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DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

Roper River fish movement study

Report on 2015/2016 data

Report number 19/2016D

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Executive summary

- This report presents a summary of the results of the first year of data collection by the Roper River fish movement study.

- The project is tracking the movements of 100 fish (80 barramundi and 20 fork-tailed catfish) using an array of acoustic receivers from near Mataranka to the mouth of the Roper River.

- The movements of fish have been tracked since October 2015, and the database held 1.25 million records by the end of July 2016.

- Results to date highlight the strong connection between large-scale movement by fish and river flow.

- While most fish were relatively sedentary and did not make substantial movements beyond the original tagging location, a minority of barramundi made substantial movements in both directions.

- Four (mostly) large barramundi embarked on a downstream spawning migration. Most of these movements coincided with periods of high flow in the river, but the timing and nature of the downstream movements were highly variable.

- A small number of (mostly) juvenile barramundi undertook an extensive upstream migration commencing near the peak of the first flood pulse of the wet season. One fish moved upstream 85 kms, and another 106 kms, in 10.3 and 8.7 days respectively.

- Although the study is in its early stages, there is preliminary evidence that river barriers present impediments to fish movement even under moderately high flows. For example passage across Roper Bar occurred at flows in excess of 40 cumecs. Further data will allow modelling of the relationship between flow and the probability of passage across potential barriers.

- Additional work is required to more fully describe the phenomenon of juvenile migration, and in particular the flow conditions required for transition to freshwater habitats.

Contents

1. Introduction

Increased demand for water resources from expanding agriculture in northern Australia will impact natural flow regimes of spring-fed rivers, including the Daly and Roper Rivers. Sustainable development of water resources will require information on the relationships between river flow and the ecology of key aquatic species, in order to ensure that the ecological requirements of these species are not compromised.

The maximum annual extraction limit under the draft water allocation plan for the Tindall Limestone Aquifer, Mataranka, is 19,500 ML, or 15% of the average annual recharge calculated for the period 1900 to 2008 of 130,000 ML. The annual extraction limit is the lesser of the maximum annual limit and 20% of the seasonal recharge, calculated by modelling based on the rainfall of the previous wet season. Water extraction will reduce river base-flow and potentially impact river functions and ecological processes. These impacts include an increase in the frequency of cease to flow events, and an increase in the spatial extent of cease to flow conditions; declines in late dry season water quality and potentially an increase in the frequency of fish kill events; diminished connectivity within the river and disruption of fish migration; changes in the ratio of groundwater and surface water leading to changed light environments and effects on benthic primary producers; and loss of productive flow dependent habitat such as riffles.

Better understanding of the spatial ecology of key fish species will contribute to an improved ecological basis for water resource management of large perennial rivers of the Top End. Barramundi (*Lates calcarifer*) is regarded as a priority species due to its high public profile and cultural importance. The basic ecology of barramundi in northern Australia has been well described in a series of publications dating from 1982-1985 (Davis 1982, Davis and Kirkwood 1984, Davis 1985, Russell and Garrett 1985). The life history of the species includes migration between freshwater and coastal marine habitats, and sequential hermaphroditism whereby larger individuals are female. Individuals can move between marine and freshwater habitats several times during their lifetime, though there is much individual variability. For many years, it has been widely accepted that the life history of barramundi includes an obligatory downstream migration for breeding followed by upstream movements of juveniles which occupy freshwater habitat until maturity. However, recent research has demonstrated high levels of individual variation in barramundi migration. The recent availability of acoustic telemetry provides the opportunity to collect much better information on the movement requirements of barramundi to support water allocation decisions. Although most of the research effort will be focussed on barramundi, some effort will be directed towards other species such as fork-tailed catfish and potentially involve other culturally important species such as bull sharks and freshwater sawfish.

This project will document and model movement responses in relation to intra and inter-annual variation in flow. This information can be used for the development of environmental flow recommendations. The project will identify specific behavioural responses to flow that could be used to optimise the utilisation of water while still protecting key components of the flow regime. Incorporation of the results of this project into environmental planning processes will achieve improved conservation outcomes for a range of fish species and riverine ecosystems more generally.

This is a collaborative project involving researchers from the Aquatic Health Unit of the Department of Environment and Natural Resources (DENR), Charles Darwin University (CDU) and NT Fisheries. Field support is provided by the Yugul Mangi Land and Sea Management rangers based at Ngukurr, NT Fisheries, and the Water Monitoring Group of DENR. The co-leaders of the project are Dr Peter Dostine (DENR) and Associate Professor David Crook (CDU). This report summarises results for the 2015/2016 wet season.

