	?	?
giant herring *Elops hawaiiensis* [Elopidae]	?	?	?	?	?	?	?
snub-nosed garfish *Arrhamphus sclerolepis* [Hemirhamphidae] ®	?	?	?	?	?	?	?
POTAMODROMOUS							
spangled perch *Leiopotherapon unicolour* [Teraponidae]	✔	✓	✓	✔	✔	✔	✔
sooty grunter *Hephaestus fuliginosus* [Teraponidae] ®	✓	✓	✓	✓	✓	✓	✓
banded grunter *Amniataba percoids* [Teraponidae]	✓		✓	✓	✓	✓	?
small-headed grunter *Scortum parviceps* [Teraponidae]	✓	✓	✓	✓	?	?	✔
golden perch *Macquaria ambigua* [Percichthyidae] ®✈	✔	✓	✓	✔	✔	✔	✓
bony herring *Nematalosa erebi* [Clupiedae]	✔	✔	✔	✔	✓	✔	✓
fly-specked hardyhead *Craterocephalus stercusmuscarum Stercusmuscarum* [Atheridae]	✓		✓	✔	✓	✓	

SPECIES POTAMODROMOUS Cont.	Seasonal Movements				Flows		
	Sum.	Aut.	Win.	Spr.	Low	Mod.	High
olive perchlet *Ambassis agassizi* [Chandidae]	✓	✔	✔	✔	✔	✔	
Rendahl's catfish *Porochilus rendahli* [Plotosidae] ®	✔	?	?	✔	?	?	✔
Hyrtl's tandan *Neosilurus hyrtlii* [Plotosidae] ®	✔	?	?	✔	?	?	✔
black catfish *Neosilurus ater* [Plotosidae] ®	✔	?	?	✔	?	?	✔
soft-spined catfish *Neosilurus mollespiculum* [Plotosidae] ®	✔	?	?	✔	?	?	✔
mouth almighty *Glossamia aprion* [Apogonidae]	✓	✓	✓	✓	✓	✓	
Eastern rainbowfish *Melanotaenia splendida splendida* [Melanotaeniidae]	✓	✓	✓	✔	✓	✔	✓
firetail gudgeon *Hypseleotris gallii* [Eleotridae]	✔	?	?	✔	?	?	✔
sleepy cod *Oxyeleotris lineolatus* [Eleotridae] ®	✔	?	?	?	?	✓	?
snakehead gudgeon *Ophieleotris aporos* [Eleotridae]	?	?	?	?	?	?	?
empire gudgeon *Hypseleotris compressa* [Eleotridae]	✔	✔	✔	✔	✔	✔	✔
purple-spotted gudgeon *Mogurnda adspersa* [Eleotridae]	?	?	?	?	?	?	?
Pacific blue-eye *Pseudomugil signifer* [Pseudomugilidae]	?	?	?	?	?	?	?
eel-tail catfish *Tandanus tandanus* [Plotosidae] ®	?	?	?	?	?	?	?
archerfish *Toxotes chatareus* [Toxotidae] ®	✓	?	?	✓	?	✓	?
mosquito fish *Gambusia Holbrooki* [Poeciliidae] ✈	?	?	?	?	?	?	?

© - Commercial Species, ® - Recreational Species, ✈ - Translocated Species

✔ - Large numbers of fish, ✓ - Small numbers of fish, ?- Limited Information

Figure 4. Bull shark (*Carcharhinus leucas*) captured 1km downstream of Clare Weir during sampling for this study.

Figure 5. Barramundi (*Lates calcarifer*) similar to those captured directly downstream of Clare Weir during sampling for this study.

Effects of Clare Weir on Fish Communities of the Burdekin River

Introduction

In 1997, the Fishway Co-ordinating Committee identified the effects of Clare Weir on the distribution of fish within the Burdekin River system as an area requiring further study. Since construction of Clare Weir and fishway in 1980, recreational anglers have made many complaints that fish numbers above the weir, especially barramundi numbers, have declined significantly. This study aimed to survey fish communities of the main riverine corridor of the Burdekin River, both upstream and downstream of Clare Weir, to establish whether construction of the weir has impacted on those fish communities.

Methods

Fish community surveys were conducted between July 1999 and December 1999 within the main channel of the Burdekin River. A total of seven sample sites were chosen between Home Hill and Burdekin Falls Dam. Specific locations and sample dates are shown in Figure 6 and Table 3. The sampling methods employed in this study were designed to ascertain all migratory fish species present and their relative size distributions at each site.

Electrofishing was the only sampling method employed in this study and was conducted on a 5.6 m vessel equipped with a Smith-Root 7.5 GPP electrofisher unit, two boom arms with 16 dropper anode arrays and hull cathode. Two dip-netters were employed during all sampling activities.

Sampling was conducted during daylight hours and standardised by fishing time (ten 2-minute ‘shots’ employing a power on - power off technique to avoid fish herding effects). Sampling encompassed all possible habitat types at each site in order to maximise the number of species represented in the catch.

All fish captured during electrofisher surveys were identified to species level, counted, measured to the nearest millimetre and released. Fork length was recorded for forked-tail species and total length for all other species. When more than 50 individuals of a single species were encountered in any single shot, randomised sub-samples of 50 fish were measured and the remainder counted. Fish observed as affected by the electric field and positively identified but not captured were recorded and have been included in abundance analyses.

Results

Pooled sampling of all sites during this study identified 3831 individuals of 28 species and 27 genera of fishes. Species captured and total numbers of fish for each species and site are provided in Table 3. Downstream of Clare Weir, 23 species of fishes were captured at sites 1 to 4 for a total catch of 3620 individuals. Upstream of Clare Weir, 14 species of fishes were captured at sites 5 to 7 for a total catch of 211 individuals.

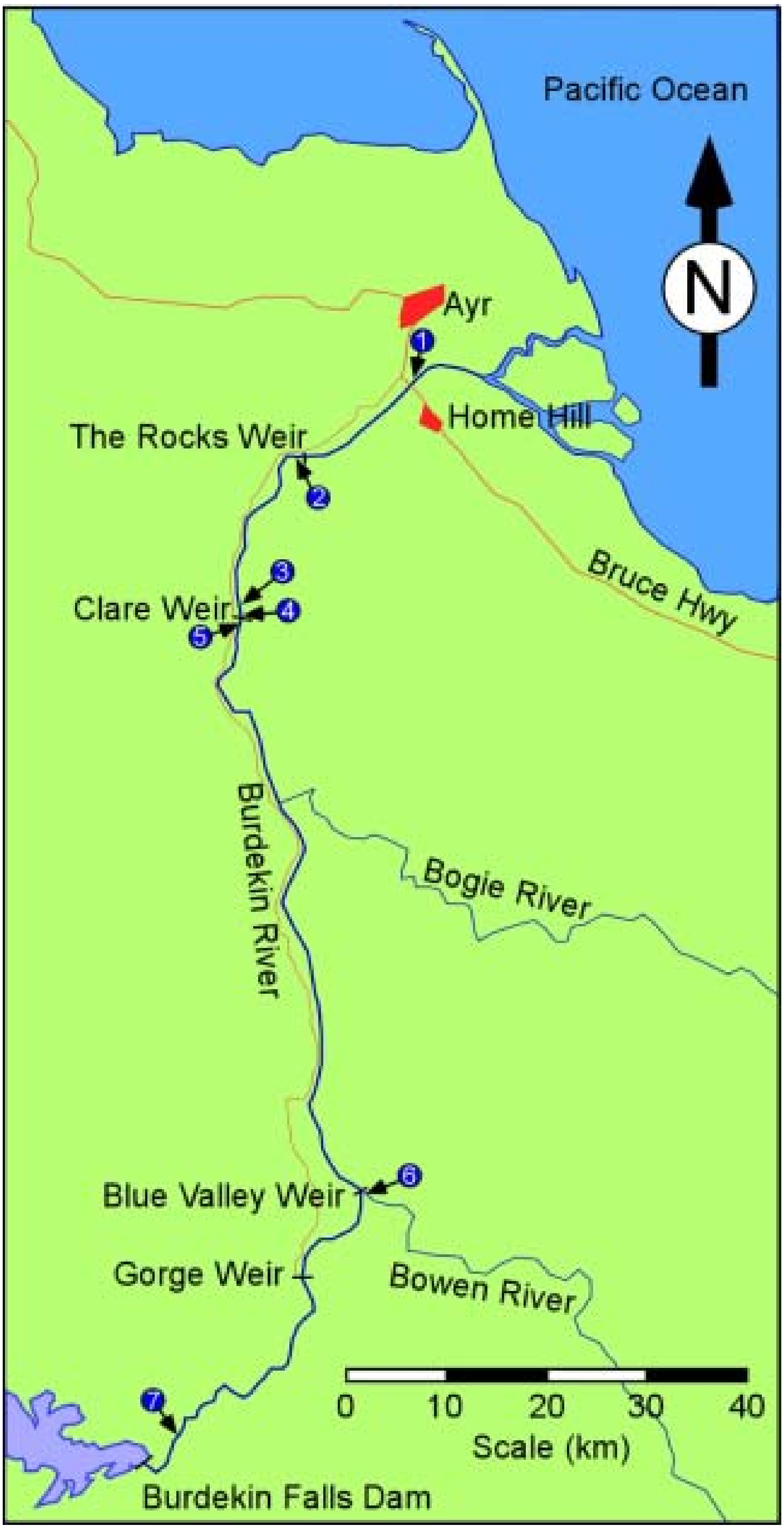

Figure 6. Sampling site locations along the Burdekin River, upstream and downstream of Clare Weir.

