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Macs & Alligator Creek Wetlands Fishway Monitoring Report

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Cover Image: From top left to right; showing juvenile fish species; red scat, tarpon, barramundi and pacific blue-eye recorded successfully ascending the Alligator Creek wetland rock chute fish passage. Landholder Jason Bradford holding a juvenile barramundi recorded successfully ascending the Macs wetland rock ramp fishway. Drone image showing the Macs wetland rock ramp fishway.

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Project Background

Reef Catchments Limited (RCL) contracted Catchment Solutions (CS) to undertake remediation works to improve aquatic connectivity and habitat at two wetland complexes. The wetlands are located in the lower Alligator Creek catchment on a property south of Mackay, central Queensland. In December 2022 fish passage was restored at two sites (Figure 1);

1. **Macs Wetland;** remediation of a small relic weir associated with the wetland outlet/spillway with a nature-like rock ramp fishway. The fishway was constructed on a small drainage line exiting the wetland, and only operates intermittently following high rainfall events. A new novel 'nursery-slot' fishway design was incorporated into the fishway. The aim of the 'nursery-slot' was to provide upstream fish passage for post-larvae and leptocephalus life-stages. These early life stages of fish are currently missing from coastal Australian fishway studies.
2. **Alligator Creek Wetlands**; fish passage was improved at this site through the construction of a bed control rock chute on a 1:30 gradient interspersed with random large boulders. Similarly to Macs Wetland, fish passage remediation works at Alligator Wetlands did not occur on a waterway, but on a small drainage line located on the outlet of the wetlands that flows intermittently following high rainfall events.

Reef Catchments approached Catchment Solutions to undertake monitoring at both sites which was conducted in early April 2023 following a high rainfall event resulting in sufficient flows to engage the fish passage works.

Figure 1. Showing locations of the fishways.

The monitoring program aimed to gather data to assess the effectiveness of the fish passage works in facilitating upstream connectivity for all life-stages and species of fish attempting to migrate upstream, including post larvae. Data collected included body length information of each species collected across day and night. Additionally, the monitoring program provided information regarding species diversity and abundance of fish migrating upstream into the recently remediated wetlands.

The Macs wetland fishway was monitored with great interest due to the introduction of a new novel 'nursery slot' design. Being the first of its kind, the nursery slot was incorporated into the nature like rock-ramp fishway which has already proven successful in many previous fish passage remediation projects. It is anticipated that the nursery slot will allow fish in post-larvae stages of their life cycle to ascend the fishway e.g. post larvae empire gudgeon and leptocephalus, which the authors have observed attempting to migrate upstream at fish barrier sites in central Queensland but are missing from fish passage studies along the east coast of Australia.

Figure 2. Top - Looking upstream (left) & downstream (right) at Alligator Creek wetland fish passage works; Bottom - Showing Macs wetland rock ramp fishway (left) & the nursery slot (right) incorporated into the design.

Prior to wetland rehabilitation works occurring at these two sites, both wetlands would often completely dry-up during the 'dry season', particularly during El Nino years. During La Nina years, occasionally water would remain in the wetlands. However, due to the shallow nature of the wetlands (water depth <800 mm deep at maximum capacity prior to restoration works) and proliferation of invasive weed of national significance; hymenachne, any remaining water within the wetlands during the dry season was often hot and lacking dissolved oxygen, resulting in anoxic conditions unsuitable to fish and other aquatic fauna. Wetlands that comprise large areas of floating hymenachne extending across open water habitats, often comprise reduced dissolved oxygen levels within the wetland. This is due to microbes on the steams of hymenachne constantly consuming oxygen, and unlike submergent aquatic macrophytes, hymenachne does not provide oxygen back into the wetland via photosynthesis (due to floating on the surface). In-addition to not providing oxygen, the hymenachne also shades out native submergent macrophytes preventing them from growing, photosynthesising, and providing valuable oxygen directly into the wetland. Further, the floating habit of hymenachne combined with its ability to rapidly colonise and spread across open water habitats reduces the ability of wind waves to provide oxygen into the wetland's surface water layers via diffusion. As a result of this, wetlands with hymenachne often provide inadequate conditions for aquatic life, especially fauna that require oxygen such as fish. To mitigate the impacts caused by hymenachne, a suite of wetland rehabilitation measures were implemented to improve overall wetland health. These measures included the construction of large deep pool refuge habitats. The refuge pools were constructed large enough (>10 m across) to prevent hymenachne from growing via runners along the water surface from one side of the refugia to the other. The deep pool refugia was constructed to a depth greater than 2 m. Deep pools assist with mediating water temperatures and aid in the retention of water during dry times, a critical feature for sustaining aquatic life.