2. Methods

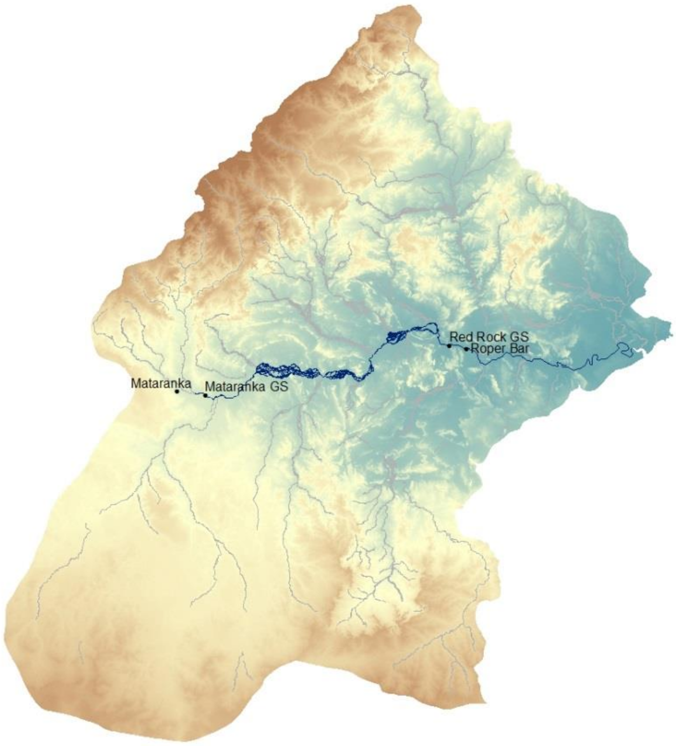
2.1 Hydrology

Hydrological data for the Roper River is available from gauging stations at Mataranka (G9030176) and Red Rock (G9030250). Data on mean daily flow and mean daily water level in the 2015/16 flow season was downloaded from the NT Water Data Portal https://nt.gov.au/environment/water/water-data-portal. Gauge station data will be augmented by water level data collected using submersible loggers at key points along the river including immediately downstream of tagging sites, and upstream of potential in-stream barriers to fish passage, including Roper Bar. Seven INW PT2X pressure and temperature loggers, and one INW CT2X pressure, temperature and conductivity logger have been deployed to record data at 15 minute intervals (Table 1, Figure 1). Five environmental loggers were downloaded in mid-June; two could not be accessed and were not downloaded.

No.	Site	G code	Latitude	Longitude	Type	Data types
1	Rocky Bar	G9035144	-14.73621	134.05002	PT2X	Level, Temp
2	Rocky Bar d/s	G9030029.02	-14.70175	134.08401	PT2X	Level, Temp
3	The Swing u/s	G9030029.01	-14.68034	134.10974	PT2X	Level, Temp
4	Big River reach	G9030036	-14.58913	134.31926	PT2X	Level, Temp
5	Rockbar 24	G9030035	-14.60402	134.35753	PT2X	Level, Temp
6	Rockbar 27	G9030034	-14.64233	134.37035	PT2X	Level, Temp
7	Scraper Hole	G9030037	-14.6848	134.37395	PT2X	Level, Temp
8	Roper Bar	G9030012	-14.71383	134.50578	CT2X	Level, Temp, EC

Table 1. Location of environmental data loggers at eight sites on the lower Roper River.

a)



b)

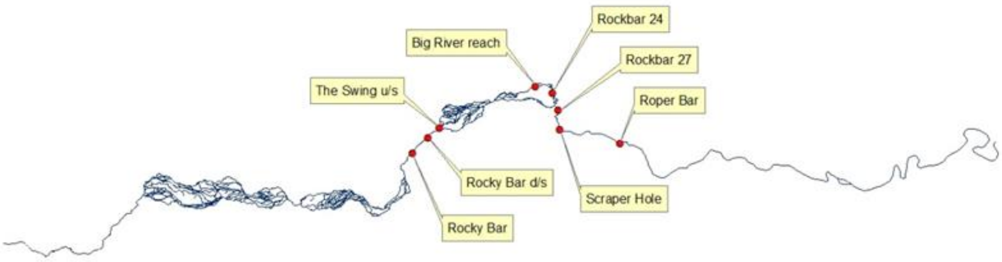


Figure 1. (a) Map of Roper catchment showing study reach and localities mentioned in text; (b) study reach and location of environmental loggers.

Figure 2. (a) Riffle cascade at ‘The Swing’ on Lonesome Dove station, (b) aerial view of ‘The Swing’, (c) riffle cascade beside lateral gravel bar, Scraper Hole paddock, Mt McMinn station, (d) aerial view of lateral gravel bar on Mt McMinn station, (e) road crossing at Roper Bar, and (f) aerial view of Roper Bar.

2.2 Fish movement

Patterns of movement of tagged fish are described from detections by an array of passive receivers. Thirty eight receivers have been deployed along the main stem of the Roper River from Elsey Station near Mataranka to the river mouth, a distance of >300 kilometres (Figure 3). All of the receivers in the freshwater section upstream of the tidal limit at Roper Bar are fixed to bankside trees with stainless steel cable, and anchored to the bottom by heavy chain (Figure 4). Most (12/15) of the receivers in the tidal portion of the river from Roper Bar to the mouth are 'pop-up' acoustic release receivers which can detach from an anchor point on the river-bed when instructed by an acoustic signal, and then be recovered after floating to the surface.

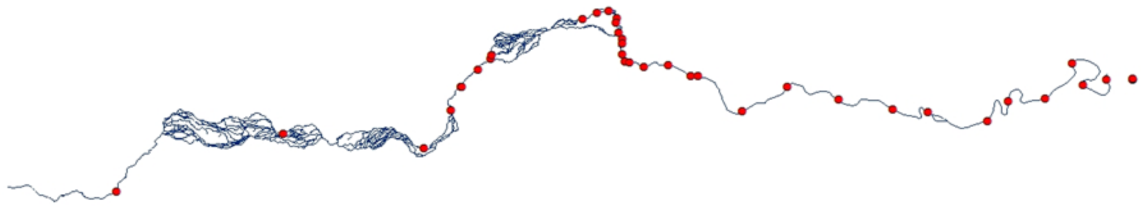


Figure 3. Distribution of VEMCO acoustic receivers in Roper River array from near Mataranka to the mouth of the Roper River.