Table 3. Total numbers of fish of all species captured during fish community sampling at seven sites on the Burdekin River, 1999/2000.

Sites Sampled	**Below Clare**-July and December 1999				**Above Clare**-July 1999			
	1	**2**	**3**	**4**	**5**	**6**	**7**	
Species Name	Home Hill	The Rocks	1km D/S Clare Weir	Directly D/S Clare Weir	Clare Weir Pool	Blue Valley Weir Pool	5km D/S Burdekin Falls Dam	**Totals**
Ambassis agrammus						3		3
Amniataba percoides						1		1
Anguilla reinhardtii	2	32	1	19	1	1	2	58
Arius graeffei	9	5	4	20			10	48
Arius leptaspis				1				1
Arrhamphus sclerolepis	2			2	1			5
Carcharhinus leucas			1	2				3
Craterocephalus stercusmuscarum st.					1			1
Elops hawaiiensis	2							2
Gerres filamentosus	3							3
Gerres subfasciatus	1	12						13
Hephaestus fuliginosus				15	1		3	19
Hypseleotris compressa	9	20	1	2				32
Lates calcarifer	7	12	23	236		1	2	281
Leiopotherapon unicolor						1		1
Lutjanus argentimaculatus	1			1				2
Megalops cyprinoides		7	4	7				18
Melanotaenia splendida splendida		9	21	4	4	1		39
Mugil cephalus	17	2						19
Nematalosa erebi	176	60	2099	725	23	108	3	3194
Neosilurus ater		1						1
Notesthes robusta			1					1
Oxyeleotris lineolatus		3	2	12	5	8	25	55
Platycephalus fuscus	8							8
Scortum parviceps						2		2
Selenotoca multifasciata	1							1
Strongylura kreffti	2		4	3				9
Toxotes chatareus		2	5				4	11
Total No. of fish	240	165	2166	1049	36	126	49	3831
Total No. of Species	14	12	12	14	7	9	7	

Sampling was dominated by bony herring (*Nematalosa erebi*), which comprised 85% of the pooled catch from sites below Clare Weir and 64% for sites above Clare Weir. Barramundi (*Lates calcarifer*) was the second most abundant species recorded totalling 7.7% of the pooled catch from sites below Clare Weir but only 1.4% for sites above Clare Weir. Sleepy cod (*Oxyeleotris lineolatus*) was the second most abundant species recorded above Clare Weir at 18% of the pooled catch.

There were 11 species of fishes recorded in samples below Clare Weir, including striped mullet (*Mugil cephalus*), ox-eye herring (*Megalops cyprinoides*), empire gudgeon (*Hypseleotris compressa*) and bullrout (*Notesthes robusta*), that were absent from samples above the weir. Potamodromous species that were recorded above Clare Weir but absent from downstream samples included sail-fin perchlet (*Ambassis agrammus*), banded grunter (*Amniataba percoides*), fly-specked hardyhead (*Craterocephalus stercusmuscarum stercusmuscarum*), spangled perch (*Leiopotherapon unicolor*) and small-headed grunter (*Scortum parviceps*).

The total number of species per site is presented in Figure 7. A drop in species diversity occurred at sites above Clare Weir that recorded an average of 7.7 species compared with 13 species for sites below the weir.

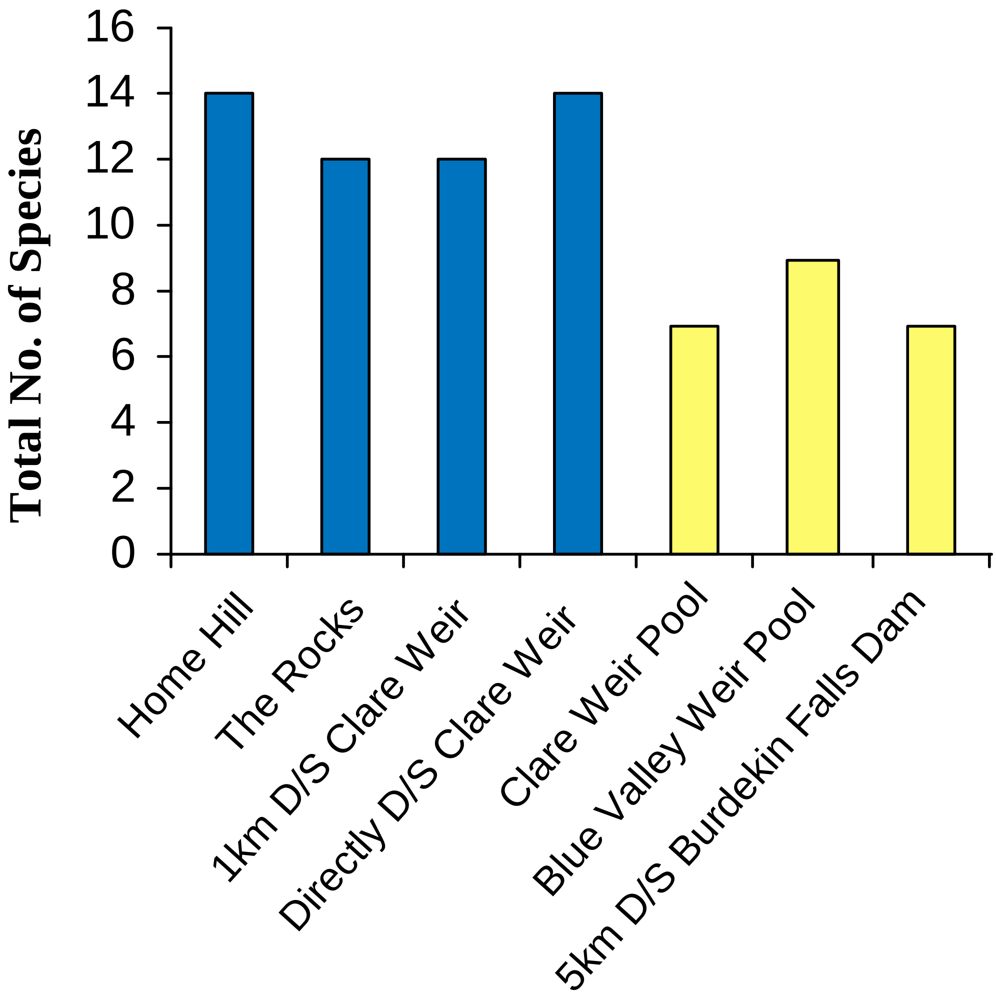

Figure 7. Total number of species per site during fish community sampling on the Burdekin River, 1999/2000.

Catch Per Unit Effort (CPUE) is presented in Figure 8. There was a marked increase in CPUE from Site 1 (Home Hill) moving upstream towards Site 4 (directly downstream of Clare Weir). Site 4 (directly downstream of Clare Weir) and Site 5 (the first site upstream of Clare Weir) represented highest and lowest values of CPUE respectively. A similar pattern for CPUE, with catch increasing up to the base of a barrier, is also evident from Site 5 (Clare Weir pool) to Site 7 (Downstream of Burdekin Falls Dam).

