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Influence of the Camballin Barrage on fish communities in the Fitzroy River, Western Australia

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Report to Land and Water Australia
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Freshwater Fish Group
CENTRE FOR FISH and FISHERIES RESEARCH

MURDOCH UNIVERSITY
PERTH, WESTERN AUSTRALIA

Land + Sea Unit

Kimberley Land Council

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Yiriman Project
Building stories in our young people

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Summary

The Camballin Barrage on the Fitzroy River presents a considerable barrier to fish migrations in this ecologically, culturally and socially important system. Disruptions in the migrations of at least a number of important species are occurring. In most years (~80%) since 1987 the barrage was only negotiable by fish for up to three months/year, even though flows may continue for much of the year. This barrier thus leads to a bottleneck of predatory species that in turn affects the prevailing fauna and disrupts important ecological aspects of the system. There are substantial differences in the fish fauna immediately below the barrage when compared to those above. This is highlighted by both a significant difference in the captures of fish in seine nets above and below and in the capture of a number of migratory species of marine origin that become congregated below the barrage, including the Bull Shark, Freshwater Sawfish, Oxeye Herring and Diamond Mullet. It is also very likely that juvenile Barramundi, which migrate up the Fitzroy River in the late wet would also become trapped below the barrage in years where water levels are insufficient to provide fish passage and become preyed on by larger predators.

While the diet of Bull Sharks, a species that has been implicated with fatal attacks on humans both in Australia and overseas, was shown to contain mainly teleost fish, the stomach of one individual was observed to contain the remains of a small Freshwater Sawfish. Predatory pressure on Freshwater Sawfish is likely to increase as the dry season persists, and the abundance of small prey species decline. The presence of large predators trapped immediately below the barrage would also affect the upstream migration of important food species such as Barramundi but also fodder and bait species such as mullet. The significant differences in the abundance of Bony Bream below the barrage compared to above also have ecological impacts on the system. Bony Bream are known to be an important prey species in tropical Australian rivers where it contributes to a considerable proportion of the diet of Barramundi. The tagging of Freshwater Sawfish demonstrated that they are regularly recaptured below the barrage with one caught four times over the duration of this study. To restore fish passage in the river a fishway should be constructed at the barrage.

Introduction

The Camballin Barrage on the Fitzroy River in the Kimberley region of Western Australia is the only major artificial barrier to fish migrations on the main channel of this system. Situated approximately 150km from the limit of tidal influence, the barrage has become a popular fishing and tourist destination due to it being one of the few readily accessible locations on the 'lower' Fitzroy River. It was originally constructed by the State Government and in the 1960s was used to redirect water to the 17 Mile Dam on Uralla (Snake) Creek to irrigate Camballin Station (Yuhun 2001). Considerable investment by the State Government was injected into developing the agriculture potential of the area from the late 1950s, with many of the ventures plagued with problems such as unreliable water supply, flood damage, pests and weeds (see Yuhun 2001). The barrage is currently not operational but continues to divert water into Snake Creek. Much of the elaborate infrastructure surrounding the barrage has now gone and the gates that used to collapse under flood conditions are now rusted and cease to function. Toussaint et al. (2001) noted that there was a lack of consultation with Traditional Owners during the barrage construction and aftermath and consequences of the project included detrimental impacts on the annual flooding of the river, the cultural life of local communities and the ecology of the area.

Fish and fishing is extremely important to the Traditional Owners of the Fitzroy River and a number of stories relating to fishing for specific species are reported in Thorburn et al. (2004). An unparalleled understanding of the diversity of fish found in the Fitzroy River is highlighted by the recognition of almost all the fish of the river by individual traditional names in the language of the Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri people (see Morgan et al. 2004a). The barrage lies on Nyikina country, and is utilised by Liveringa Station.

The fish fauna of the Fitzroy River is diverse by Western Australian standards, with the 24 freshwater species recorded from the river surpassing that combined for all the rivers of Western Australia south of the Fitzroy River (Morgan et al. 1998, 2004a, Morgan and Gill 2004).

The river houses a number of fish that are listed as threatened by the IUCN, including the Northern River Shark (Glyphis sp. C) (critically endangered), Freshwater Whipray (Himantura chaophraya) (vulnerable), Freshwater Sawfish (Pristis microdon) (endangered), Dwarf Sawfish (Pristis clavata) (endangered), Greenway's Grunter (Hannia greenwayi) (data deficient) and the Barnett River Gudgeon (Hypseleotris kimberleyensis) (near threatened/lower risk). Four of these species are migratory elasmobranchs (sharks and rays), including the Freshwater Whipray, known as Biya in Nyikina, the Dwarf Sawfish and Freshwater Sawfish (both of which are known as Wirridanyniny), Bial Bial (or Pial Pial) in Nyikina, and the Northern River Shark (L. Marshall and L. Buckle-Frazer pers. com., Morgan et al. 2004a, Thorburn and Morgan 2004, Thorburn et al. 2004,).

Other marine/estuarine species that utilise the freshwaters of the Fitzroy River as a nursery area include Barramundi (Lates calcarifer, Birloonkoordany in Nyikina), Ox-eye Herring (Megalops cyprinoides, Karlanyjarri in Nyikina), Greenback Mullet (Liza subviridis, Lawoorrinyji in Nyikina), Diamond Mullet (Liza alata, Lawoorrinyji in Nyikina), Whipfin Silver-biddy (Gerres filamentosus),

Roach (Gerres subfasciatus), Spotted Scat (Scatophagus argus, Kirrang kirrang in Nyikina), Striped Butterfish (Selenotoca multifasciata, Kirrang kirrang in Nyikina) and Merauke Toadfish (Marilyna meraukensis, Konngonoong in Nyikina) (Morgan et al. 2004a, Thorburn et al. 2004).

Migratory species, such as those listed above, would be impeded by the barrage during their upstream juvenile migrations, particularly during poor wet seasons and throughout the dry. Thus, this study aimed to:

(1) Detail an account of the fish fauna immediately above and below the barrage.

(2) Determine the timing of flood events and the annual allowable duration of fish migrations over the barrage; and

(3) Discuss the significance of fish passage in relation to the barrage.

Methodology

Fish surveys above and below the barrage

Fish were captured above and below the barrage using both seine and gill nets during November 2004 and July 2005. Sites upstream were selected within ~800m of the barrage while sites below the barrage were sampled within a large pool a kilometre or so downstream of the barrage. Three replicate gill net sets, consisting of 20m panels of 50, 100, 150 and 200mm monofilament stretched mesh were set during day-light hours for a period of two hours on each sampling occasion above and below the barrage, i.e. 12 sets in total. Nets were set both above and below the barrage during day-light hours and for short durations to minimise the by-catch of Freshwater Crocodiles (Crocodylus johnstoni) and reduce the potential for death in fish caught. Additionally, two panels of the largest mesh (150 and 200 mm) were set overnight directly below the barrage. Three replicate seine net samples were collected both above and below the barrage on each sampling occasion, i.e. 12 samples in total. The seine net was 26m in length and consisted of a 10m pocket of 3mm woven with two wings comprised of 6mm woven mesh and on average covered an area of 110m^2. The majority of fish captured using both methods were identified, measured (total length (mm)) and released.