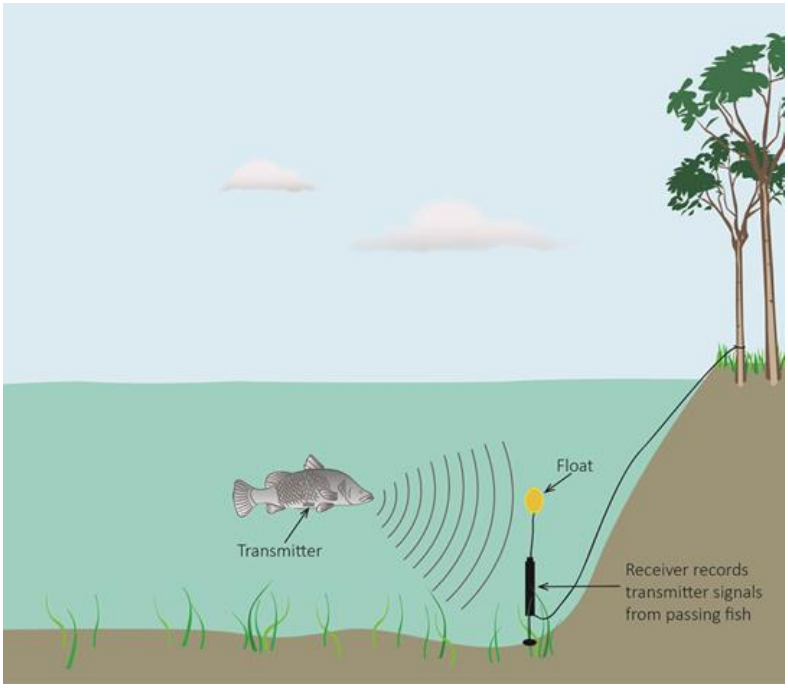


Figure 4. Diagram showing method of deployment of VEMCO receivers in the freshwater section of the Roper River.

Transmitters have been surgically implanted into the abdominal cavity of 100 fish, including 80 barramundi (*Lates calcarifer*) and 20 fork-tailed catfish (*Neoarius graeffei*). Fifty barramundi and 20 fork-tailed catfish were tagged in the Roper River on Mt McMinn station between 14-23rd September 2015. All but two barramundi were tagged at the same site; two fish were captured, tagged and released in the channel just downstream from the main site. Thirty barramundi were tagged in the Roper River on Flying Fox station from 16-19th November 2015. Given the estimated tag-life of 1,316 days, tags are expected to expire from 22nd April 2019. This tag-life will provide data across four wet seasons until the end of the wet season of 2018/19.

Dates of data retrieval from acoustic loggers in 2015/16 are listed in Table 2.

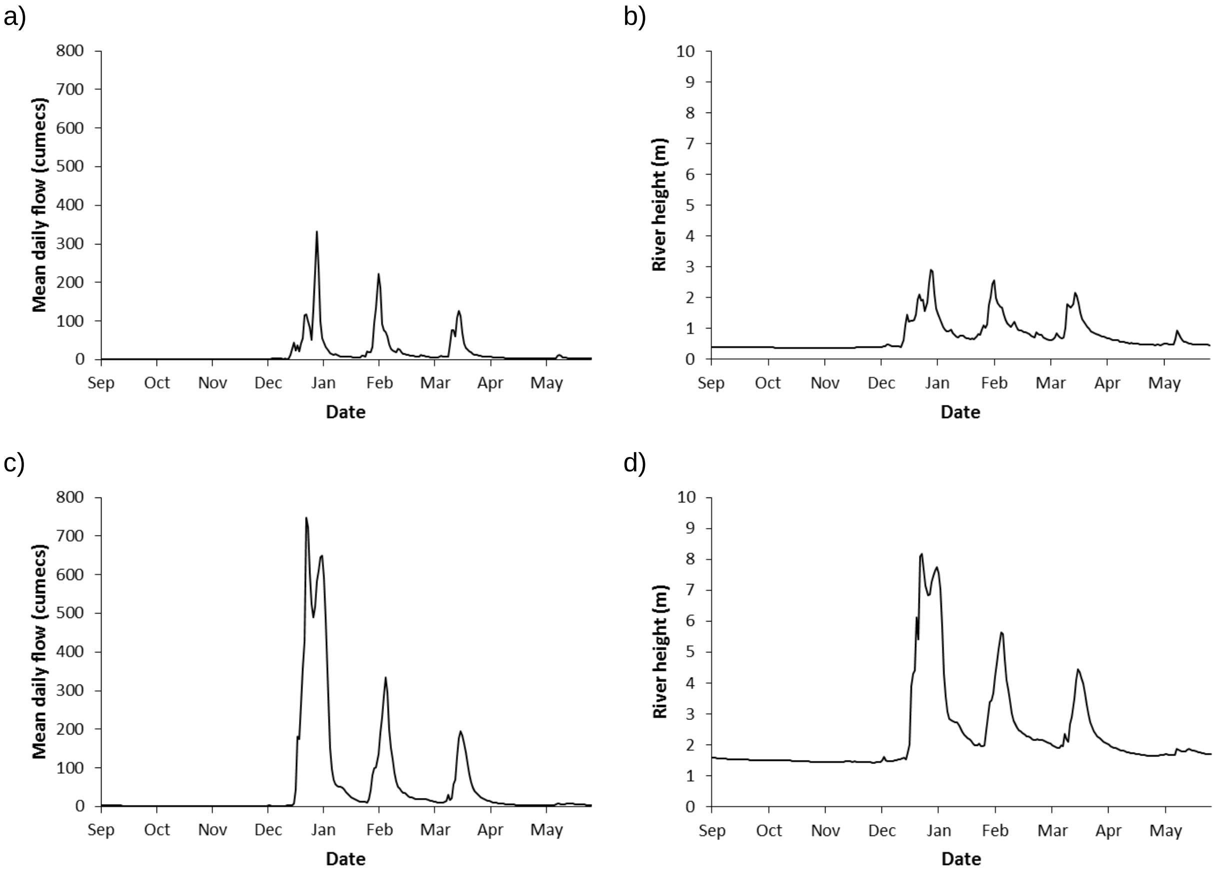


Figure 5. (a) Mean daily flow (cumecs) at Mataranka gauge station (G9030176) from 1 Sep 15 to 31 May 16, (b) mean daily river height (m) at Mataranka, (c) mean daily flow at Red Rock gauge station (G9030250) from 1 Sep 15 to 31 May 16, (d) mean daily river height at Red Rock.