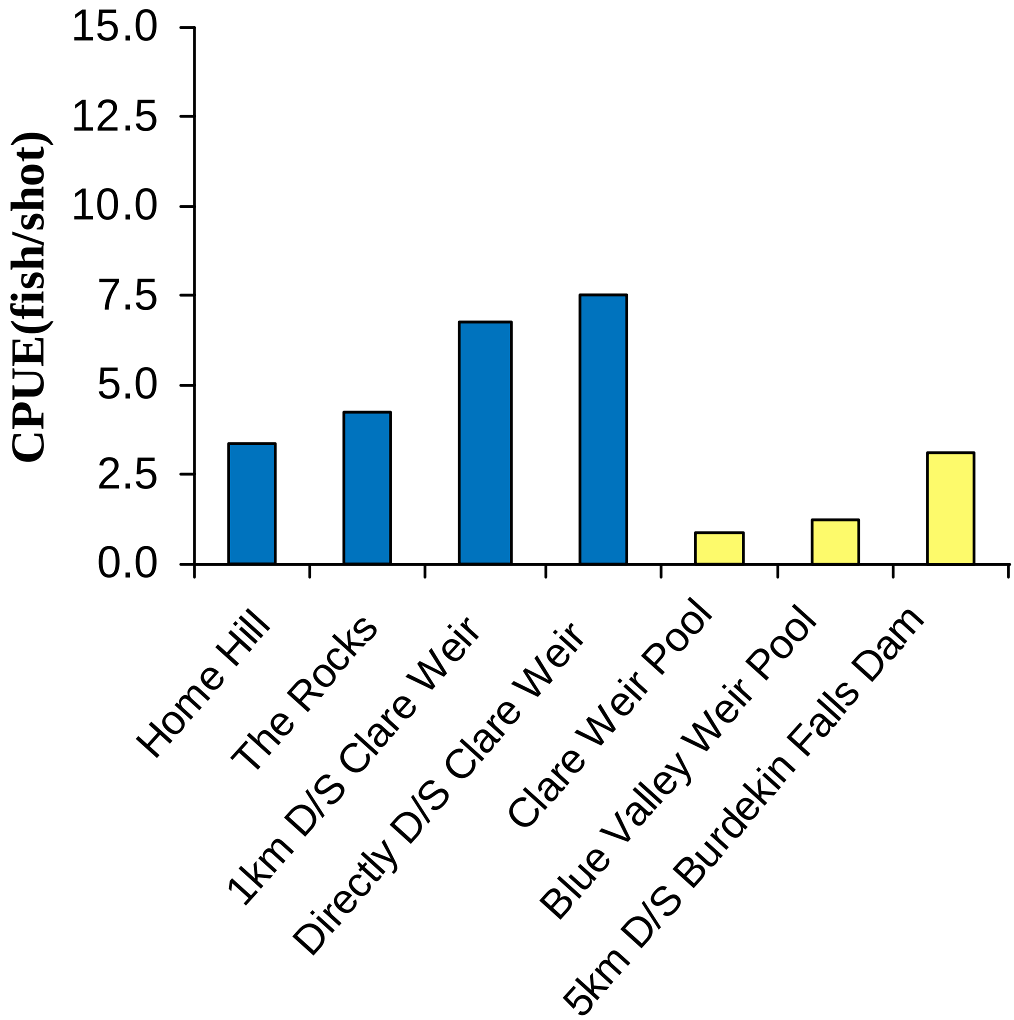

Figure 8. Catch per unit effort (CPUE) for all sites and pooled sample dates during fish community sampling on the Burdekin River, 1999/2000.

CPUE for the six most abundant species sampled is presented in Figure 9. Of these, ox-eye herring and empire gudgeon were not recorded in sampling above Clare Weir. CPUE for barramundi increased upstream from Sites 1 to 4 where an obvious accumulation of fish occurred directly below Clare Weir. Upstream of Clare Weir CPUE dropped dramatically for barramundi, bony herring and long-finned eel with very few individuals captured from Site 5 through to Site 7. Very large captures occurred for bony herring within one kilometre downstream of Clare Weir at Sites 3 and 4. A gradual increase in CPUE was evident for sleepy cod from Site 2 through to Site 6. Peak catches for sleepy cod occurred at Site 7, more than double the CPUE value for all other sites.

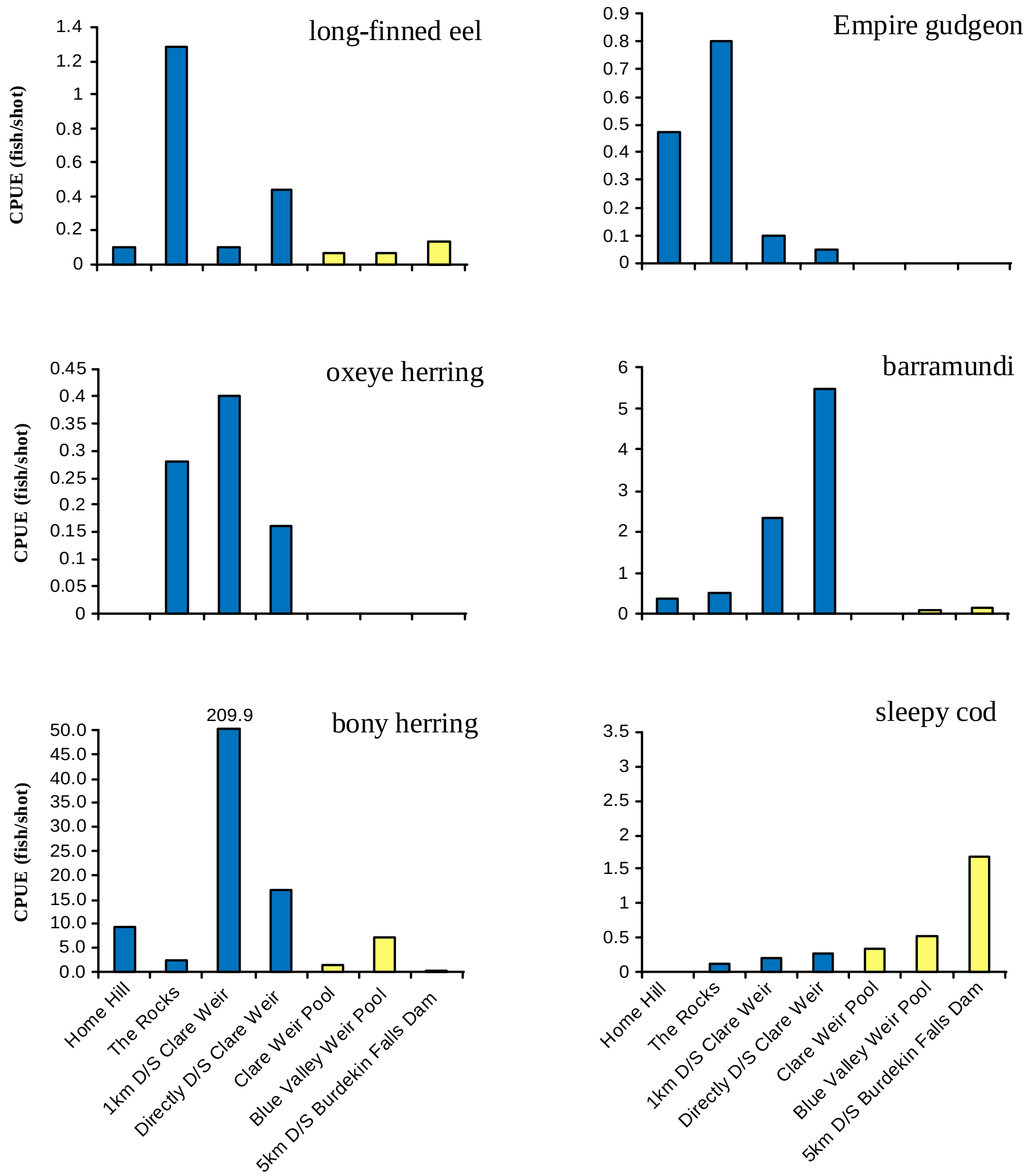

Figure 9. CPUE for individual species for all sites and pooled samples during fish community sampling on the Burdekin River, 1999/2000. Only the most abundant species captured during sampling have been presented

Discussion

Individual Species Diversity and Abundance

The results of this study show that there is a substantial decrease in both the diversity and abundance of freshwater migratory fish species upstream of Clare Weir, whilst large accumulations of potential migrants are present below the weir. The noticeable drop in species diversity above the weir is likely to be a consequence of the barrier effect of Clare Weir on migratory species that are unable to access habitats or maintain populations upstream of the weir. Welcomme (1985) emphasised the tendency of dams and weirs to lower the net fisheries productivity of river ecosystems, and initial increases in fisheries production following dam closure are unlikely to be sustainable. A number of species either no longer occur or are present in very small numbers upstream of Clare Weir. Some of these species include barramundi, eels, striped mullet, ox-eye herring and bullrout.