Furthermore, the land holder is implementing control measures including a rotational grazing strategy that allows livestock to feed on the hymenachne periodically and intermittently spraying herbicides as a control measure. Included as part of the remediation works, large woody debris' were installed within the wetlands to provide in-stream habitat for fish and other aquatic life. Endemic riparian plantings were also included in the rehabilitation design.

This report briefly details the methods and results of the monitoring period following construction of the fish passage remediation works and provides a summary outlining the performance of the fishways in providing aquatic connectivity at these locations.

Methods

Fishway Trapping

Sampling was conducted over three days (4th – 6th of April 2023) four months post-construction of each fishway. This sampling involved trapping at the top of both fishways with the same methods followed at both sites. Trapping focused on the upstream movement of fish into the recently remediated wetlands, where channels and refuge pools were excavated to provide long-term fish habitat. To determine the overall fish passage performance at the site, two indicators were monitored: species utilisation and body length frequency. To aid in the interpretation of results, associated water quality parameters were also recorded from upstream and downstream of the fishway over the course of the monitoring period.

Fishway trapping utilised purpose-built traps, with 10mm round bar and shade cloth (4.0 mm mesh size) covering the frame. Shade cloth wing walls prevented fish from swimming around the traps on either side. Sandbags and star pickets were used to secure the traps and wing walls in place. The trap consisted of a single cone entrance, with dimensions of 1.4 m x 1.0 m x 1.1 m. Traps were set and checked multiple times per day to minimise stress, potential predation, and fish escaping the trap. Catch rates were standardised using Catch Per Unit Effort (CPUE) with unit effort being reported in days. Sampling effort for the monitoring event is summarised in Table 1.

Table 1: Fishway sampling effort summary.

Location	Trap type	Dates	Effort (hr.)
Mac's wetlands fishway	Single Cone	04/04/23 – 06/04/2023	53.92
Alligator Creek wetlands fishway	Single Cone	04/04/23 – 06/04/2023	50.25

All fish captured during a trap set were identified to species level, counted, and measured to the nearest millimetre (fork length of forked-tail species, total length for all other species). If large numbers of a species were captured during a single set, a random subset of 20 fish were measured. The remaining fish were counted and only contributed to abundance data. After processing, all fish were released upstream, away from the fishway.

Figure 3. Showing a typical trap haul (left); Sorting fish species and measuring lengths (right)

Water Quality Parameters

Water quality parameters including temperature, pH, dissolved oxygen, and conductivity were measured using a YSI – Pro Plus multiprobe. The water quality sampling method involved placing the probe into the water at a depth of 0.1 m. After readings had stabilised, values were recorded for each of the water quality parameters. Water quality measurements were recorded from both the top and bottom of the fishway. The parameters recorded were;

- pH
- Dissolved Oxygen (mg/L & % saturation)
- Electrical Conductivity (µs/cm)
- Temperature (°C)

Results

Macs Wetlands Fishway

Fish movements

A total of 2,730 fish were captured over the three-day monitoring period at Macs wetland fishway. Fish were captured at a rate of 1,215.1 fish successfully ascending the fishway each day. The most abundant species were empire gudgeon (*Hypseleotris compressa*) and Agassizi's glassfish (*Ambassis agassizii*). In a single trapping operation, 986 empire gudgeon were captured which heavily influenced their abundance totals. 12 native fish species were captured during the monitoring, including barramundi (*Lates calcarifer*), giant herring (*Elops hawaiensis*), tarpon (*Megalops cyprinoides*), and purple-spot gudgeon (*Mogurnda adspersa*). The only non-native species captured was mosquito fish (*Gambusia holbrooki*). The smallest individual was an empire gudgeon measuring 15 mm and largest was a long-finned eel measuring 550 mm. The overall median length of individuals ascending the fishway was 35 mm. Approximately 60% of fish species recorded successfully ascending the fishway were diadromous, undertaking life-cycle dependant migrations between marine and freshwaters. Fish movements data is summarised in Table 2.