Receiver number	Receiver type	Date	River reach	# detections
126746	VR2W	22-Jun-16	freshwater	13
126727	VR2W	08-Oct-15	freshwater	32
126727	VR2W	16-May-16	freshwater	14
126728	VR2W	17-May-16	freshwater	298
126749	VR2W	17-May-16	freshwater	49904
126744	VR2W	17-May-16	freshwater	163567
126753	VR2W	17-May-16	freshwater	8526
126752	VR2W	17-May-16	freshwater	198
126745	VR2W	17-May-16	freshwater	93
126735	VR2W	18-May-16	freshwater	42
126736	VR2W	21-Sep-15	freshwater	5720
126736	VR2W	23-Sep-15	freshwater	6972
126736	VR2W	13-Oct-15	freshwater	68475
126736	VR2W	18-May-16	freshwater	508694
126747	VR2W	16-Sep-15	freshwater	890
126747	VR2W	21-Sep-15	freshwater	11665
126747	VR2W	23-Sep-15	freshwater	5237
126747	VR2W	23-Oct-15	freshwater	56993
126747	VR2W	17-May-16	freshwater	345805
126724	VR2W	17-May-16	freshwater	19375
126741	VR2W	18-May-16	freshwater	696
126738	VR2W	18-May-16	freshwater	42
126739	VR2W	18-May-16	freshwater	82
126733	VR2W	18-May-16	freshwater	37
126742	VR2W	18-May-16	freshwater	55
126748	VR2W	18-May-16	freshwater	987
126734	VR2W	12-Sep-15	freshwater	1
126734	VR2W	18-May-16	freshwater	130
126743	VR2W	12-Sep-15	freshwater	1
126743	VR2W	18-May-16	freshwater	210
126731	VR2W	08-Dec-15	freshwater	0
126731	VR2W	04-Apr-16	freshwater	1003
126731	VR2W	17-May-16	freshwater	174
126729	VR2W	04-Apr-16	tidal	15
126729	VR2W	17-May-16	tidal	0
126737	VR2W	05-Apr-16	tidal	294
126737	VR2W	17-May-16	tidal	298
126726	VR2W	05-Apr-16	tidal	74
126726	VR2W	17-May-16	tidal	0
545970	VR2AR	05-Apr-16	tidal	40
545970	VR2AR	17-May-16	tidal	0
545966	VR2AR	17-May-16	tidal	45
545967	VR2AR	17-May-16	tidal	46
545964	VR2AR	17-May-16	tidal	51

545972	VR2AR	06-Apr-16	tidal	6
545965	VR2AR	06-Apr-16	tidal	33
545974	VR2AR	06-Apr-16	tidal	15
545969	VR2AR	06-Apr-16	tidal	55
545971	VR2AR	06-Apr-16	tidal	418
545975	VR2AR	14-May-16	tidal	346
545968	VR2AR	18-May-16	tidal	627

Table 2. Dates of data retrieval from acoustic loggers in Roper River array.

3. Results

3.1 Hydrology

There were three flood pulses in the Roper River in the 2015/16 wet season, with the largest flood occurring in late December and early January (Figure 5). Water level profiles differed between sites depending on channel morphology. Flood heights are lower in sections with low banks near braided channels (e.g. Figure 6b). Conversely, flood heights are higher in channels with high banks (e.g. Figure 6c). The conductivity data collected at Roper Bar was compromised by data drift.