The abundances of the different fish species captured above and below the barrage were examined using Analysis of Variance (ANOVA) in the SPSS Package and Analysis of Similarity (ANOSIM), Classification and Ordination in the PRIMER Package (Clarke and Gorley 2001).

Freshwater Sawfish tagging

On each sampling occasion 20m panels of 150 and 200mm mesh gill net were set overnight immediately below the barrage. All Freshwater Sawfish that were captured had their total length measured, were sexed with the maturity status of the males identified by an examination of their clasper morphology, the number of teeth on the left and right side of their rostrum (saw) counted, the rostrum length measured and a tag attached to their 1st dorsal fin. Any recaptures during this study, and from recreational fishers that phoned in details, were recorded (see Table 2). These data were used in conjunction with the previous tagging of Freshwater Sawfish in the river by the Centre for Fish and Fisheries Research at Murdoch University and the Kimberley Land Council (see Thorburn et al. 2004).

Dietary analysis of predatory species

Due to restricted habitat below the barrage it is hypothesised that larger predatory fishes, such as Barramundi and Bull Sharks, will become congregated downstream of the barrage and will heavily prey on smaller fish. It is expected that this high level of predation may lead to a shift in food (prey) resources than would naturally occur. In order to address this part of the study, the stomach contents of large predators (Barramundi and Bull Sharks) captured during this study, during that by Thorburn et al. (2004), and from samples obtained from recreational fishers, were examined using the points method. A comparison of the diets of Bull Sharks and Barramundi

below the barrage was compared with those captured in other unregulated sections of the river. In the case of Barramundi a comparison was done with fish from Geikie Gorge while for Bull Sharks it was from elsewhere in the Fitzroy River.

Each fish was measured to the nearest 1mm (total length) and each dietary item within each stomach was identified to the lowest possible taxon and its percentage contribution to the total volume estimated (Hynes 1950). The percentage contribution of each prey item of each species in the different parts of the river was then tabulated. To determine differences in the diets between sites, the dietary data from all individual stomachs for each species from the different sites, i.e. immediately below the barrage and those captured elsewhere in the river, were used to construct a similarity matrix using the Bray-Curtis similarity coefficient in the PRIMER package (Clarke and Gorley 2001). In order to test the hypotheses that the diets of these two species below the barrage will differ to those elsewhere in the river, the similarity matrix for the dietary data from all individual stomachs of both species was subjected to one-way analysis of similarity (ANOSIM) (Clarke and Gorley 2001).

In this methodology the test statistic (R), is a measure of the average rank similarities within a priori designated groups compared with the average rank similarity of all replicates between these groups, and is calculated. An R value of 0 indicates that similarities between and within groups are the same on average, i.e. there are no differences between groups, and an R value of 1 indicates that all replicates within groups are more similar to each other than to any other replicate from a different group.

Determination of water levels that allow fish passage

Data recorded by the Department of Environment from their gauging station at the barrage was used to determine:

(1) The mean daily stage heights at the barrage wall from September 1986 until 1st January 2005. N.B. The stage height of the barrage is 10 m.

(2) The mean number of days per year that the barrage was drowned out (inundated) (1987-2004), i.e. there was no fall of water downstream of the barrage and no obvious riffle zone discernable. This was identified by the Department of Environment as being at a stage height of ~12.3m.

(3) The mean number days that fish were able to negotiate the barrage (1987-2004), i.e. when upstream and downstream water levels were both at or above the level of the barrage. This assumes that fish do not 'jump' over the wall, but must swim over the barrier. This occurs when a stage height of ~11m is attained.

Results

Fish surveys above and below the barrage

A total of 1310 fish from 19 species were captured at the barrage using gill nets and seine nets (Plate 1, Table 1, Figures 1 and 2). While only two species (Bony Bream and Lesser Salmon Catfish) were captured using both methods, 10 species were captured using gill nets and 11 species were captured using seine nets (Table 1). Only five species of fish were caught with gill nets above the barrage compared to nine species below. Conversely, 10 species were captured above the barrage using seine nets while eight species were captured below. Due to the low numbers of fish captured using gill nets (i.e. a total of 25 individuals captured above and 31 below), statistical comparisons of mean differences of fishes above and below the barrage were not able to be performed. Importantly though, four of the species that were only captured below the barrage using gill nets were migratory species that breed in the estuary or marine environment and include P. microdon (Freshwater Sawfish), C. leucas (Bull Shark), L. alata (Diamond Mullet) and M. cyprinoides (Oxeye Herring). Two species that are currently listed by the IUCN were captured at the barrage; the Freshwater Sawfish and Greenway's Grunter.

In contrast, the captures using seine nets, which efficiently capture small fish over a given area, were compared using ANOVA and ANOSIM. The six replicate seine nets above the barrage yielded 1036 individual fish from 10 species while the six replicate seines below the barrage captured only 218 individual fish from eight species (Table 1, Figure 2). Significant differences ($p<0.001$) in the fish fauna above and below the barrage were demonstrated using ANOSIM. The MDS plot of the catches comprising the seine net samples demonstrates the differences in fish fauna above and below the barrage using this method (Figure 3). For example, those samples above the barrage are found in the top left of the plot compared to those below being found in the bottom right of the plot (Figure 3).

Much of the disparity between the fish above and below the barrage is a consequence of the far greater abundance of N. erebi (Bony Bream) captured in seines above the barrage (n=647 above versus n=8 below) (significantly different $p\leq0.05$) (Table 1, Figure 4). Similarly, there were considerably greater numbers of C. lentiginosus (Prince Regent Hardyhead) above than below (223 cf. 103), while M. australis (Western Rainbowfish), Ambassis sp. (undescribed Glassfish) and A. graeffei (lesser Salmon Catfish) were only captured in seine nets above the barrage (Table 1, Figure 2). Furthermore, there was much greater recruitment of juvenile freshwater fish above the barrage than below. For example, larval and juvenile N. erebi (Bony Bream) were only captured above the barrage where they were found in large numbers (Figure 4). This species is considered an important prey species in tropical Australia where it is known to comprise a considerable proportion of the diet of Barramundi (see Table 3 and Davis 1985, Herbert and Peeters 1995, Morgan et al. 2004b). It is likely that a high degree of predation below the barrage has led to the discrepancy in the abundance and population demographics of this ecologically important species (Table 3, Figure 4).

Table 1 The numbers of individual fish from each species captured above and below the barrage using seine nets and gill nets.