Figure 4. Showing fishway conditions during monitoring (top left); Giant herring caught in an overnight trap operation (top right); Empire gudgeon captured during a trapping operation (bottom left); Landholder Jason Bradford releasing a barramundi in the wetland upstream of the fishway.

Empire gudgeon were the most abundant species recorded during the fishway monitoring (n=1,887, 839.91 fish/day). Most individuals were captured within 15-20mm (51%) size ranges with a median length of 20 mm (Table 2). These length and size ranges are considerably small. This may be an indication of the nursery slot successfully accommodating weaker swimming/ small-bodied fish species. Further monitoring would be required to confirm this.

Agassizi's glassfish were the second most abundant species recorded during fishway monitoring (n=772). Most individuals were within the 35-40 mm (46.3%) and 30-35 mm (28.4%) size ranges, with a median length of 37 mm (Table 2).

Table 2: Macs wetlands fishway species, abundance, and catch rates.

Common Name	Species Name	Size Min (mm)	Size Median (mm)	Size Max (mm)	Total Individuals	CPUE (fish/day)
Agassizi's glassfish	*Ambassis agassizii*	21	37	51	772	343.62
Banded scat	*Selenotoca multifasciata*	36	49.5	134	10	4.45
Barramundi	*Lates calcarifer*	232	232	232	1	0.45

Eastern rainbowfish	*Melanotaenia splendida splendida*	26	39.5	54	4	1.78
Empire gudgeon	*Hypseleotris compressa*	15	20	74	1887	839.91
Flyspecked hardyhead	*Craterocephalus stercusmuscarum*	21	21	21	1	0.45
Giant herring	*Elops hawaiensis*	75	75	75	1	0.45
Long-finned eel	*Anguilla reinhardtii*	75	85	550	3	1.34
Mosquito fish**	*Gambusia holbrooki*	19	24	34	22	9.79
Mullet	*Mugil sp.*	72	72	72	1	0.45
Purple-spot gudgeon	*Mogurnda adspersa*	47	49	51	2	0.89
Spangled perch	*Leiopotherapon unicolor*	51	68	82	21	9.35
Tarpon	*Megalops cyprinoides*	62	80	84	5	2.23
Overall Min., Median, Max., Total individuals and CPUE		15	35	550	2730	1215.13
Total Species				**13**		

** Non-native species

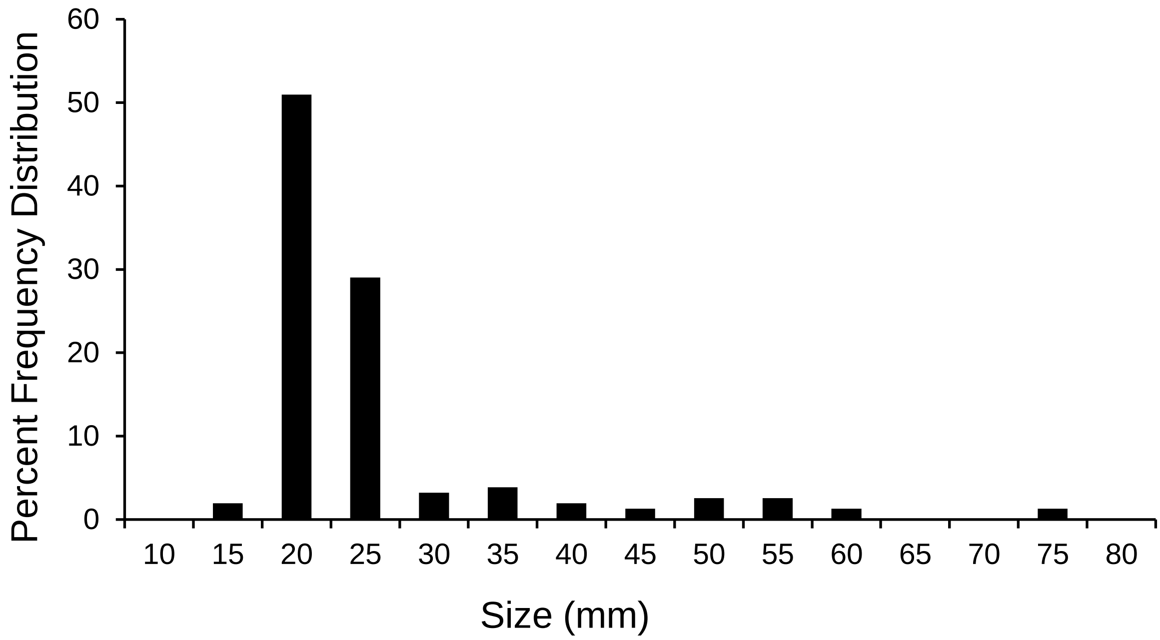

Figure 5: Percent length frequency distribution of empire gudgeon (*H. compressa*) in Macs wetlands fishway (n=155).