Catadromous species such the long-finned eel have been negatively affected by the presence of the weir as juveniles of this species are inhibited from migrating upstream when returning to the river after spawning. This species is adept at climbing barriers to migration (Beumer 1996) yet the results indicate fewer eels are utilising upstream habitats in the Burdekin River. Long-finned eels migrate right throughout the catchment of most coastal streams along the East coast of Australia. They are found all the way up into the headwaters of these streams, unless a barrier interrupts their migrations. A suggested reason for reduced numbers of eels upstream of Clare Weir is the existence of the rail lines across the weir-top and the observed difficulty elvers have finding their way over or around these structures (Pers. Comm. Alf Hogan).

The CPUE results for barramundi are also highly significant. A catadromous species, barramundi require passage to salt water for spawning, and access to freshwater for post-spawning, upstream migrations of immature fish. Barramundi are found hundreds of kilometres inland in many other barrier free catchments along the Queensland coast, and have prior to the construction of Clare Weir been recorded upstream to Urannah station (≈250km AMTD) on the Broken River, a tributary of the Bowen River (Midgley 1977). The extremely low catch rates of barramundi above Clare Weir compared to those below (3 out of 281) strongly suggests that the weir is effectively blocking this species from migrating upstream of the weir. It is also likely that the three fish caught above the weir were stocked fish from stockings in either Burdekin Falls Dam or Clare Weir Pool (DPI Stocking data), further indicating that the weir is significantly affecting this species. This barrier has therefore significantly reduced the habitat available to barramundi in the Burdekin River (Figure 10) and has most likely reduced the overall population of barramundi in the river system as is perceived by many anglers (Pers. Comm. BRFSA).

Potadromous species also appear to be affected by Clare weir, even though they do not need to migrate to the sea to breed, populations are affected by the weir that blocks upstream migrations. A prominent potadromous species, bony bream, occurred in high numbers directly below the weir during sampling. This species undertakes significant upstream migrations and with the construction of the weir has now had its migrations disrupted. Accumulations of this species make them vulnerable to predation and disease and separation of fish into upstream and downstream populations may impact on the ability of the species to maintain populations in the isolated reaches. Even though potadromous species are able to maintain populations both upstream and downstream of the weir, they are still affected by the weir in a variety of ways.

Fish Community Characteristics

Changes in overall fish communities are likely to have occurred downstream of the weir, upstream of the storage and within the storage itself as a result of the construction of Clare Weir. This has led to a fundamental change in the fish communities of the river. The reduced numbers of species such as barramundi, eels and oxeye herring evidences reduced predator biomass upstream of the weir. Marsden *et al.* (1997) discusses the consequences of reduced predator biomass at or near the top of the food web suggesting a concomitant increase in the transport of nutrients downstream into the storage, with possible implications for water quality and algal management by water authorities. Below the weir there are increased concentrations of predator and prey species that may be susceptible to predation and disease (Welcomme 1985). Piscivorous birds can exert heavy predatory pressure on concentrated fish communities (Marsden 1997, after Elson 1962) and may be having a significant impact on accumulating fishes below Clare Weir. Although not reported at Clare Weir, disease can also cause extremely high mortalities in riverine fish at times when populations are concentrated in relatively small habitats (Welcomme 1985), such as below dams or weirs. It should also be noted that accumulations of the popular sportfish barramundi, and other target recreational species, below the weir has led to an increased targeting by anglers (pers comm. BRFSA). Another consequence of the construction of the weir is the shift from lentic to lotic habitat conditions within the weir pool. This shift changes the diversity of habitat within this section of the river, increasing open water habitat types and reducing bank habitats favoured by most native fish species (Gehrke et.al 2001). This sampling of fish communities both upstream and downstream of Clare Weir has clearly demonstrated the negative impacts Clare Weir is having on the migratory fish communities of the Burdekin River.

Figure 10. Current and historical distribution of wild barramundi in the lower Burdekin River system.

Fish Passage Requirements at Clare Weir

Introduction

The Fishway Coordinating Committee identified the migratory behaviour and size distribution of native fish at Clare Weir as an area requiring further study in 1997. More data was required on which flows fish are moving on, what size range of fish are migrating and where fish are accumulating below Clare Weir. This data would then be used in determining the appropriate design and location of a fishway.

Methods

Electrofishing surveys were conducted on four occasions between July 1999 and May 2000 directly below Clare Weir. Sampling was conducted on both low (500 - 1500Ml/day) and high (23554 - 66,093Ml/day) flows. The sampling methods used were designed to ascertain migratory fish species present and their relative size distributions.

The 5.6m electrofishing vessel "Discopyge" was used for sampling below Clare Weir on all occasions. This vessel was equipped with a Smith-Root 7.5 GPP electrofisher unit, two boom arms with 16-dropper anode arrays and hull cathode. The electrofisher unit was set to 120pps frequency, 20% duty cycle and between 340V and 500V.

The sampling procedure involved electrofishing all navigable areas below the weir in a set series of discrete zones (Figure 11) that included:

1. A 100m section downstream of the old fishway on the right-bank (red area).

2. Around the entrance to the old fishway (pink area).

3. Along the edge of the flow from over the weir crest and outlet works (orange area).

4. Across the centre of the weir (green area).

5. Adjacent to the weir and left-hand bank (blue area).

One operator controlled the boat while two operators captured fish from the front of the boat. Sampling was conducted during daylight hours and standardised by fishing time (2-minute 'shots' employing a power on - power off technique to avoid fish herding effects). Immobilised fish were netted from the river and transferred to a holding tank to recover until the end of each shot.

All fish captured during electrofishing surveys were identified to species level, counted, measured to the nearest millimetre and released. Fork length was recorded for forked tail species and total length for all other species. When more than 25 individuals of a single species were encountered in any single shot, random sub-samples of 25 fish were measured and the remainder counted. Fish observed as affected by the electric field and positively identified, but not captured, were recorded and have been included in abundance analyses.