		Above Barrage		Below Barrage	
Species	**Common name**	*Seine net*	*Gill net*	*Seine net*	*Gill net*
P. microdon	Freshwater Sawfish	-	-	-	1
C. leucas	Bull Shark	-	-	-	1
L. calcarifer	Barramundi	-	2	-	1
L. alata	Diamond Mullet	-	-	-	4
A. graeffei	Lesser Salmon Catfish	7	14	-	12
M. cyprinoides	Ox-eye Herring	-	-	-	2
T. kimberleyensis	Kimberley Archerfish	-	-	-	1
N. erebi	Bony Bream	647	4	8	4
N. ater	Black Catfish	-	1	-	-
H. jenkinsi	Black Bream	-	1	-	-
L. unicolor	Spangled Perch	3	-	1	-
A. percoides	Barred Grunter	94	-	85	-
H. greenwayi	Greenway's Grunter	8	-	4	-
M. australis	Western Rainbowfish	23	-	-	-
C. lentiginosus	Prince Regent Hardyhead	223	-	103	-
G. giurus	Flathead Goby	22	-	9	-
S. krefftii	Freshwater Longtom	1	-	1	-
Ambassis sp.	NA	8	-	-	-
G. aprion	Mouth Almighty	-	-	7	-
	TOTAL	**1036**	**25**	**218**	**31**

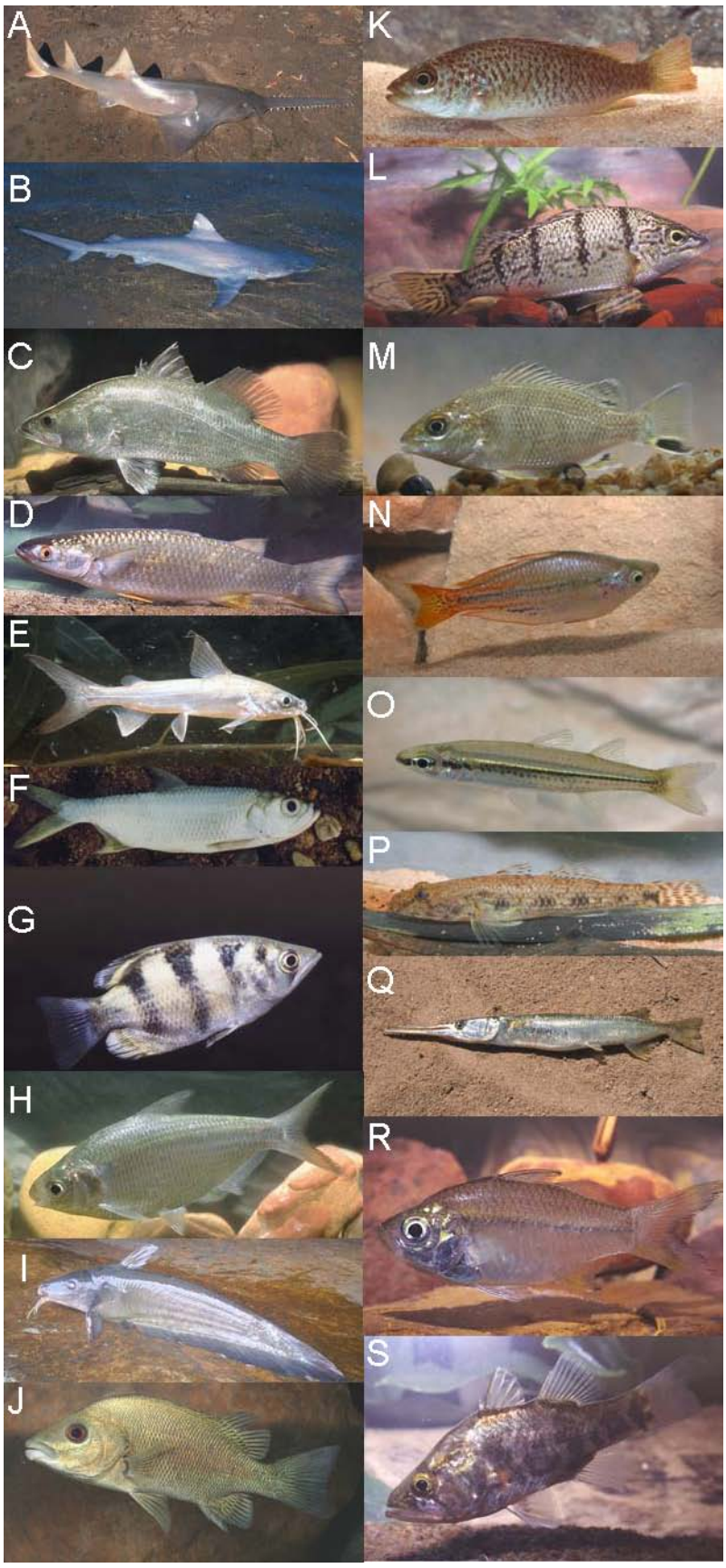

Plate 1 The fish captured during this study. A. Freshwater Sawfish. B. Bull Shark. C. Barramundi. D. Diamond Mullet. E. Lesser Salmon Catfish. F. Ox-eye Herring. G. Kimberley Archerfish. H. Bony Bream. I. Black Catfish. J. Black Bream. K. Spangled Perch. L. Barred Grunter. M. Greenway's Grunter. N. Western Rainbowfish. O. Prince Regent Hardyhead. P. Flathead Goby. Q. Freshwater Longtom. R. Ambassis sp. S. Mouth Almighty. Photographs: D. Morgan (A, B, D-G, I, K, L, Q-S), S. Visser (J, M-P) and M. Allen (C, H).