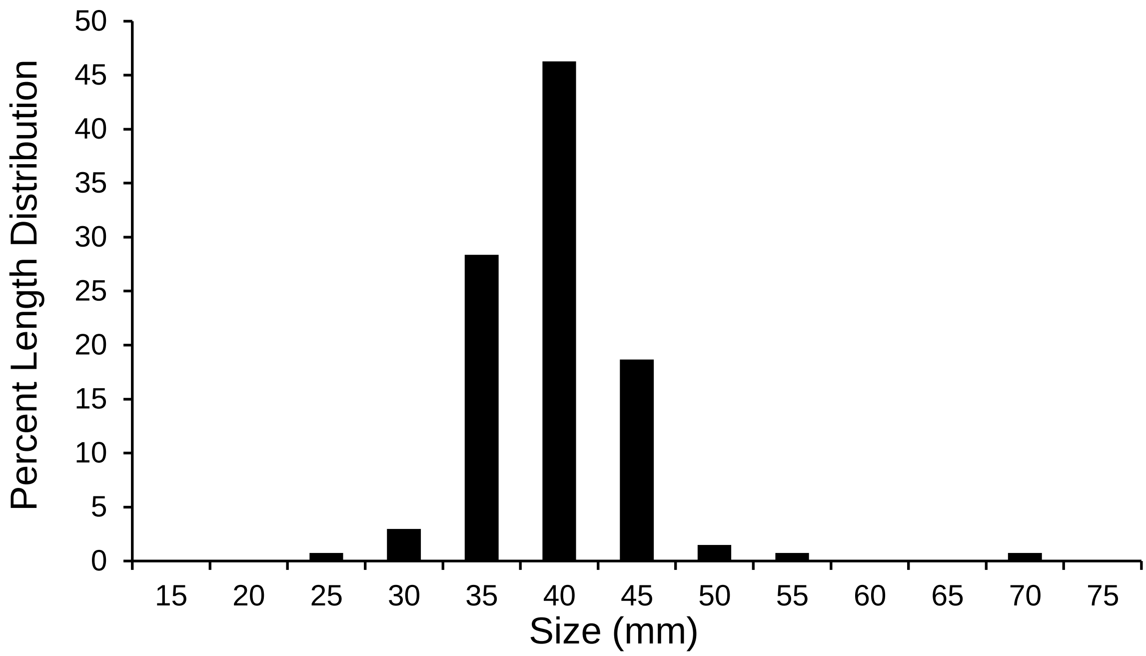

Figure 6: Percent length frequency distribution of Agassizi's glassfish in Macs wetlands fishway (n=133).

Water Quality

The water quality measurements at Macs wetland fishway were typical for a central Queensland lowland wetland located within a sugar cane catchment and comprising hymenachne (Table 3). The dissolved oxygen levels were very low at times, particularly in the mornings following reduced opportunities for photosynthesis during the overnight-early morning period. Low dissolved oxygen levels may have inhibited fish migration for some species and size classes, especially those species less tolerant of low dissolved oxygen levels e.g. mullet species.

Table 3: Water quality parameters recorded at Macs wetland fishway.

Date/Time of reading	Location	Temperature (°C)	DO (mg/L)	DO (%sat)	EC (us/cm)	pH
4/04/2023 8:00	Top	25.2	2.51	29.7	190.2	6.57
	Bottom	26.3	1.17	15.5	17968	6.89
4/04/2023 12:00	Top	25.1	3.78	43.8	123	7.30
	Bottom	25.4	3.50	43.8	2034	6.92
4/04/2023 16:50	Top	24.3	0.51	6.3	171	6.74
	Bottom	24.1	1.04	12.4	337	6.68
5/04/2023 9:00	Top	26.4	2.30	27.5	183	6.52
	Bottom	27.5	2.80	37.7	255	6.41
5/04/2023 14:30	Top	26.5	4.78	51.8	181	7.70
	Bottom	26.6	5.92	63.8	781	6.96
5/04/2023 16:50	Top	24.2	0.80	9.6	174	6.54
	Bottom	24.8	1.20	13.6	171	6.57
6/04/2023 9:20	Top	25.5	0.26	4.0	175	6.36
	Bottom	26.4	1.99	24.2	184	6.42