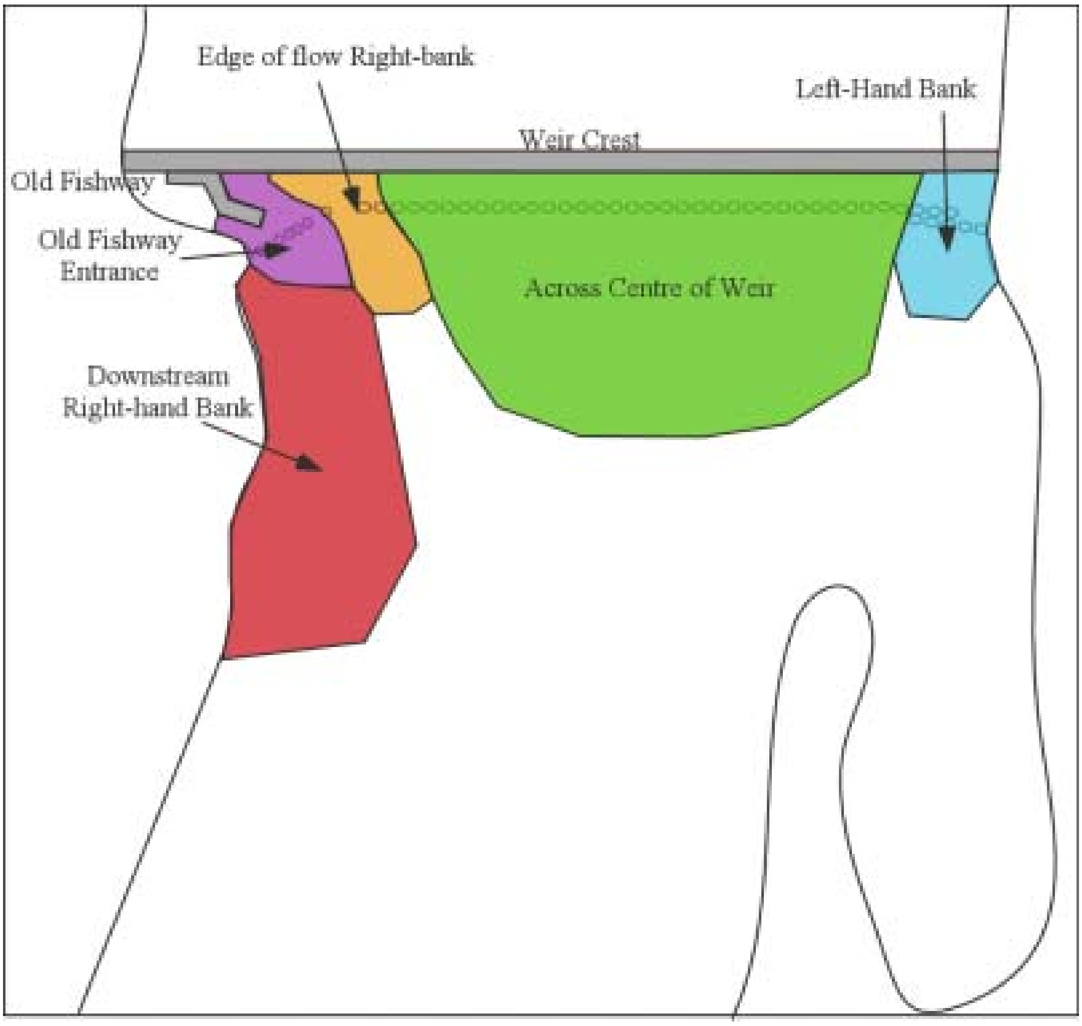

Figure 11. Location of zones sampled below Clare Weir.

<u>Results</u>

Sampling of the five zones below Clare Weir captured 1048 individuals of 14 migratory fish species (Table 4) over four sampling occasions. There were greater concentrations of fish directly below the weir than further downstream. These concentrations were considered to be fish attempting to migrate upstream, beyond Clare Weir. The mean number of fish below the weir remained relatively constant for both low and high flow periods (Figure 12) over the duration of sampling.

Table 4. Total numbers of fish sampled during the zones of accumulation experiment.

Species	**Total no.**
bony bream (*Nematalosa erebi)*	725
barramundi *(Lates calcarifer)*	235
fork-tailed catfish *(Arius graeffei)*	20
long-finned eel *(Anguilla reinhardtii)*	18
sooty grunter *(Hephaestus fuliginosus)*	16

sleepy cod *(Oxyeleotris lineolatus)*	12
oxeye herring *(Megalops cyprinoids)*	7
Eastern rainbowfish (*Melanotaenia splendida splendida)*	4
freshwater longtom *(Strongylura kreftii)*	3
empire gudgeon *(Hypseleotris compressa)*	2
bull shark*(Carcharhinus leucas)*	2
snub-nosed garfish *(Arrhamphus sclerolepis)*	2
mangrove jack *(Lutjanus argentimaculatus)*	1
salmon catfish *(Arius leptaspis)*	1
Total	**1048**

The individual zones with the highest concentration of fish during low flow periods (Figure 13) were site b (the old fishway entrance, 17.38 fish/shot), site e (left-hand bank, 9.67 fish/shot) and site c (edge of flow right-bank, 6.88 fish/shot). Low flow periods showed considerable variation of fish numbers and species between sampling occasions, however fish were most likely to be found close to the weir crest. The only site that had consistent catches between low-flow samples was site a (downstream right-hand bank), which had low catches (2.00 fish/shot) on all sampling occasions.

During high flows (23554 - 66093Ml/day), fish concentration at site e (24.00 fish/shot) on average exceeded that of site b (21.00 fish/shot) (Figure 13). The number of fish at these two sites far exceeded site c. (7.50 fish/shot), while sites a and d had abundances well below all other sites.

The distribution pattern of fish across all sites remained similar from low flows to high flows (Figure 13). There was an overall increase in abundance between low and high flows at site b (16.75 to 21.00 fish/shot), site e (9.67 to 24.00 fish/shot), site a (2.00 to 5.50 fish/shot) and site c (6.88 to 7.50 fish/shot) sites. Site d was the only site to demonstrated a declined between low flows and high flows (5.17 to 0.75 fish/shot) due to the increased turbulence in this area.

The size distribution of fish collected below Clare Weir varied from 21mm empire gudgeons to 1200mm long-finned eels with a range of other species and sizes between these extremes. Length frequency histograms were plotted for the most numerous species, barramundi (Figure 14) and bony bream (Figure 15). No other species were captured in significant enough numbers to analyse length data. Barramundi demonstrated a typical length frequency, with fish ranging in size from 150mm to 900mm. The most common size that barramundi occurred below the weir was around 450mm to 600mm. The length frequency of bony bream showed two distinct size classes of fish, with small fish from 20-100mm long and large fish from 250mm to 325mm long, possibly indicating two year classes of this species.

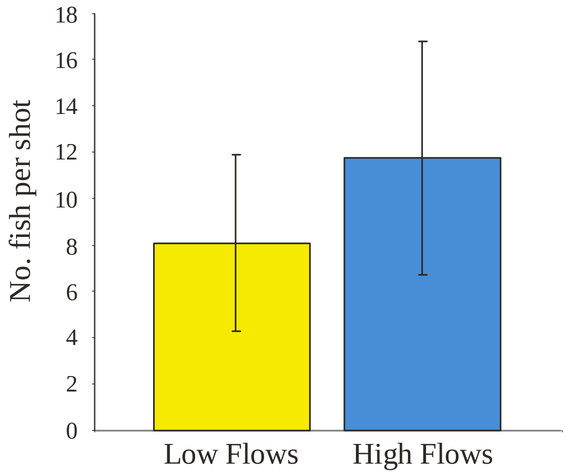

Figure 12. Mean number of fish caught from all sites below Clare Weir during high and low flows.

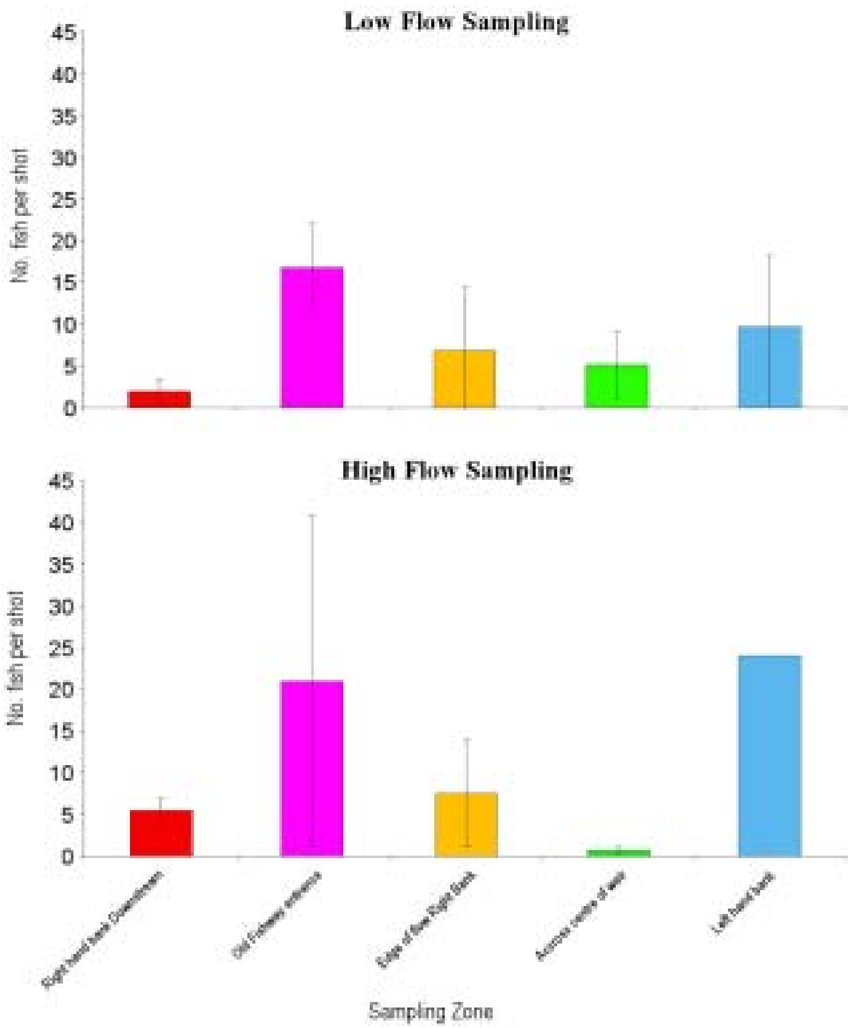

Figure 13. The number of fish sampled per shot for site a (downstream right hand bank), site b (old fishway entrance), site c (edge of flow right bank), site d across the centre of weir) and site e (left hand bank) during low and high flow sampling below Clare Weir, 1999/2000 (See Figure 11 for location of zones).