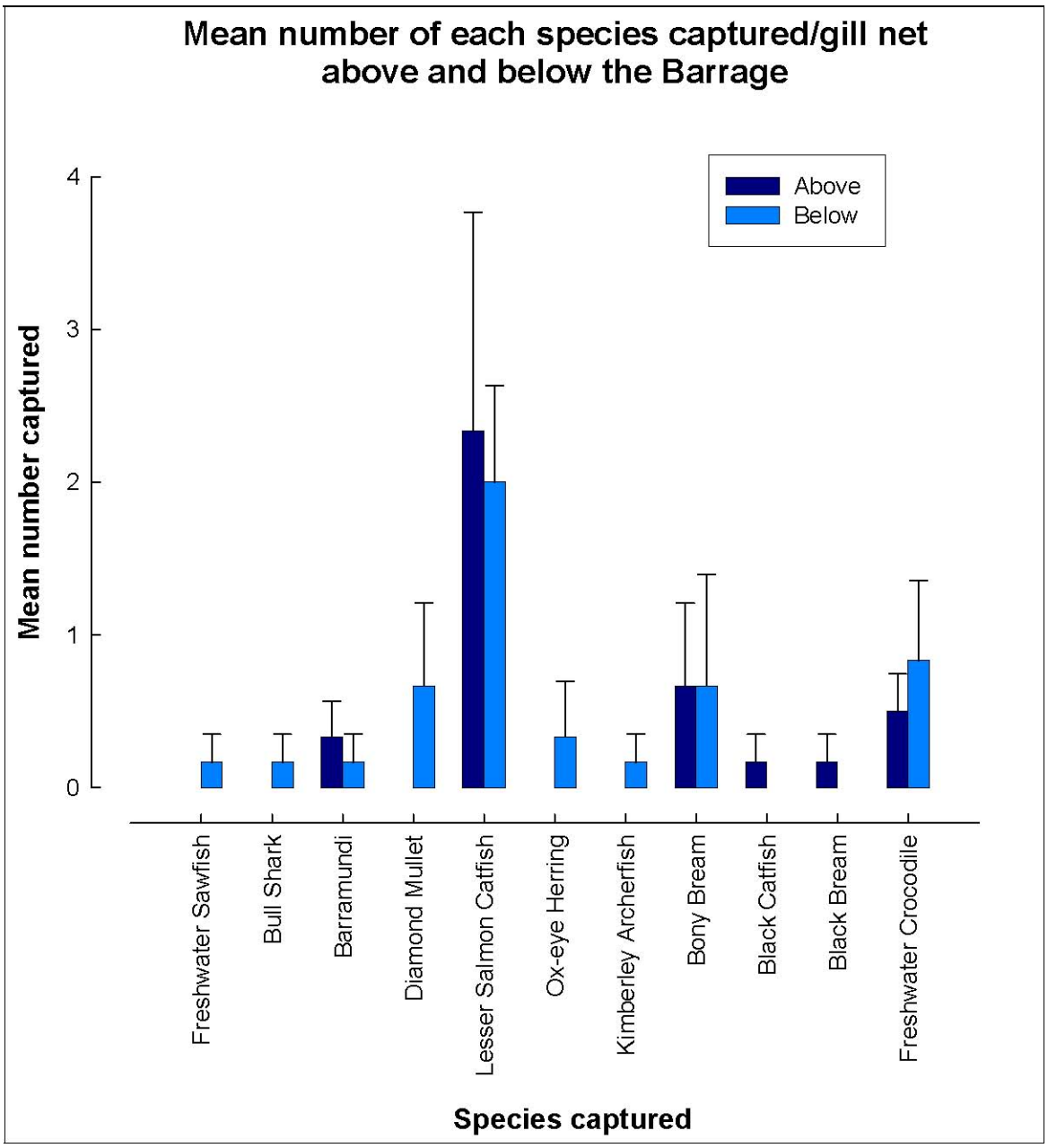

Figure 1 Mean number (+ 1 S.E.) of each species captured per gill net set above and below the barrage.

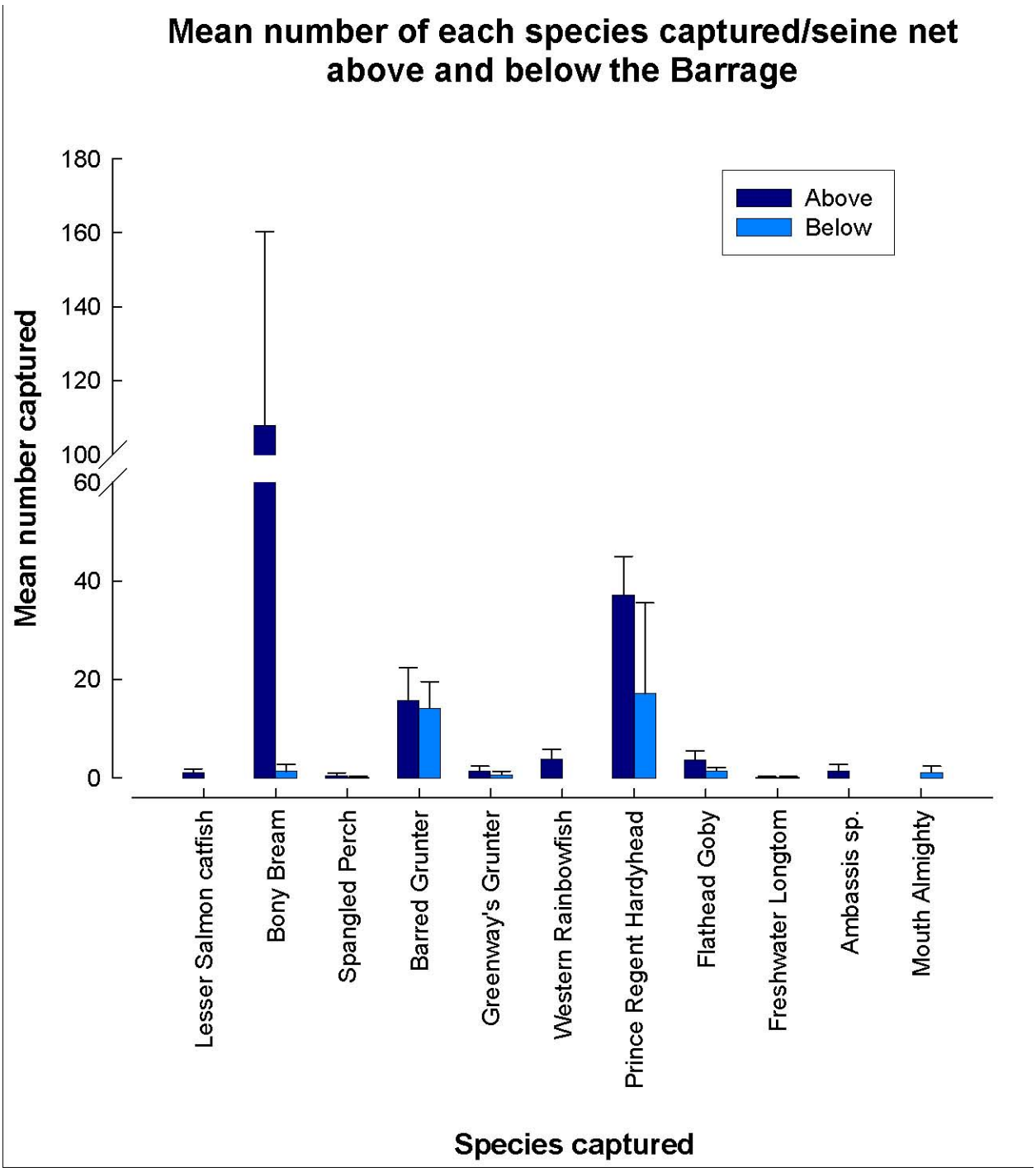

Figure 2 Mean number (+ 1 S.E.) of each species captured per seine net above and below the barrage.