Alligator Creek Wetland Fishway

Fish movements

A total of 887 individuals representing 17 fish species at a catch rate of 414.8 fish per day were recorded successfully ascending the rock chute fish passage during the monitoring period. The most abundant species were Agassizi's glassfish (*A. agassizii*) and mosquito fish (*G. holbrooki*). Fifteen native fish species were recorded during monitoring, including barramundi (*L. calcarifer*), crescent perch (*Terapon jarbua*), tarpon (*M. cyrprinoides*), and purple-spot gudgeon (*M. adspersa*). Two non-native species were also captured, including mosquito fish (*G. holbrooki*) and platy (*Xiphophorus* maculatus). The smallest individual captured was an Agassizi's glassfish (18 mm) and largest was a tarpon (197 mm). The overall median length of fish recorded during monitoring was 39 mm. Ten of the fifteen (67%) native species recorded successfully ascending the fishway were diadromous.

Figure 7. Showing fishway conditions during monitoring (top left); Large haul of tarpon and other species (top right); Crescent perch, purple-spot gudgeon, banded scat, and Agassizi's glassfish captured during monitoring (bottom left); Two barramundi captured on the last day of monitoring.

Agassizi's glassfish were the most abundant species recorded during fishway monitoring (n=267, 127.52 fish/day). Most Individuals were within the 45-50 mm size ranges (34%), with a median length of 37 mm. Empire gudgeon (*H.compressa*) were in far lower numbers than those recorded at Macs wetland fishway, with 104 individuals captured (49.67 fish/day).

Tarpon were the second most abundant native species recorded during fishway monitoring (n=106, 50.63 fish/day). 102 out of 106 individuals were captured in a single trapping operation. Tarpon were mostly caught in the 155-160 mm size ranges (45.8%), with a median length of 152 mm. Capturing fish in this size range demonstrates the fishway is successful at facilitating connectivity for larger-bodied individuals as well as small/weaker swimming fish.

Table 4: Alligator Creek Wetlands fishway species, abundance, and catch rates.

Common Name	Species Name	Size Min (mm)	Size Median (mm)	Size Max (mm)	Total Individuals	CPUE (fish/day)
Agassizi's glassfish	*Ambassis agassizii*	18	37	47	267	127.52
Banded scat	*Selenotoca multifasciata*	25	50	63	18	8.60
Barramundi	*Lates calcarifer*	71	74	77	2	0.96
Crescent perch	*Terapon jarbua*	30	53.5	73	10	4.78
Empire gudgeon	*Hypseleotris compressa*	19	21	94	104	49.67
Estuary glassfish	*Ambassis Marianus*	31	31	31	1	0.48
Midgley's carp gudgeon	*Hypseleotris species 1*	31	31	31	1	0.48
Mosquito fish**	*Gambusia holbrooki*	17	25	42	207	98.87
Mullet	*Mugil sp.*	36	48.5	81	65	31.04
Pacific blue-eye	*Pseudomugil signifer*	21	29	32	3	1.43
Platy**	*Xiphophorus maculatus*	18	21.5	36	19	9.07
Purple-spot gudgeon	*Mogurnda adspersa*	42	68	83	25	11.94
Spangled perch	*Leiopotherapon unicolor*	59	74	88	16	7.64
Spotted scat	*Scatophagus argus*	32	41	72	7	3.34
Tarpon	*Megalops cyprinoides*	145	152	197	106	50.63
Threadfin silver-biddy	*Gerres filamentosus*	32	42	51	15	7.16
Unknown goby species	*Gobiidae sp.*	32	32	32	1	0.48
Overall Min., Median, Max., Total individuals and CPUE		18	39	197	867	414.09
Total Species		**17**				