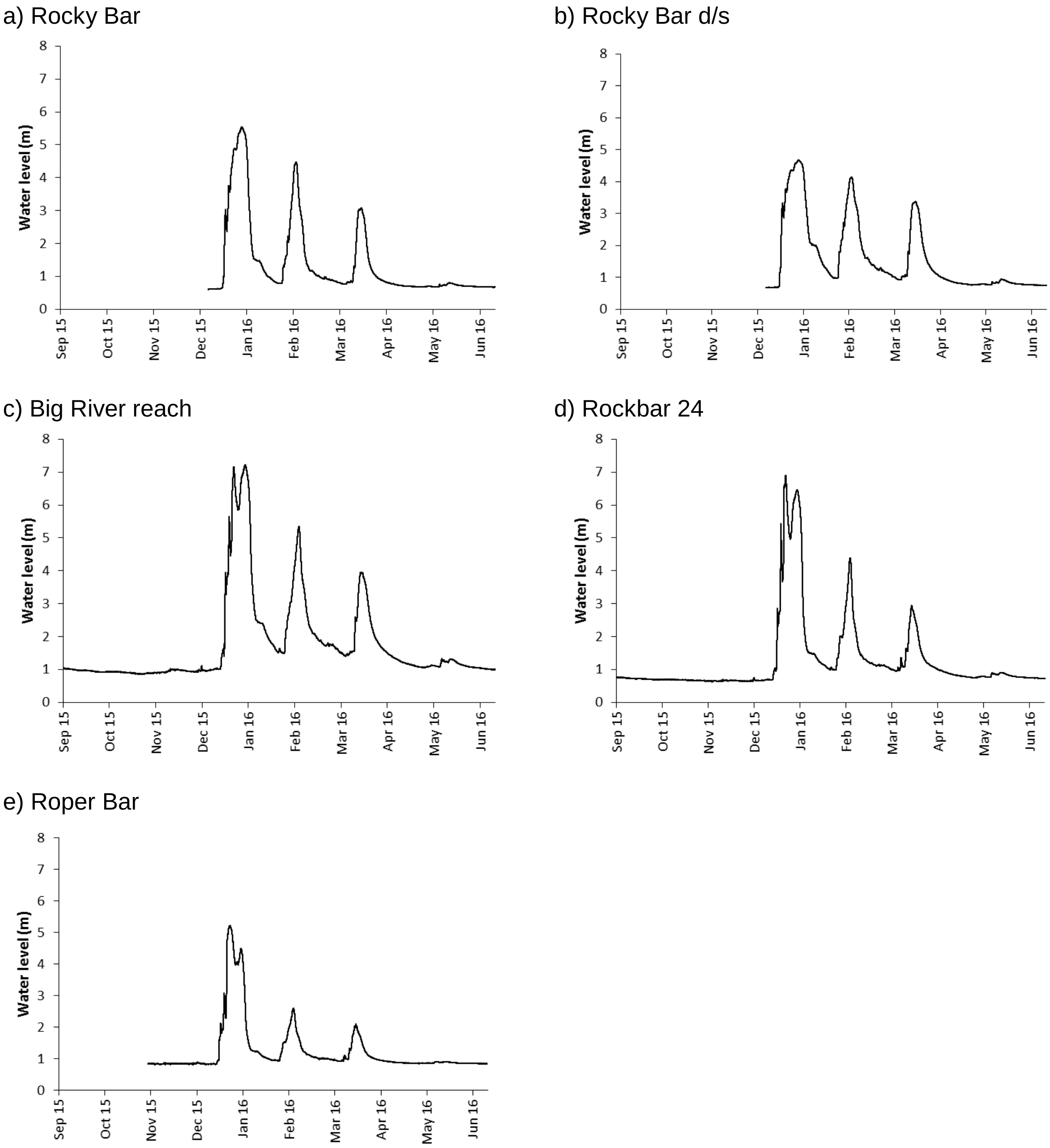


Figure 6. Water level at five sites on the lower Roper River during the 2015/16 wet season. Level not corrected to AHD.

3.2 Fish length frequency distribution

The body lengths of fish tagged at Mt McMinn ranged between 450 and 1010 mm, with a median length of 645 mm; the body lengths of fish tagged at Flying Fox ranged between 440 and 800 mm, with a median length of 610 mm (Figure 7).

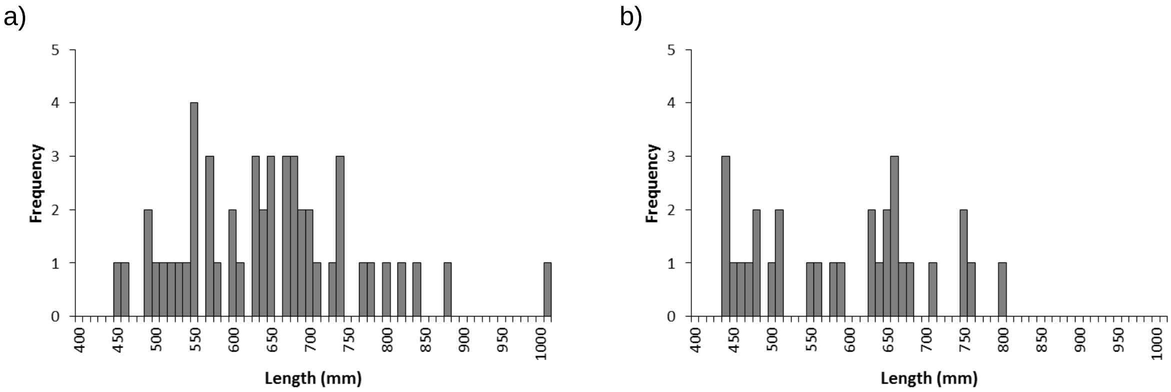


Figure 7. Frequency distribution of total body length of barramundi tagged at (a) Mt McMinn, and (b) Flying Fox stations on the Roper River.

Mt McMinn n = 50, range 450-1010, median = 645 mm; Flying Fox n = 30, range 440-800, median = 610 mm

3.3 Database records

The database (as at 30th June 2016) contains over one million detection records. All but three barramundi and two fork-tailed catfish are represented in the data. The detection data are summarised in Table 3. Barramundi contributed about 60% of the total number of detection records; fork-tailed catfish contributed 40% of detection records, reflecting the fact that the more sedentary catfish were detected very frequently on receivers installed near the original tagging location. A screen-shot of the VUE database displaying detection histories of individual fish shows a gap in the records associated with the first major flood in late December (Figure 8).

Species	# tagged	# detected	# detections	%
Barramundi	80	77	745,711	59.6
Fork-tailed catfish	20	18	504,904	40.4
Total	100	95	1,250,615	

Table 3. Summary of detection record data in VUE database.

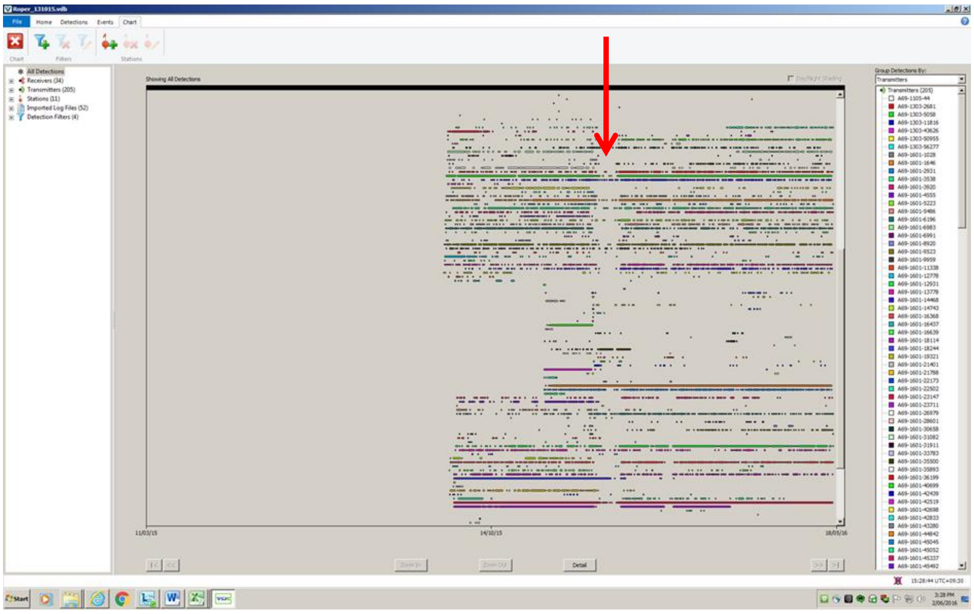


Figure 8. Screen shot of VEMCO VUE database showing effect of high wet season flow on detection histories. Tagged fish are less likely to be detected during periods of high river flow (shown at red arrow).