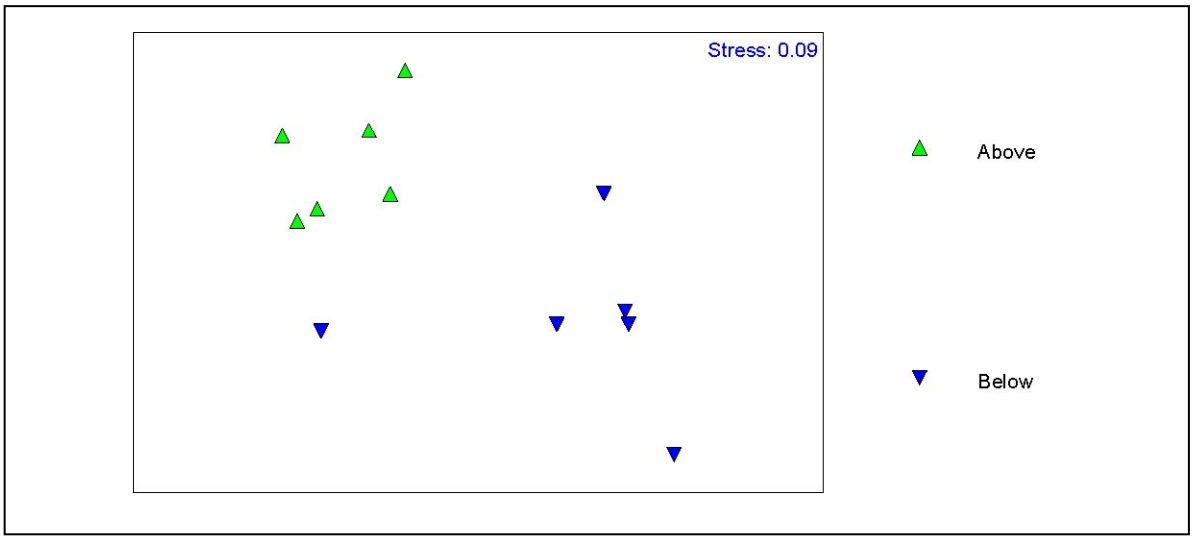

Figure 3 MDS (multidimensional scaling) of individual seine net samples of the fish captured above and below the barrage during this study.

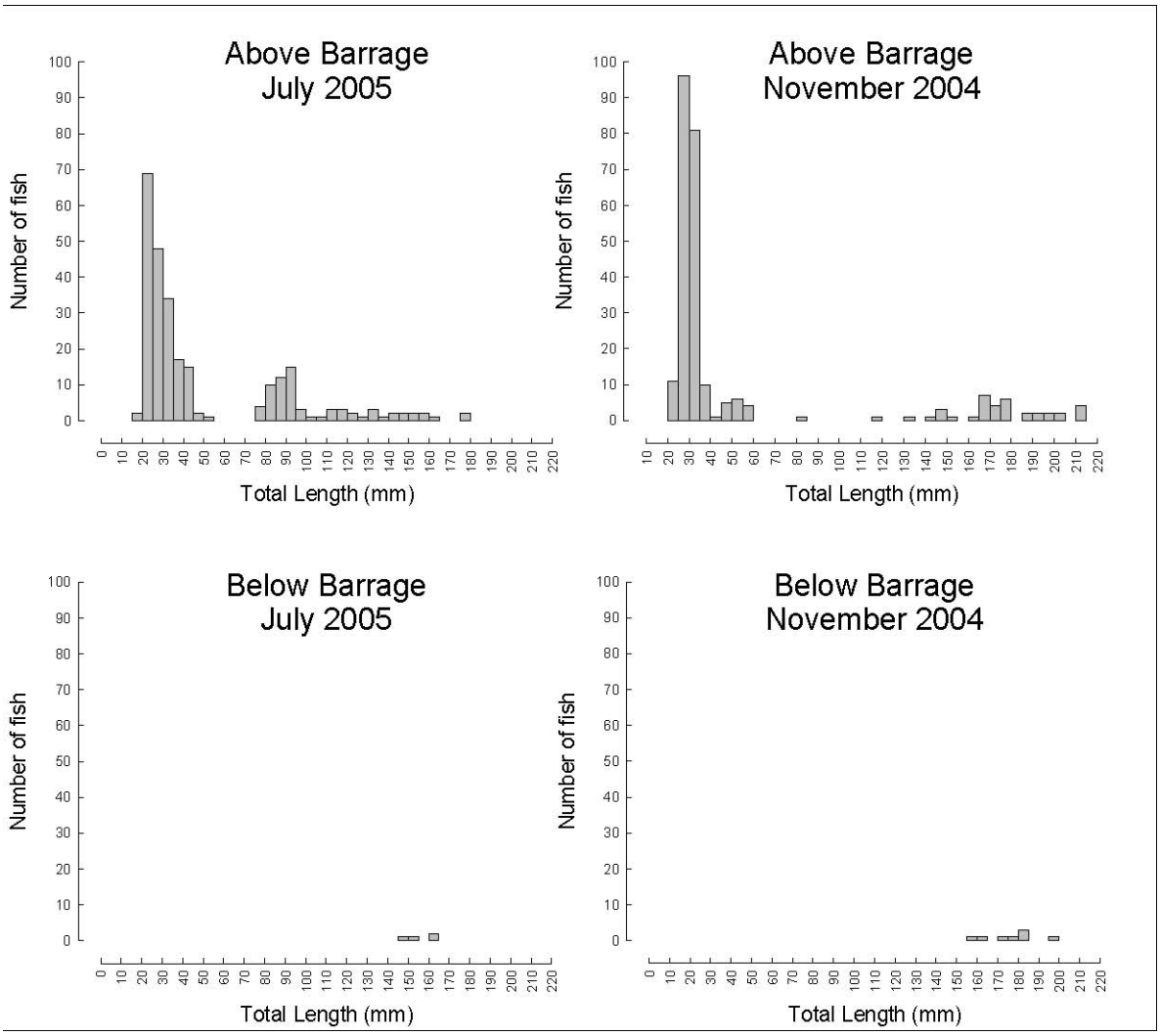

Figure 4 Length-frequency histograms of Bony Bream (Nematalosa erebi) captured above and below the barrage in November 2004 and July 2005.

Freshwater Sawfish tagging

Overnight gill net sets below the barrage in November 2004 and July 2005 yielded six Freshwater Sawfish, with one being caught twice (see Table 2 for tag numbers, sex, total length, rostrum length and number of recaptures).

Five of the sawfish captured were female with total lengths ranging from 2300mm to 2630mm while the one male captured measured 2059mm TL and was immature (Table 2). The three Freshwater Sawfish that were captured on 7-8/11/04 were all recaptures that we originally tagged in July 2004 (Table 2). Two of these sawfish have been recaptured a minimum of two times, with the sawfish with tag7056 recaptured on three occasions. Tag7056 was first recaptured in October 2005 by a recreational fisher, then it was again caught in November 2004 (this study) and again in May 2005 by a recreational fisher. This sawfish, including the initial capture, has thus been caught at the barrage on four occasions over a period 10 months. Furthermore, this sawfish did not move upstream during the wet of 2004/2005.

The 2300mm female sawfish tag7079 captured on 13-14/07/05 was again caught at the barrage by a recreational fisherman on 25/07/05, less than two weeks after it was tagged. We caught this animal twice over two days, first caught on hand line by Nyaburu Watson when it was originally tagged (see Figure 5) and again that night in a net.

All but one of the sawfish captured at the barrage had fishing line either wrapped around their rostrum or coming out of their gill openings (Figure 6). This is not surprising considering that heavy line is the preferred method to catch fish at this location and that sawfish become concentrated in small pools below the barrage and readily take bait.

Figure 5 Measuring and tagging a Freshwater sawfish at the barrage in July 2005 and a released Freshwater Sawfish showing the tag on the dorsal fin (Photographs S. Visser).