** Non-native fish species

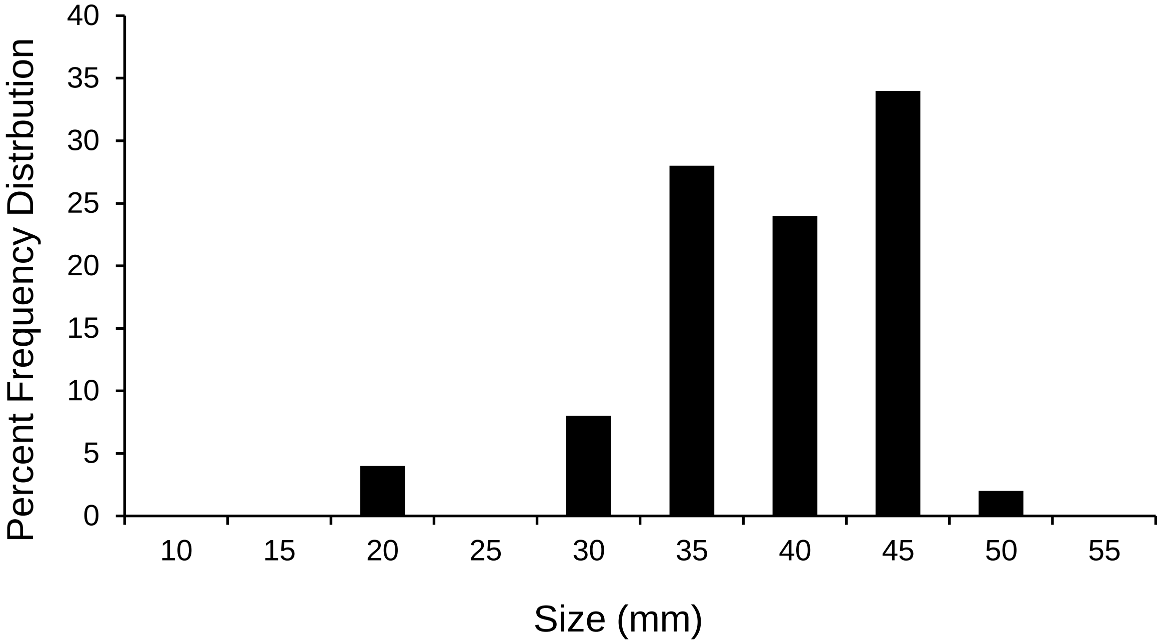

Figure 8: Percent length frequency distribution of Agassizi's glassfish (*A. agassizii*) in Alligator Creek wetlands fishway (n=50).