3.4 Fish movement

Most barramundi tagged on Mt McMinn station (42 of 50) did not undertake significant movements in either an upstream or downstream direction. Six barramundi were detected immediately upstream of Roper Bar during the wet season, with four fish migrating to the Roper estuary mouth. The timing of departure of these fish varied between individual fish, but mostly coincided with flow peaks during the wet season, although one fish departed after the cessation of high flows in late April. Three of the four fish that migrated to the mouth were >800 mm in length. The migration from fresh water was accomplished either in a single direct movement (Figure 9a) or with several 'false starts' (Figure 9c). One fish made a return upstream journey from the Roper mouth almost to Roper Bar (Figure 9d).

Four barramundi made significant upstream movements during the wet season. The longest upstream movement was undertaken by fish #59868 which moved 106 kilometres from Flying Fox Station to Red Lily lagoon on Elsey station in 8.7 days at an average of 12.2 km/day. By comparison, fish #59909 moved a distance downstream of 173 kilometres in 5.6 days, at an average rate of 30.9 km/day (Table 4).

Data for the dates of commencement of movement by barramundi, and flows at the time of the commencement of movement, are presented for four movement classes: downstream, upstream, successful crossing of Roper Bar, and approach but unsuccessful crossing of Roper Bar (Table 5, Figure 12). In summary, downstream movements involved large fish (range 550-1010 mm), coincided with a steady or falling hydrograph, and spanned the wet season from mid-December to late April. In contrast, upstream movements involved small fish (450-740 mm), were initiated near peak flood, and occurred nearly simultaneously in late

December. Fish crossed Roper Bar at flows of at least 43 cumecs, and were not recorded crossing the bar at flows of 24 cumecs and below.

Of the 20 tagged fork-tailed catfish, two were undetected throughout the period, ten were detected by only a single receiver, seven were detected by both receivers at the tagging site, and only one moved beyond the tagging pool at Mt McMinn station (Figure 11). Fish #59833 made two forays downstream during the rising limb of the first flood in late December, returning to the tagging site on each occasion, and remained in the vicinity of the downstream logger for the remainder of the period.

Fish ID	Direction	Distance (kms)	Duration (days)	Rate (kms/day)
59896	upstream	85	10.3	8.3
59852	upstream	52	5.0	10.4
59868	upstream	106	8.7	12.2
59909	downstream	173	5.6	30.9

Table 4. Direction, distance moved, duration and rate of movement of four tagged barramundi.

Movement type	Fish ID	Length (mm)	Date	Flow (cumecs)	Hydrograph
Downstream	59914	800	18/12/15	45	Rising
Downstream	59843	840	15/1/16	38	Falling
Downstream	59843	840	23/1/16	12	Steady
Downstream	59891	1010	7/3/16	10	Steady
Downstream	59909	640	22/3/16	141	Falling
Downstream	59855	550	22/3/16	141	Falling
Downstream	59904	730	23/4/16	4	Steady
Upstream	59868	660	23/12/2015	428	Rising
Upstream	59878	480	23/12/2015	428	Rising
Upstream	59896	450	27/12/2015	524	Falling
Upstream	59852	740	3/01/2016	592	Rising
Roper Bar success	59914	800	19/12/2015	181	Rising
Roper Bar success	59843	840	29/01/2016	43	Rising
Roper Bar success	59891	1010	16/03/2016	69	Rising
Roper Bar success	59909	640	22/03/2016	141	Falling
Roper Bar success	59855	550	24/03/2016	83	Falling
Roper Bar failure	59843	840	18/01/2016	24	Falling
Roper Bar failure	59843	840	25/01/2016	13	Steady
Roper Bar failure	59904	730	12/05/2016	8	Rising

Table 5. Date, estimated flow and hydrograph behaviour at onset of migration of barramundi.