Table 2 Capture dates, tag number, sex, total length, rostrum length and recaptures[1,2,3,4] of the Freshwater Sawfish at the barrage during this project.

Capture Date	Tag Number	Sex	Total Length (mm)	Rostrum Length (mm)	Recaptures[1,2,3,4]
7-8/11/2004	*7056*	Female	2630	570	3[1]
7-8/11/2004	*7057*	Female	2344	520	1[2]
7-8/11/2004	*7058*	Female	2410	540	2[3]
13-14/7/2005	*7079*	Female	2300	513	2[4]
13-14/7/2005	*7076*	Male	2059	495	0

[1]Freshwater Sawfish *7056* was originally tagged on 15/7/04 at Barrage.
* Recaptured on the 19/10/04 at Barrage (by N. Harrington)
* Recaptured again on the 7-8/11/04 at Barrage (this study)
* Recaptured again on the 19/5/05 at Barrage (by M. Bartlett)

[2]Freshwater Sawfish *7057* was originally tagged on the 15/7/04 at Barrage.
* Recaptured on the 7-8/11/05 at Barrage (this study)

[3]Freshwater Sawfish *7058* was originally tagged on 15/7/04 at Barrage.
* Recaptured on the 28/10/04 at Barrage (by L. Unga)
* Recaptured on the 7-8/11/04 (this study)

[4]Freshwater Sawfish *7079* was originally tagged on 13/7/05 at Barrage (N. Watson this study).
* Recaptured on the 14/7/05 (this study)
* Recaptured on the 25/7/05 at Barrage (by J. Watts)

Figure 6 A Freshwater sawfish at the barrage in November 2004 with fishing line around its body and rostrum (Photographs D. Morgan).

Dietary analysis of predatory species

The diets of Barramundi and Bull Sharks from the barrage and elsewhere in the Fitzroy River are presented in Table 3. There was a significant difference in the diets of Barramundi examined at the barrage compared to elsewhere in the Fitzroy River ($p<0.001$, ANOSIM). This is due to a much greater proportion of Bony Bream ingested by Barramundi elsewhere in the Fitzroy River (~46% overall contribution to the diet elsewhere) compared to below the barrage (5.0% contribution). At the barrage, Barramundi consumed a much greater proportion of Lesser Salmon Catfish (45% of the diet) than in other parts of the river (~8%).

In contrast, the differences in diet of Bull Sharks at the barrage compared to elsewhere in the river were not found to be significantly different. Lesser Salmon Catfish was consumed in the greatest amount by Bull Sharks, however, they also were found to eat Bony Bream, Freshwater Sawfish, Freshwater Crocodiles, feral pigs, mullet and Barramundi (Table 3). The Freshwater Sawfish and pig that was found in the gut of a Bull Shark was from below the barrage. There was a lower proportion of Bony Bream and Barramundi consumed by Bull Sharks below the barrage but a higher proportion of Lesser Salmon Catfish and coleopterans (beetles) (Table 3).

Table 3 The relative proportion of the different food items consumed by Barramundi and Bull Sharks below the barrage compared to elsewhere in the Fitzroy River.

	Barramundi		Bull Shark	
Prey type	Barrage (n=20)	Fitzroy River (n=76)	Barrage (n=8)	Fitzroy River (n=16)
Sand	0.25	-	-	-
Aquatic vegetation	-	-	0.64	0.31
Terrestrial vegetation	-	3.16	0.75	1.27
Gastropod	-	0.13	-	-
Coleopteran	-	-	6.25	1.27
Cherabin	26.25	29.6	0.62	1.91
Orthoptera	-	2.63	-	-
Lesser Salmon Catfish	45.0	8.29	62.44	50.32
Bony Bream	5.0	45.66	5.56	14.01
Mullet sp.	-	-	4.69	-
Barramundi	-	-	6.25	17.83
Freshwater Sawfish	-	-	6.25	-
Teleost portions	23.5	10.53	-	0.13
Freshwater Crocodile	-	-	-	12.61
Pig	-	-	6.88	-

Determination of water levels that allow fish passage

Data recorded by the Department of Environment demonstrate that the barrage has a stage height of 10m and is completely drowned out at a stage height of 12.3m (Figure 7). When there is no fall of water from the upstream side of the barrage to the tailwater below the top of the barrage the stage height is 10.99m. It is at this point that we consider it to be negotiable to most fish, however, for fish that are powerful swimmers and are able to leap it may be negotiable at lower levels. For fish that are benthic (bottom-dwelling), the wall may still act as a barrier and these species might only be able to move upstream from below the barrage by swimming around the structure. Nevertheless, in the years examined between September 1986 and December 2004 the barrage was at least drowned out in all years with the exception of 1992 (Figure 7). The number of consecutive days when downstream water levels were at, or above, the barrage varied considerably between years (Figure 8). For example, while the downstream water levels were at the top of the barrage for almost 250 days in 1987, for 14 of the last 17 years the downstream water levels were at the top of the barrage for less than three months per year. Thus, the barrage would stop fish movements for up to nine months of the year in most years. Furthermore, in eight of the last 17 years the barrage would have been negotiable for only up to two months per year (Figure 8).