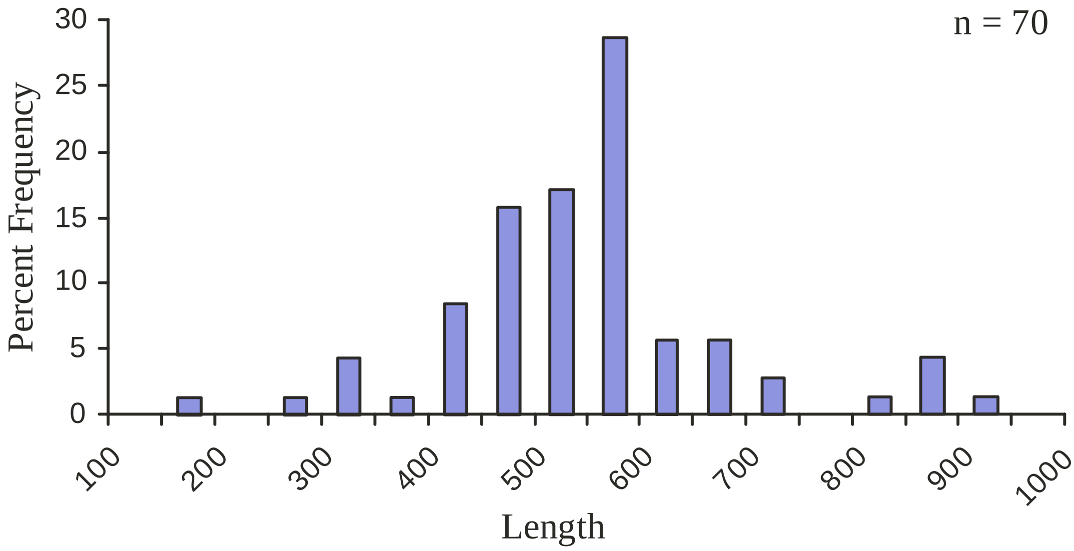

Figure 14. Length frequency of barramundi captured below Clare Weir during zones of accumulation sampling.

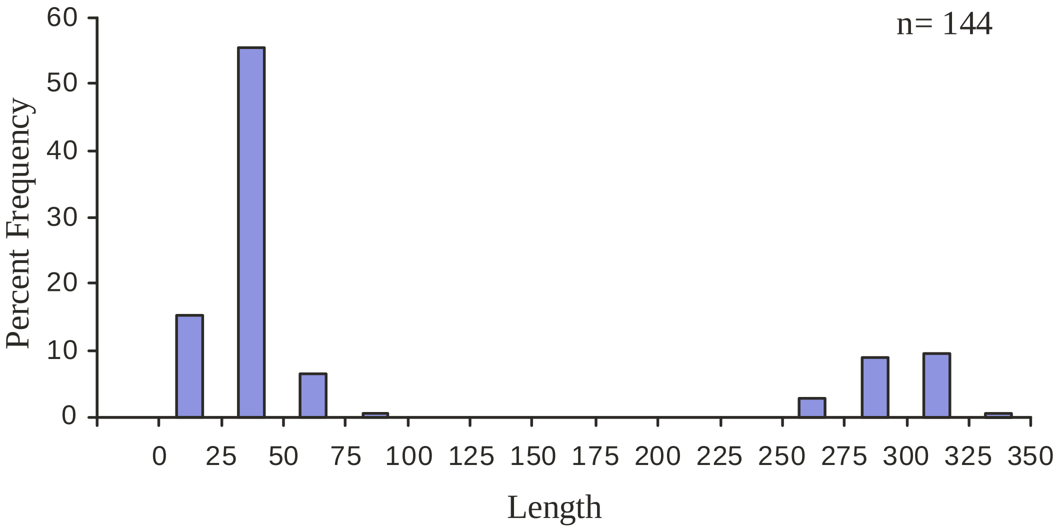

Figure 15. Length frequency of bony bream captured below Clare Weir during zones of accumulation sampling.

Discussion

Timing of Migrations

Sampling from fishways along the East Coast of Australia, indicates that upstream migrations are likely to occur all year round in the Burdekin River system (Thorncraft 1995, Mallen-Cooper 1996, Marsden 1997, Stuart and Berghuis 1999, Stuart 1999). These studies have found that the greatest numbers of migratory fish such as barramundi, bony bream, fork-tailed catfish and sooty grunter are caught during the wet season in association with high flow events (Hogan *et al*. 1997, Stuart 1999, Stuart and Berghuis 1999, McGill and Marsden 2000), with juveniles and sub-adults forming the majority of migrating fish (Stuart 1999, McGill and Marsden 2000). High flows during the wet season have been identified as important trigger events for fish movement throughout Australia and it has often been assumed that migrations of native fish only took place on these flows. High flows allow fish to spread out into newly inundated areas and the fact that many fish are found in billabongs, which are only connected to the main river channels during high flows, backs up the assumption of fish movement on these flows. However the results from sampling of fish accumulations below Clare Weir and other recent studies in the Fitzroy (Stuart 1999), Pioneer (McGill and Marsden 2000) and Burnett (Stuart and Berghuis 1999) systems indicate significant fish migrations are also occurring on low to moderate flows during the dry season. Table 2 outlines known migration times for each species found within the Burdekin River.

Migration flows

Sampling conducted during this study found that fish were accumulating below Clare Weir on low flows (970Ml/day) as well as high flows (66,093 Ml/day). This range of flows covered around 93% of the range of flows that can occur at Clare Weir. Should passage only be provided on either high or low flows a large portion of the migrating fish population will be disadvantaged in their endeavour to reach upstream habitats. Other studies have demonstrated that whenever there is flow in the river some species of migratory fish will be attempting to migrate (Stuart 1999, Stuart and Berghuis 1999, McGill and Marsden 2000). Every effort should be made to provide passage on the widest range of flows possible to ensure that migratory needs of all species and life stages are met.

Size of migrating fish

A broad size range of fish were captured accumulating below the weir during the sampling downstream of Clare Weir. Bony bream and empire gudgeons as small as 21mm were captured below the weir. These species have been recorded migrating at this size in a number of studies throughout Eastern Australia (Stuart 1999, Stuart and Berghuis 1999, McGill and Marsden 2000). Providing passage for these small fish is essential as they are particularly vulnerable to predation when accumulating below a weir, with mass mortalities occurring from predation by other fish recorded at the Ben Anderson Barrage (Pers. Comm. Ivor Stuart). In addition to these small fish a number of moderate to large fish species were sampled below the weir. The bull shark has been recorded in freshwater to 2.0m long, while barramundi have been recorded up to 1.3m long in freshwater. Generally these species move when they are around 500mm long, but larger individuals have been recorded using fishway in other streams (Stuart 1999). Provision of passage for these larger species is also important to ensure a balanced community of fish throughout the river system

Location of proposed fishway entrance

The sampling of fish below Clare Weir indicates that the area where the weir crest intersects either the right or left banks has the highest accumulations of fish numbers and species. During high flows fish move along the bank, where the lowest velocities occur, until they reach a point close to the weir crest (sites b and e) where they can proceed no further due to high velocities. The two zones, site b (around the old fishway entrance on the right-bank) and site e (on the left bank), consistently had the highest density of fish during sampling. Placement of the fishway entrance near either of these two accumulation zones should enable passage to be provided for the entire operational range of the fishway.

Some fish were attracted to flow from the outlet works (site c), with this zone having the next highest density of fish. Redirection of the outlet works flow along the right bank, instead of across the weir face, would further enhance attraction of fish to the zone around the old fishway entrance (Site b). Consideration should be given to altering the outlet works if a fishway is built on the right-bank.

Fishway Design for Clare Weir

Sampling of fish communities conducted at Clare Weir and in the waters of the Burdekin River upstream and downstream of the weir indicates that the weir has had a detrimental impact on migratory fish communities of the Burdekin River. Reduced numbers of species and individuals upstream of the weir and accumulations of fish at the base of the weir demonstrate this. Provision of fish passage at this site by way of a working fishway should help to ameliorate some of the negative impacts the weir has had on fish communities of the Burdekin River. Initial design consultation has taken place for a fishway at Clare Weir, with a site inspection undertaken to identify areas of concern from both biological and engineering considerations. This discussion takes into consideration a number of points raised at this site meeting.