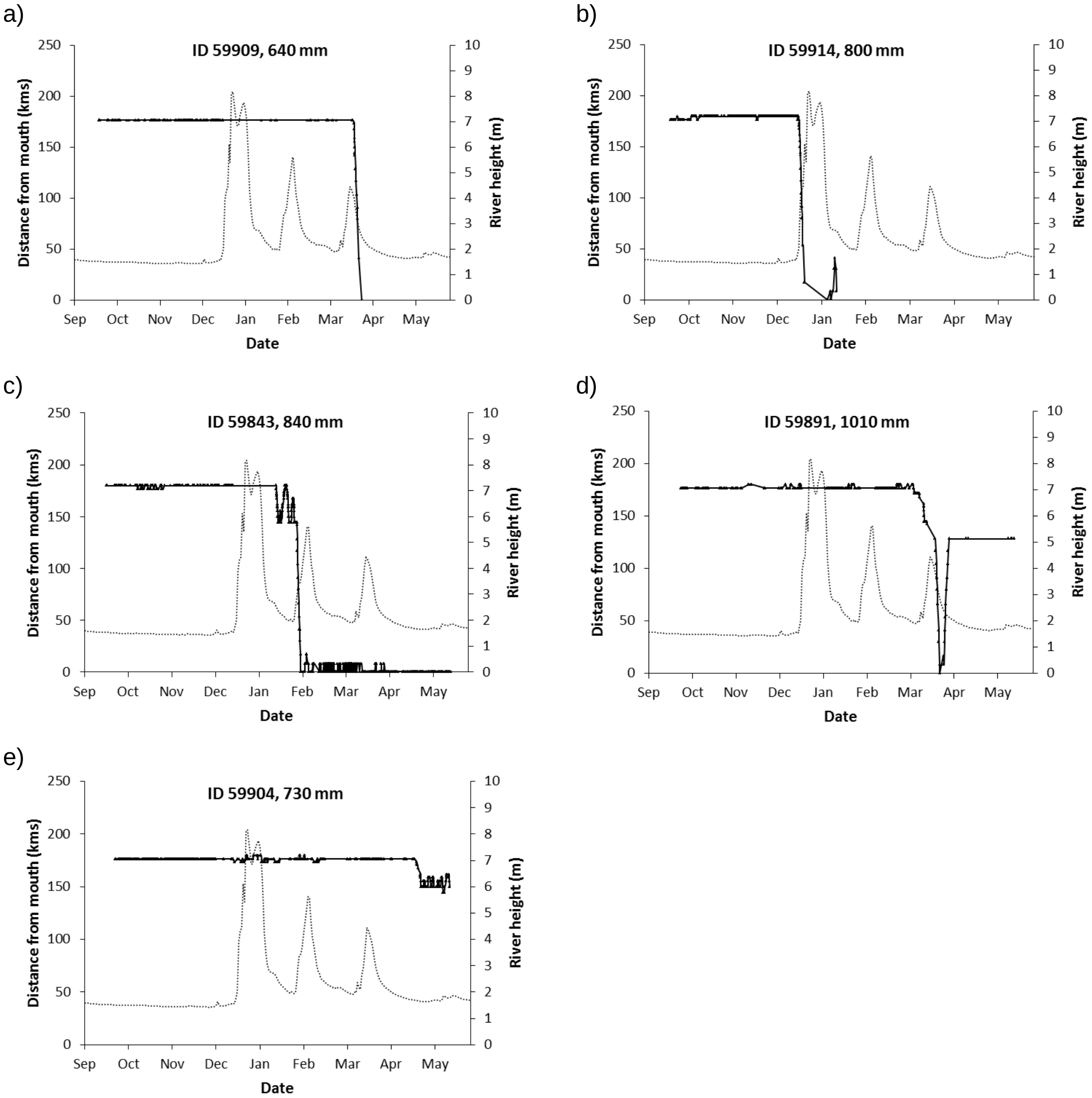


Figure 9. Significant downstream movements by five barramundi in the Roper River. Four of these five fish (a-d) crossed Roper Bar and moved downstream to the Roper mouth. The fifth fish (e) failed to cross Roper Bar.

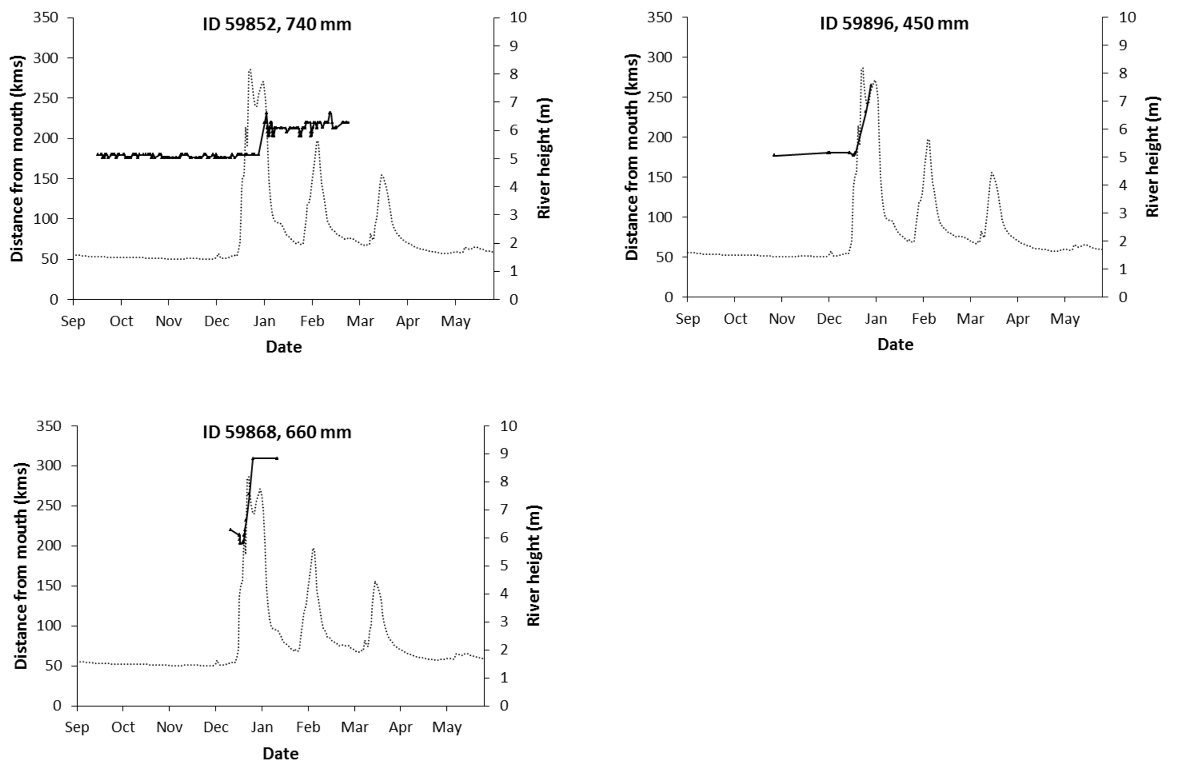
a)
b)
c)


Figure 10. Significant upstream movements of three barramundi in the Roper River, (a) fish #59852 was tagged at Mt McMinn, (b) fish #59896 was tagged at Mt McMinn, and (c) fish #59868 was tagged at Flying Fox.

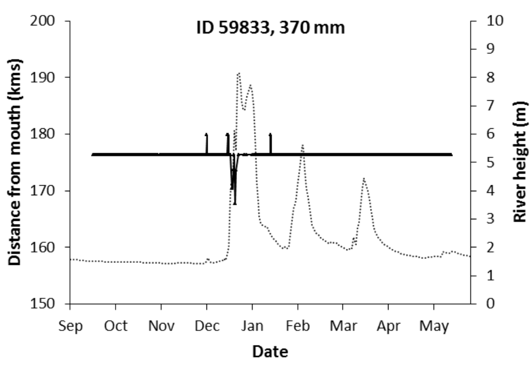


Figure 11. Movement patterns of fork-tailed catfish #59833.