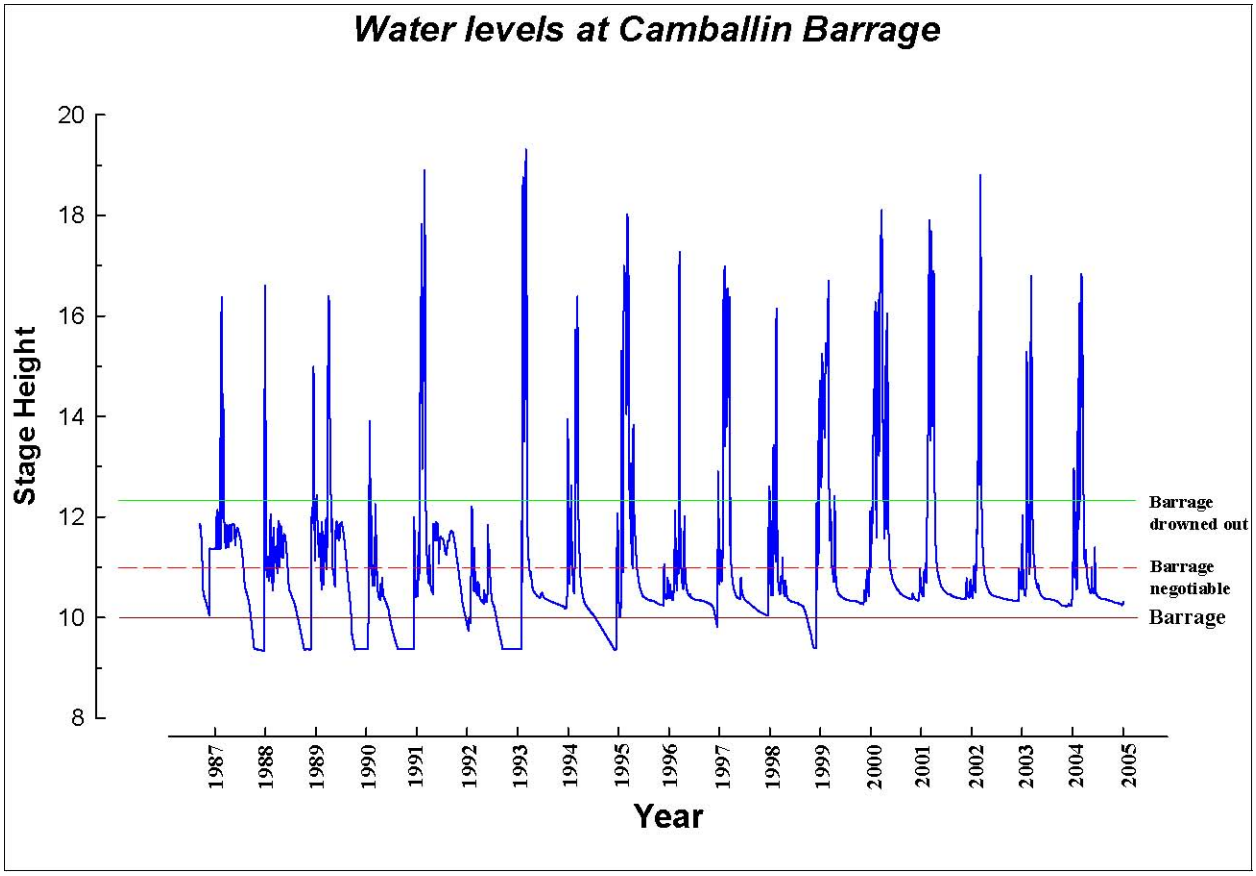

Figure 7 Water levels (stage heights) at the barrage between September 1986 and December 2004. The barrage is at stage height 10m, is considered negotiable by fish at stage height 10.99m and is drowned out at 12.3m. Raw data provided by the Department of Environment.

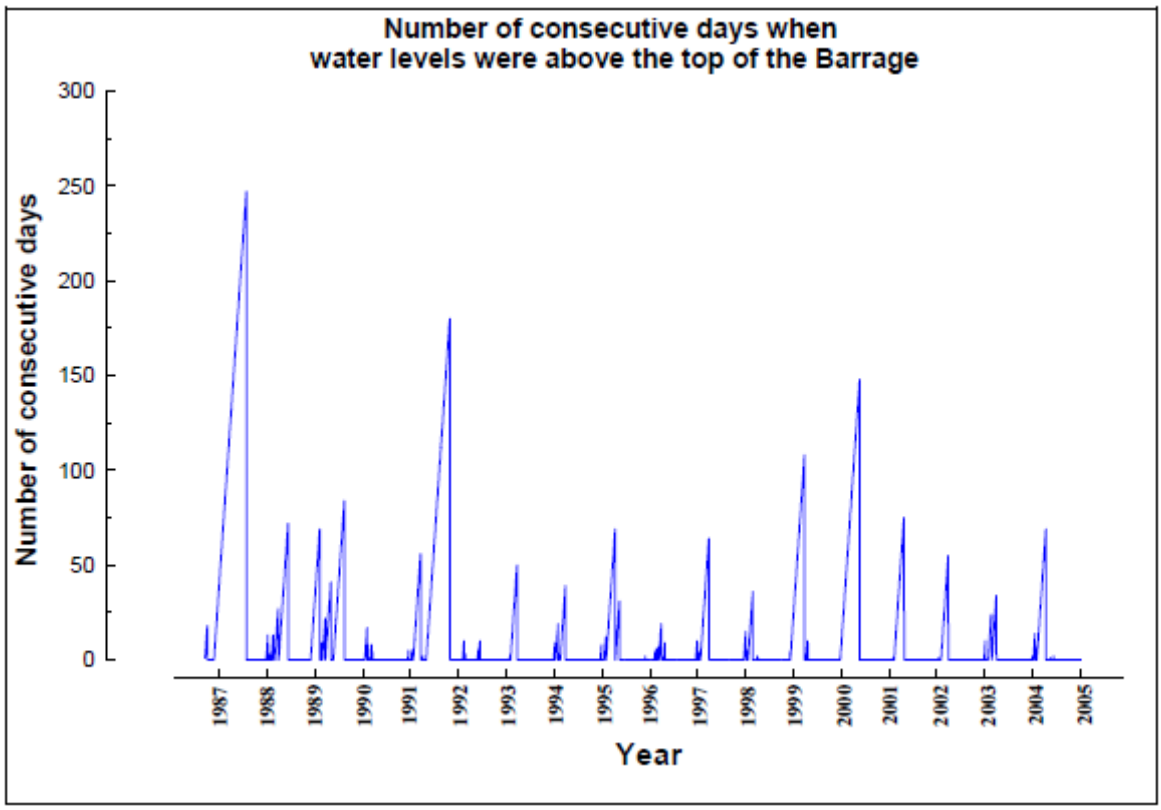

Figure 8 Number of consecutive days in each period between September 1986 and December 2004 that the downstream water levels were above the top of the barrage. Raw data provided by the Department of Environment.

Discussion

The barrage on the Fitzroy River presents a considerable barrier to fish migrations in this ecologically, culturally and socially important system. For example, disruptions in the migrations of at least a number of important species are occurring. In most years (~80%) since 1987 the barrage is only negotiable by fish for up to three months of the year, even though flows may continue for much of the year. This barrier thus leads to a bottleneck of predatory species that, in turn, affects the prevailing fauna and disrupts important ecological aspects of the system.

There are substantial differences in the fish fauna immediately below the barrage when compared to those above. This is highlighted by both a significant difference in the captures of fish in seine nets above and below and in the capture of a number of migratory species of marine origin that become congregated below the barrage, including the Bull Shark, Freshwater Sawfish, Oxeye Herring and Diamond Mullet. It is also very likely that juvenile Barramundi, which migrate up the Fitzroy River in the late wet would also become trapped below the barrage in years where water levels are insufficient to provide fish passage and become preyed on by larger predators. When these species become trapped below the barrage they are not only subjected to increased predation but they are also more easily targeted by recreational fishers. Much of the fishing at the barrage involves the use of heavy gauge lines. The large majority of Freshwater Sawfish encountered at this site have fishing line entangled around their rostrums, a morphological trait that allows then to also be readily tangled in gill nets. Often the degree of entanglement was severe; with line cutting considerable distances into the rostrum (see Figure 6).

Freshwater Sawfish, like Barramundi, probably migrate up the river during the wet season as juveniles (Thorburn et al. 2004). They then continue to move upstream and have been recorded as far up the Fitzroy as Margaret River Gorge, some 400km from the coast (Morgan et al. 2002). The impact of the barrage to the migration of this species is highlighted by the fact that Thorburn et al. (2004) recorded 34 of the 79 Freshwater Sawfish immediately below the barrage. Furthermore, the only recaptures of tagged Freshwater Sawfish that were officially reported have been from immediately below the barrage - 11 recaptures. Information collated from the recaptures of Freshwater Sawfish has demonstrated that at least one that was tagged below the barrage in 2004 did not move over the barrage during the last wet season.