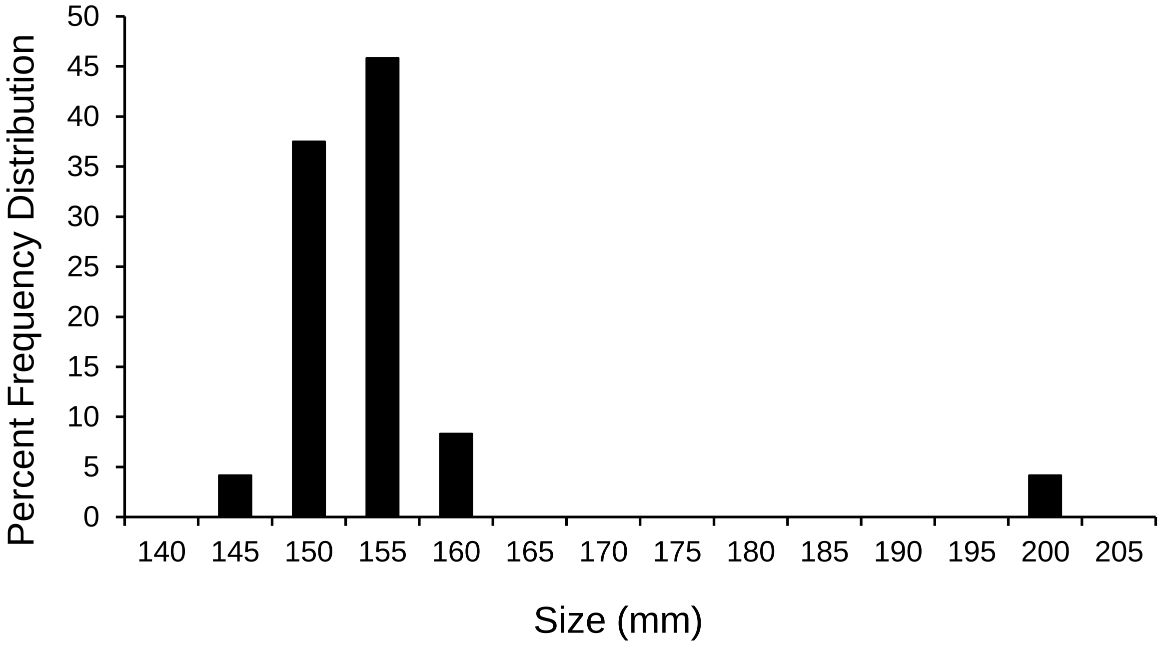

Figure 9: Percent length frequency distribution of tarpon (*M. cyprinoides*) in Alligator Creek wetlands fishway (n=24).

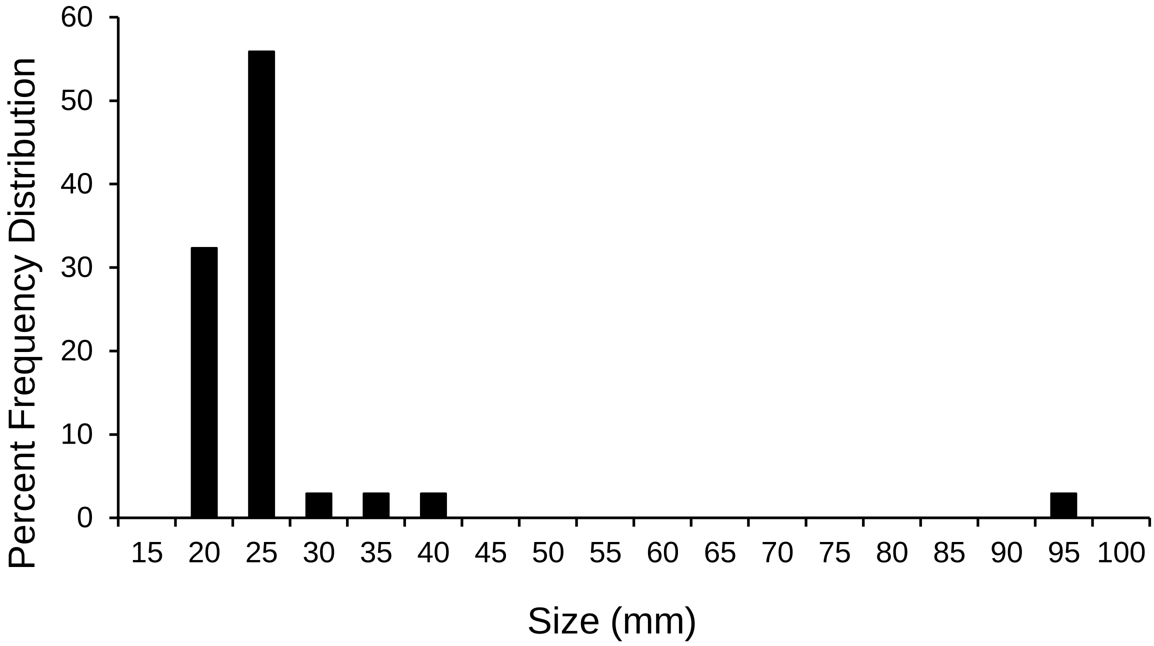

Figure 10: Percent length frequency distribution of empire gudgeon (*H. compressa*) in Alligator Creek wetlands fishway (n=34).

Water Quality

The water quality measurements were typical for the habitat at Alligator Creek wetlands. The dissolved oxygen levels fluctuated slightly throughout the monitoring period. However, it is not likely to have influenced captures within the fishway.

Table 5: Water quality parameters recorded at Alligator creek wetlands fishway.

Date/Time of reading	Location	Temperature (°C)	DO (mg/L)	DO (%sat)	EC (us/cm)	pH
5/04/2023 16:05	Top	26.2	3.6	46.2	4994	6.3
	Bottom	26.6	1.76	22.6	2328	6.6
4/04/2023 15:00	Bottom	21.5	1.76	21.5	1029	6.6
6/04/2023 10:25	Top	25.8	1.65	20.5	3038	6.4
	Bottom	26.5	2.45	30.1	1720	6.5