Design Constraints

As this is a retrofitting exercise, a number of constraints are placed on the design that affects the type of fishway that can be built, its location and operational regime. The right-bank of the weir incorporates the existing fishway, as well as a railway used by the gantry crane that is used to raised the gates across the weir crest. The outlet works, which direct flows across the weir face towards the left bank, are also located on the right bank. The left bank is also affected by the gantry rail system and by the island downstream, which creates a large backwater area. The substrate of the bank on the left side is also a consideration, as a fishway on this side would require extensive foundation works to provide a sufficiently stable base.

Fishway location

Sampling below the weir indicates that there are accumulations of fish occurring on both the right and left bank at the base of the weir crest. Any fishway built should ensure that the entrance is located close to these areas to increase the likelihood of fish successfully finding the fishway entrance. The right-bank appears to be the most straightforward site for the fishway, as there is a solid bedrock foundation that would provide a strong stable base for a fishway. The left bank, although without the complications of the existing fishway of the right bank, has a base that would require extensive foundations to be built.

If the fishway were located on the right bank, the entrance of the fishway would be best placed near the bend in the old fishway, with the bottom leg of that fishway to be removed. Provision of additional attraction flow in this area would also ensure that fish would be attracted to the new fishway entrance. This could be achieved through a combination of redirection of the outlet works and changed operation of the hydraulic gates (Figure 16)

Headwater-Tailwater Ranges

Sampling below the weir showed that there are accumulations of fish occurring on both high (66,000 Ml/day) and low flows (970 Ml/day). The fishway should therefore operate over the widest range of flows practical and at a minimum cover at least 95% of flows to at least to 80,000 Ml/day, slightly more than was sampled during the zones of accumulation sampling (Figure 17). To cover this range of flows the fishway would required to operate between a minimum tailwater level of EL. 13.9m and a maximum tailwater level of EL 16.6m. To match these tailwater levels the fishway would be required to operate over an estimated headwater range of between EL 18.5m and EL 21.0m (DNR 1997). Operation of weir gates and outlet works may affect these levels and it is recommended that detailed hydrological studies confirm details of the water levels required to successfully operate the fishway up to this flow level.

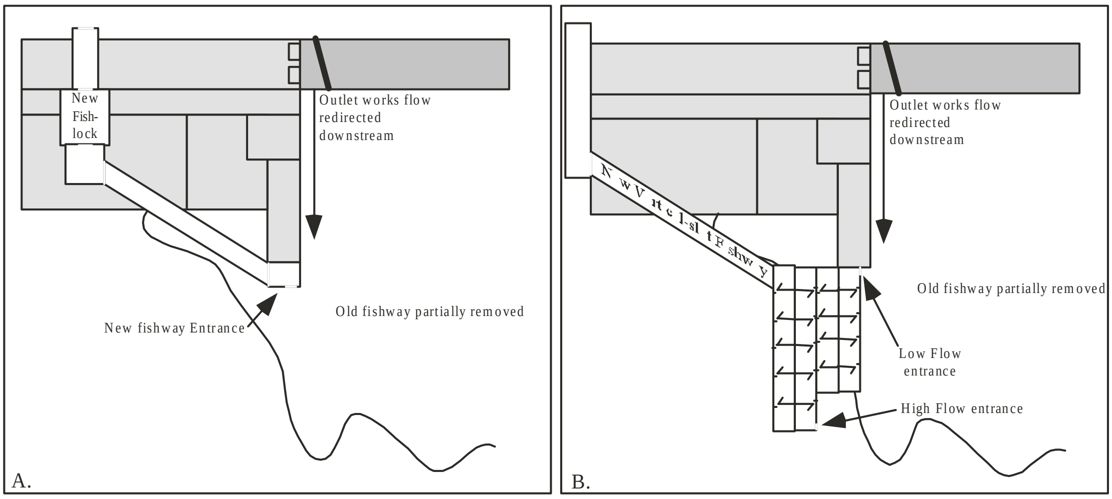

Figure 16. Ideal entrance locations for a fish-lock (A) and Vertical-slot (B) fishways at Clare Weir.

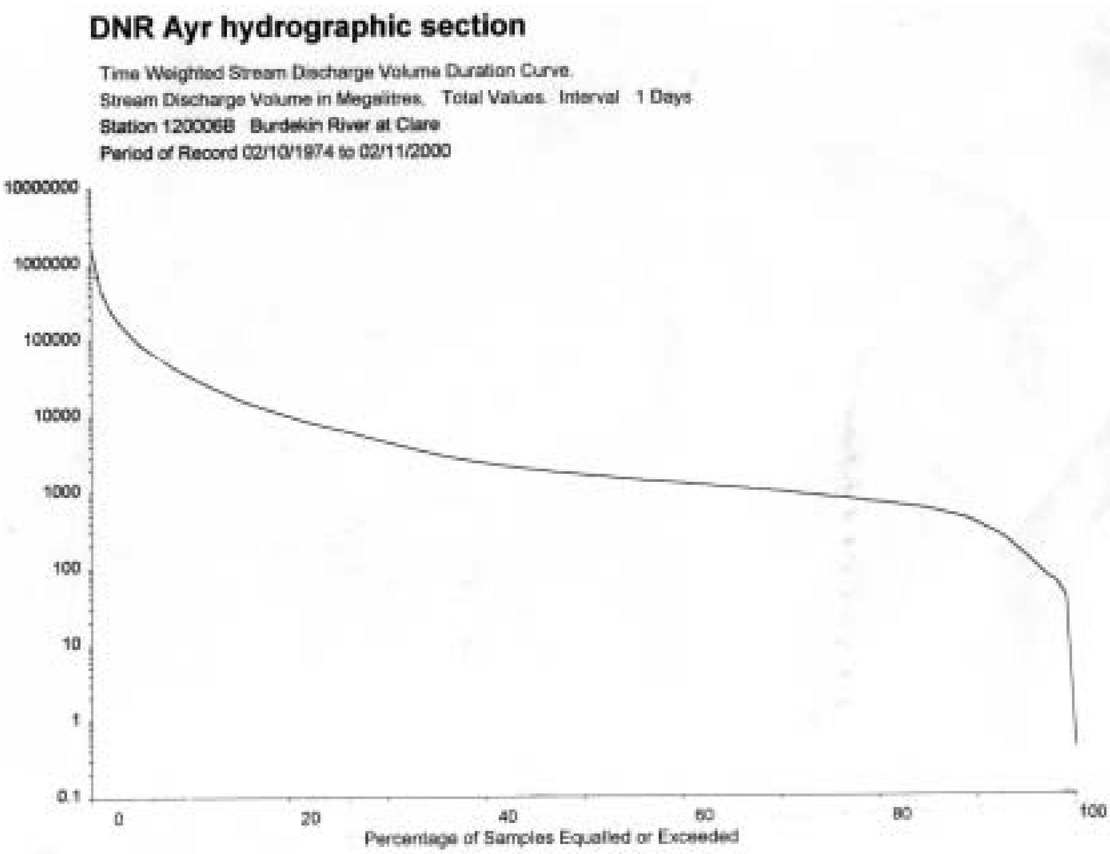

Figure 17. Flow duration curve for the Burdekin River at Clare Weir (supplied by DNR).

Attraction Flows and Gate Operation

Attraction flows around fishway entrances are essential for ensuring that fish find the fishway. As Clare Weir is such a wide structure, attracting fish to the fishway entrance is of particular importance. A number of modifications to the outlet works flow and hydraulic gate operation will be required to provide essential attraction water at the fishway entrance. Releases from the outlet works are currently diverted across the weir face by a retaining wall, into the main river channel 30-50m from the right bank. If this situation continued after fishway construction, the flow created would attract fish away from the fishway entrance. It is therefore essential that releases are directed along the right bank, past the old fishway towards the proposed fishway entrance (Figure 16). The operation of the hydraulic gates must also be modified to provide effective attraction water to the fishway. At present the first 5-10 gates on the right-bank remain raised in all but the highest flows. Most water overtopping the weir enters the river channel 30-50m from the bank. SunWater has proposed new operating guidelines that will change the way in which these gates operate. Under new guidelines, the gates nearest the new fishway entrance will be the first gates to open during a flow event and the last gates to be closed on a receding flow. This operating strategy will add to the attraction water in the area where the new fishway entrance will be placed, increasing the attraction of fish to the fishway.