While the diet of Bull Sharks was shown to contain mainly teleost fishes, the stomach of one individual was observed to contain the remains of a small Freshwater Sawfish. Predatory pressure on Freshwater Sawfish is likely to increase as the dry season persists, and the abundance of small prey species decline. The presence of large predators trapped immediately below the barrage would also affect the upstream migration of important food species such as Barramundi but also fodder and bait species such as mullet.

The significant differences in the abundance of Bony Bream below the barrage compared to above also have ecological impacts on the system. Bony Bream are known to be an important prey species in tropical Australian rivers where it contributes to a considerable proportion of the diet

of Barramundi (Table 3, Davis 1985, Herbert and Peeters 1995, Morgan et al. 2004b) and its reduction in numbers from below the barrage are likely to be the result of high predation.

Bull Sharks have been implicated with fatal attacks on humans both in Australia and overseas (Cliff 1991). In terms of attacks on humans, Bull Sharks have been identified as one of the four most dangerous sharks in the world; considered by Last and Stevens (1994) as potentially more dangerous than the Tiger Shark (Galeocerdo cuvier) or the White Shark (Carcharodon carcharis). This aggressive species thereby poses a real threat to people swimming at the barrage. Within the Fitzroy River they are generally <1.4 m in total length (~20 kg) and use the river as a nursery where they live for a few years before moving to offshore areas (Thorburn unpublished data). The species is opportunistic in terms of feeding, eating mainly fish in the Fitzroy but also taking pigs, crocodiles and sawfish (this study, Table 3). However, when food resources become limited below the barrage as a result of constant predation by larger fishes, they may attack swimmers. There is a need to put in place warning signs at the barrage highlighting the presence of this dangerous species, much in the same way that signs exist further downstream on the Fitzroy alerting to the presence of Saltwater Crocodiles (Crocodylus porosus).

Ideally the barrage should be removed, however if this was to occur it may compromise the fish of Snake Creek (Uralla Ck) and would impact on the water supply to Liveringa Station. Snake Creek is diverse in terms of fish (Morgan et al. 2004a) and has extremely high numbers of Freshwater Crocodiles. Further, the large pool above the barrage would be altered substantially.

Rarely considered is the consequence of what happens to fish moving downstream. The barrage would also impact on the movement of fishes downstream. While this will affect all species in some way, it is the maturing Barramundi, Freshwater Sawfish and other species that require the estuarine or marine environment for breeding and small juvenile and larval fish that would be most affected. Morgan and Beatty (2005) demonstrated that fish do 'swim' over weirs, probably unknowingly and more so at night than during the day. Survival would be dependant on the height of the fall, the depth of the water below and the ability of specific species to survive such falls.

It is recommended that a feasibility study is employed to construct a fishway at the barrage and determine the hydrological impacts to the upstream pool and to Snake Creek. However, there is only limited information regarding the utilisation of fishways by many of the rivers fishes, and in particular Freshwater Sawfish and Barramundi. Data collated by Doupé et al. (2005) from a number of studies detailing fishway usage suggests that many of the species found in the Fitzroy River have been shown to use vertical-slot fishways while only a few have been demonstrated using bypass fishways or fish locks. However, there is no information available that demonstrates that Freshwater Sawfish use fishways. This is not surprising as there are so few populations of Freshwater Sawfish remaining that the Fitzroy River is seen as one of the last strongholds of this threatened species (Thorburn et al. 2004). The acknowledgement of their rarity has recently seen the species protected under state regulations for the first time in 2005.

References

Clarke, K.R and Gorley, R.N. (2001). PRIMER v5: User manual/tutorial. Plymouth: PRIMER-E.

Cliff, G. (1991). Shark attacks on the South-African coast between 1960 and 1990. South African Journal Of Science 87 (10): 513-518.

Davis, T.L.O. (1985). The food of barramundi, Lates calcarifer (Bloch), in coastal and inland waters of Van Diemen Gulf and Gulf of Carpentaria, Australia. Journal of Fish Biology 26: 669-882.

Doupé, R.G., Morgan, D.L. and Gill, H.S. (2005). Prospects for a restorative fishery enhancement of Lake Kununurra: a high-level tropical impoundment on the Ord River, Western Australia. Pacific Conservation Biology 11: 136-146.

Herbert, B. and Peeters, J. (1995). Freshwater fishes of far north Queensland. Department of Primary Industries, Queensland.

Hynes, H. B. N. (1950). The food of sticklebacks with a review of the methods used in studies of the food of fishes. Journal of Animal Ecology 19: 36-58.

Last, P.R and Stevens, J.D. (1994). Sharks and Rays of Australia. CSIRO Division of Fisheries, CSIRO, Australia.

Morgan, D., Allen, M., Bedford, P. & Horstman, M. (2002). Inland fish fauna of the Fitzroy River Western Australia (including the Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri names). Report to the Natural Heritage Trust. December 2002. Project Number 003123.

Morgan, D.L., Allen, M.G., Bedford, P. & Horstman, M. (2004a). Fish fauna of the Fitzroy River in the Kimberley region of Western Australia – including the Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri Aboriginal names. Records of the Western Australian Museum 22: 147-161.

Morgan, D. & Beatty, S. (2005). The Goodga River Fishway – two years of monitoring the Western Australian trout minnow (Galaxias truttaceus). Report to the Department of Fisheries Western Australia.

Morgan, D.L. & Gill, H.S. (2004). Fish fauna in inland waters of the Pilbara (Indian Ocean) Drainage Division of Western Australia – evidence for three subprovinces. Zootaxa 636: 1
43.

Morgan, D.L., Gill, H.S. & Potter, I.C. (1998). Distribution, identification and biology of freshwater fishes in south-western Australia. Records of the Western Australian Museum Supplement No. 56: 97 pp.

Morgan, D.L., Rowland, D., Gill, H.S & Doupé, R.G. (2004b). Implications of introducing a large piscivore (Lates calcarifer) into a regulated northern Australian river (Lake Kununurra, Western Australia). Lakes & Reservoirs: Research and Management 9: 181-193.

Thorburn, D., Morgan, D., Gill, H., Johnson, M., Wallace-Smith, H., Vigilante, T., Croft, I. & Fenton, J. (2004). Biology and cultural significance of the freshwater sawfish (Pristis microdon) in the Fitzroy

River Kimberley, Western Australia. Report to the Threatened Species Network.

Thorburn, D.C. & Morgan, D.L. (2004). The northern river shark Glyphis sp. C (Carcharhinidae) discovered in Western Australia. Zootaxa 685: 1-8.

Toussaint, S., Sullivan, P., Yu, S. & Mularty, M. Jr. (2001). Fitzroy Valley Indigenous cultural values study (a preliminary assessment). Report for the Water and Rivers Commission.

Yuhun, P. (2001). Camballin Irrigation Area – a summary of cropping and pasture studies 19581970. Resource Management Technical Report No. 46. Department of Agriculture Western Australia.