Discussion

Macs Wetland Fishway

Fishway monitoring at the Macs wetland site demonstrated that the fishway is successful at providing connectivity for a diverse range of fish species, sizes, and life stages. Size ranges varied greatly, with fish as small as 15 mm and as large as 550 mm recorded, demonstrating that the fishway provides passage for small-bodied fish with weaker swimming abilities and large-bodied species. Thirteen species were recorded successfully ascending upstream through the fishway comprising eight diadromous, four potamodromous, and one invasive. The largest individual recorded navigating the fishway was a long-finned eel which was 550 mm in length. Empire gudgeon were captured at different stages of maturity and sizes as small as 15 mm and up to 74 mm. While limited numbers of larger fish were captured (2% of fish measured >100 mm). This is typical for lowland coastal

Queensland wetlands, whereby upstream fish migrations are generally undertaken by juvenile diadromous and small-bodied fish species.

The nursery slot performed as intended with smaller fish, primarily empire gudgeon, observed utilising the shallow film of water to successfully ascend the fishway. The stepped increments of the nursery slot provide a range of flows and depths in the slot which allowed fish of different sizes and swimming abilities to ascend. In addition to trap sampling, remote video stations comprising Go Pros were used to capture footage of the nursery slot, where small empire gudgeon and crescent perch could be seen easily ascending through the slot. Empire gudgeon were observed migrating upstream through the edge slot with the shallowest film of water <8 mm. The shallow film of water in-conjunction with the surface roughness of the concrete creates friction resulting in a boundary layer of reduced velocity. Small fish, including 15 mm empire gudgeon were recorded ascending this shallow film of water.

Larger bodied fish such as crescent perch were recorded using the opposite and deeper (>150 mm) side of the nursery slot. Unfortunately, no leptocephalus were captured during the monitoring period. However, this may be due to their migration from marine to freshwaters occurring prior to the monitoring period. Tarpon leptocephalus were observed in the fishway, including the 2nd last pool from the exit (top) in early January 2023 during the first flow event down the fishway. These specimens were recorded by the authors using a dip net. Very little information is known about the migration habitats of tarpon. Research from overseas suggests tarpon leptocephalus migrate from offshore marine waters towards the coast and eventually upstream through estuaries to freshwater around December-January period. Monitoring of the fishway occurred in April. It's possible that leptocephalus were not recorded in April because they had already metamorphised into juvenile fish by this stage. Juvenile tarpon grow at between 30-40 mm per month. Tarpon around 120 mm were recorded successfully ascending the fishway in April. It's possible that these 120 mm tarpon belonged to the same cohort of tarpon leptocephalus observed at the fishway site 3 months earlier in January.

Figure 11. Showing tarpon leptocephalus (longer translucent specimens) and post larvae empire gudgeon (shorter specimens), recorded via a dip net in the second last pool (exit) of the fishway in early January prior to fishway trap sampling. Leptocephalus and post larvae empire gudgeon have not been recorded in Australian fishway studies, so it's unlikely that they ascended the conventional rock ramp slot, and more likely that they used the novel nursery slot design.

Alligator Creek Wetland Fishway

Similarly to Macs wetland fishway, monitoring of the Alligator Creek wetland fishway demonstrated successful passability for fish of different life stages, sizes, and swimming abilities. Seventeen fish species were recorded successfully moving upstream through the fishway. These species comprised nine diadromous, four potamodromous, two marine vagrants, and two invasives.

The simple rock chute design on a 1:30 gradient with interspersed large boulders that were used to facilitate connectivity at the site provided passage for both small-bodied and larger-bodied fish, including juvenile diadromous species. The largest individual captured was a tarpon measuring 197 mm in length. The smallest species recorded was Agassizi's glassfish at 18 mm. Larger fish were in greater abundance than those recorded at Mac's wetland fishway. At the Alligator Creek site, 8% of fish measured were greater than 100 mm in length compared to only 1.35% at Mac's wetland fishway. However, all fish caught over 100 mm were tarpon, with most caught in a single trap set.

Significantly, fish trap monitoring successfully recorded juvenile diadromous fish species that make up important recreational, commercial, and indigenous fisheries, such as barramundi, tarpon and mullet species. These species seek out lowland freshwater wetlands as nursery habitats during their early life-stages. Lowland wetlands provide key refuge, shelter and food resources that allow these fish to grow rapidly, increasing their chances of survival during their return migration back to marine habitats in the following years. Facilitating this life-cycle dependant migration ensures regional fish communities condition remains healthy, sustaining both the environment and coastal Queensland communities.

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