Suitable Fishway Types

Vertical-slot Fishway

Vertical-slot fishways have been successfully fitted to a number of weirs in Queensland and NSW and are considered the best fishway type for weirs below six metres height. The Moura Weir vertical-slot fishway on the Dawson River has extended the maximum height for this fishway type, being installed on a seven metre high weir. An evaluation of the success of this fishway is currently being conducted, with initial sampling indicating many fish are successfully using the fishway. An advantage of vertical-slot fishways is that they do not have the hydraulically driven moving parts that fish locks have and therefore require less on-site maintenance. Issues that have been raised about construction of a vertical-slot fishway at Clare Weir revolve around sufficient structural strength to withstand flooding and also the problem of sediment and other debris blocking the fishway. Modern vertical-slot fishways are extremely well engineered and should be capable of handling the large flows that occur within the Burdekin system. Unlike the besser block construction of Collinsville Weir fishway, new vertical-slot fishways are fully constructed from reinforced concrete, allowing the fishway to withstand large floods with little or no damage. Sediment carried by the river in these flows is likely to be deposited in the fishway. However given the extended time between these events, appropriate maintenance can be implemented from the nearby Ayr office that would ensure the fishway remains operational.

To cater for the majority of fish species present the fishway should have slots between cells of 200mm with drops between cells of 100mm. This will allow all but the largest of species (bull shark > 1m) to enter the fishway. In addition, appropriate cell sizes to produce minimum turbulence (Figure 18) will allow fish as small as 20mm to ascend to the top of the fishway. Other specific dimensions for a vertical-slot fishway at Clare Weir are outlined in Figure 18.

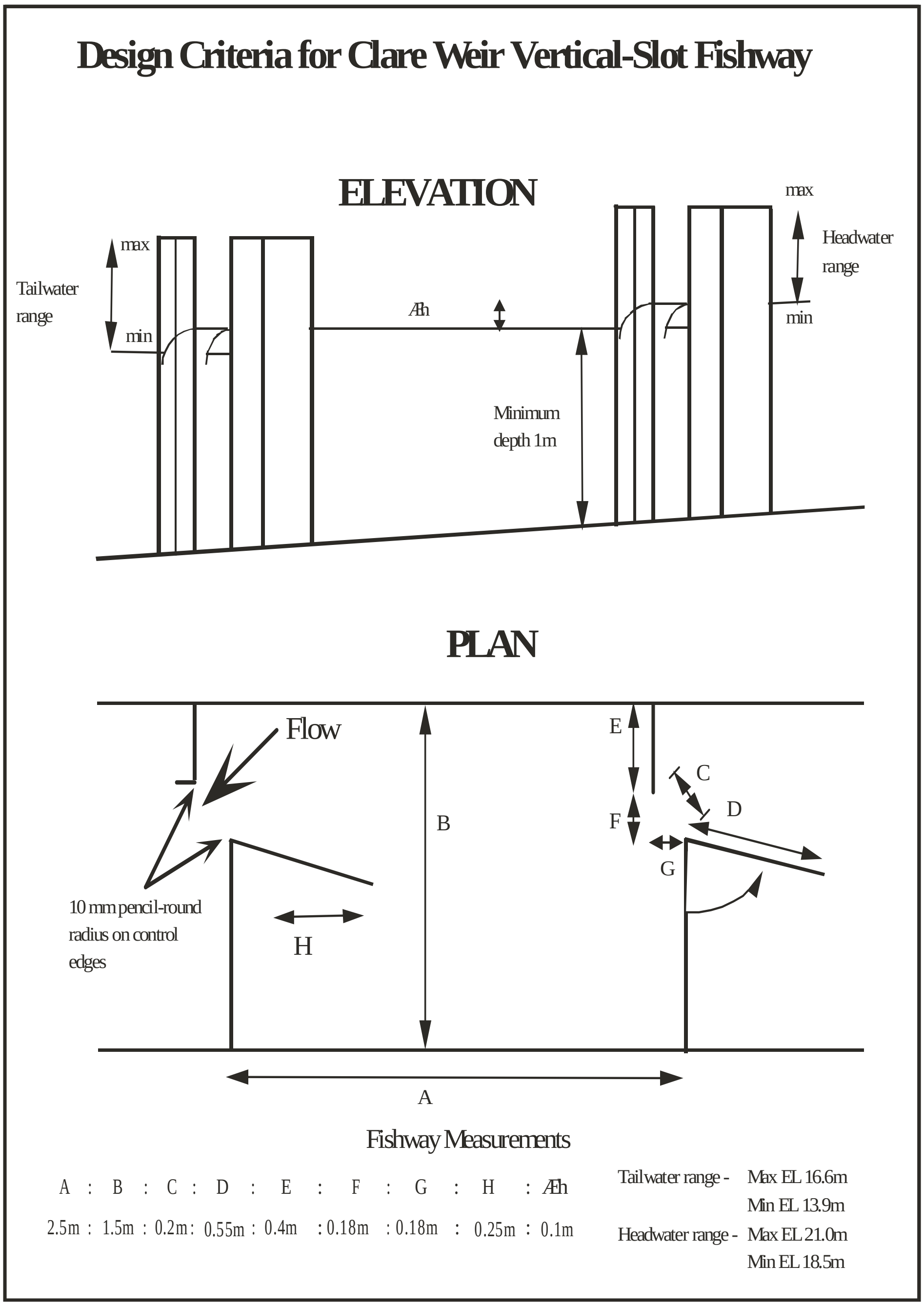

Figure 18. Design criteria for a vertical-slot fishway at Clare Weir.

Fish-lock

Fish-locks have been successfully fitted to a number of weirs in Queensland and NSW, but until recently were seen as unreliable in operation. The recently completed Neville Hewitt Weir fish-lock has proven more reliable than its predecessors and has improved acceptance of reliable fish-locks operating in Queensland. If fitted to Clare Weir, although well within its operational height limits, the lock would be the lowest height fish-lock in Australia.

A fish-lock has a number of advantages to offer at Clare Weir that would make it an appropriate choice for this site. As the fish-lock is not reliant on narrow slots to reach specific velocity and turbulence measures, it is able to offer passage to a greater range of fish species. The large entrance slot width and low water velocities enable very large fish such as the bull shark (> 1m) as well as very small and juvenile fish such as perchlets (<20mm) to utilise the fishway for upstream passage. The cost of a fish-lock is generally lower at this height than a vertical-slot fishway as there is less formwork required during construction. The ongoing maintenance costs of the fish-lock are usually higher than the vertical-slot design due to the mechanical nature of the design. As long as nearby operations staff are committed to maintaining the fish lock in an operational condition, problems should be minimal. This has been seen at Walla and Neville Hewitt Weirs where the fish locks are proving to be quite reliable.

Recommendations

- Sampling indicates Clare Weir is having a negative impact on migratory fish communities of the Burdekin River. To ameliorate negative impacts of this weir a new fishway should be constructed to provide passage past the weir.

- The fishway should be built on the right-bank, with it entrance near the end of the old fishway (after the bottom leg of the old fishway is removed).

- Work should be carried out to ensure outlet works flows are redirected and hydraulic gates operated to provide attraction water near the new fishway entrance.

- The fishway should be built to operate over at a minimum of 95% of flows with consideration of operation on higher flows given within budgetary constraints.

- Either a vertical-slot or a lock type fishway should be built. Both are suitable for this site and engineering and maintenance/operating considerations should determine the final design.

- If a vertical-slot fishway is built it should have cells 2.5m long by 1.5m wide and a slot width of 200mm (refer to Figure 18 for greater detail).

- If a fish-lock is built it should be of similar design to Neville Hewitt Weir fish-lock, with some minor alterations to improve attraction water within the fishway during certain stages of the lock cycle.

- The fishway should be operational whenever there is sufficient flow (or irrigation releases) in the river to operate the fishway.

- Once any modifications to the gates and outlet have occurred, further downstream sampling should be undertaken to identify any new zones of accumulation and suggest solutions for any problem areas that may occur.

- The fishway should be assessed to determine its effectiveness at passing the fish species of the Burdekin River.

- Sampling of fish communities upstream and downstream of the weir should be undertaken to determine the effect a working fishway has had on these fish communities.

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