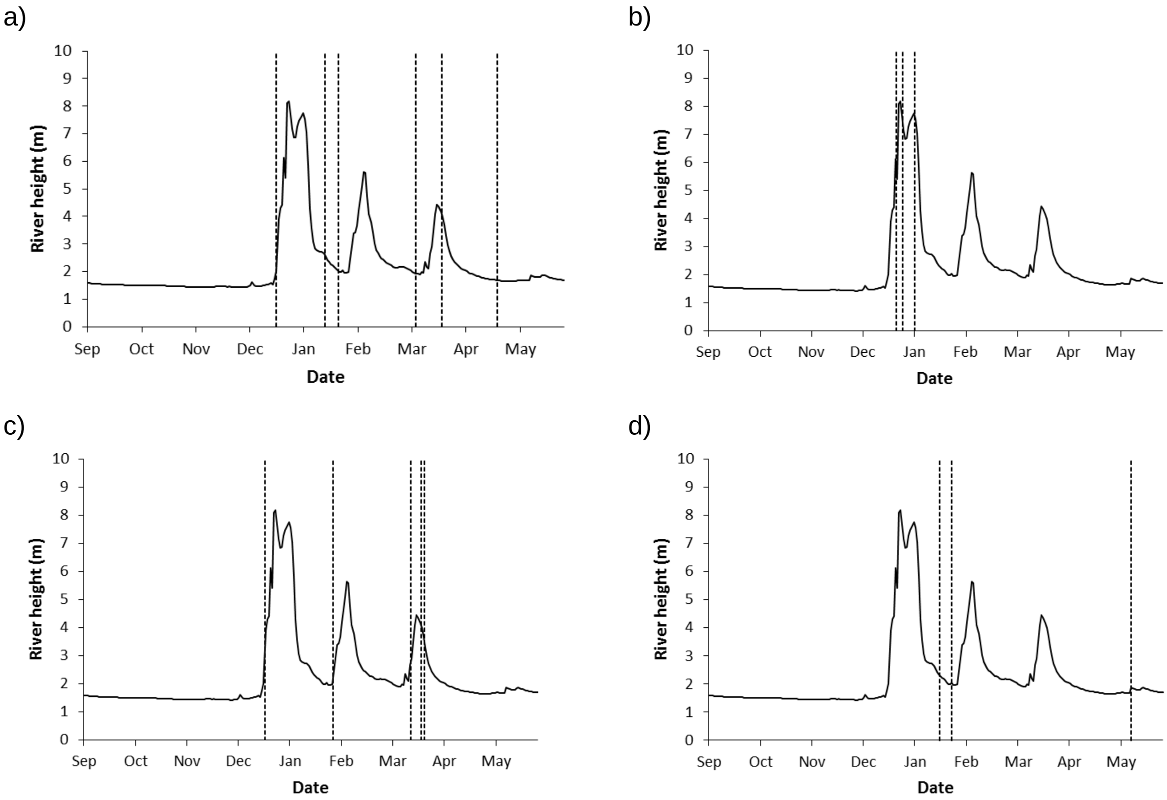


Figure 12. Hydrograph from Red Rock gauging station showing mean daily flow and (a) dates of first detection of migrating barramundi downstream from tagging location, (b) dates of first detection of migrating barramundi upstream of tagging location, (c) dates of first detection of migrating barramundi downstream of Roper Bar, and (d) dates of last detection of migrating barramundi that failed to cross Roper Bar.

4. Discussion

This project is providing valuable information on the nature, timing and extent of large-scale movement of barramundi in the freshwater and estuarine portions of the Roper River, and will make a significant contribution to understanding of flow–ecology relationships in Top End rivers. This information is critical for ecologically sensitive management of spring-fed rivers such as the Roper and Daly rivers. Preliminary results confirm the significance of flow in the ecology of barramundi in the rivers of northern Australia, as described in previous studies using different methodologies. Robins *et al*. (2006) found that growth rates of barramundi are positively related to freshwater flows to the estuary, using data from a long-term tagging program. Milton *et al.* (2008) used otolith chemistry to infer that growth rates are related to time spent in freshwater systems. The life-history of the species is intimately associated with variation in flow. High flows are thought to be required to allow migration of juveniles from estuarine to freshwater habitats; flow also appears to cue downstream spawning migration and to initiate upstream migration by sub-adult fish.

The majority of tagged barramundi demonstrated fidelity to dry season habitat and did not make substantial movements beyond the tagging site. Relatively few fish made substantial movements downstream. The movement behaviours of these fish were highly idiosyncratic, with individual fish departing throughout the wet season, with movements mostly associated with moderate and not peak flows. Few, mostly smaller, fish made substantial movements upstream. These movements appeared to be synchronous and occurred near the peak of the first flood of the wet season. There was little evidence of large-scale longitudinal movements in fork-tailed catfish *Neoarius graeffei*.

Information on the timing of passage across barriers will be used to model the relationship between probability of passage and flow. Data will be collected across successive years; preliminary data suggests that passage at Roper Bar requires flows in excess of 40 cumecs. This and other similar information will be used to inform risk assessment of the consequences of flow reduction. Whilst in its preliminary stages, our study is the first to collect detailed information on the movement responses of barramundi to specific hydrological events and, thus, will provide a better understanding of the environmental water requirements of this key species.

5. Acknowledgements

The project benefited greatly from the support and assistance of the Yugul Mangi rangers. Thanks are also due to the following individuals and organisations: Chris Errity, Wayne Baldwin, Simon Xuereb and Thor Saunders from NT Fisheries; Lachlan Hetherington, Kyle Tyler and Allen Fitzsimmons from Charles Darwin University; Andrew Drenen from Roper Landcare; Dean Donald and the Mangarrayi ranger group; Richard Campbell and Russell Irving from the Northern Land Council; and the leaseholders and managers of pastoral stations along the Roper.

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