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SHORT COMMUNICATION

Mammal predation by an ariid catfish in a dryland river of Western Australia

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The presence of the spinifex hopping mouse *Notomys alexis* in the diet of lesser salmon catfish *Neoarius graeffei* from the Ashburton River, Western Australia, is reported for the first time. The consumption of terrestrial mammals by Australian freshwater fishes is widely considered to be an infrequent occurrence, of limited importance to aquatic food webs. However, remains of *N. alexis* were present within the stomachs of 44% of *N. graeffei* sampled, constituting approximately 95% of the total stomach contents. These findings suggest that *N. graeffei* will consume large quantities of terrestrial vertebrates when available, and may represent a valuable energy source for this ecologically important species in dryland rivers.

Key words: boom, bust, fish, food web, rodent, terrestrial subsidies

Introduction

Understanding the source and transfer of energy between terrestrial and aquatic ecosystems is vital to our understanding of riverine and riparian ecosystems. Recent studies suggest that allochthonous sources of carbon may be significant for fishes in Australian rivers that experience substantial hydrological variability (i.e: dryland and wet-dry tropical rivers) (Sternberg *et al.* 2008; Davis *et al.* 2010; Blanchette *et al.* 2014; Thorburn *et al.* 2014). Identifying the relationship between variable flow regimes and terrestrial-aquatic subsidies is important for the management and conservation of dryland rivers. This is of increasing importance as Australia's warming climate, and increasing challenge to meet growing water demands, is likely to disrupt the flow regimes in many of Australia's rivers.

Dryland rivers are influenced by highly variable climatic and hydrological conditions, that produce flood pulses and 'boom' and 'bust' ecological cycles (Sternberg *et al.* 2008; Arthington and Balcombe 2011). The flood pulse concept (Junk *et al.* 1989) emphasises the importance of flood events in these systems, as they facilitate lateral exchange of biotic material between terrestrial and aquatic ecosystems. According to this concept (Junk *et al.* 1989), terrestrial inputs into aquatic ecosystems are of greater importance during flooding, and regular flood pulses promote aquatic organisms to exploit the aquatic/terrestrial transition zone. This is supported by dietary studies of fishes in Australian dryland and wet-dry tropical rivers, which indicate a high level of opportunism and omnivory; likely an adaptive response to temporally available resources (Sternberg *et al.* 2008; Davis *et al.* 2010; Blanchette *et al.* 2014; Medeiros and Arthington 2014). However, dietary studies on fishes in dryland rivers are limited, and the importance of seasonally variable terrestrial inputs, in particular, remains unclear.

Lesser salmon catfish *Neoarius graeffei* (Kner and Steindachner 1867), are a widely distributed freshwater fish in northern Australia, and compose a large percentage of total fish biomass in many northern Australian rivers (Bishop *et al.* 2001; Jardine *et al.* 2012). *N. graeffei* is an opportunistic omnivore that will ingest a wide range of different food types in response to temporally available resources (Jardine *et al.* 2012; Thorburn *et al.* 2014). Pusey *et al.* (2010) classified *N. graeffei* of the Burdekin River as an algivore-terrestrial invertivore, noting no significant ontogenetic or temporal diet variation. However, sampling for this study occurred in a river that experienced minimal habitat variation during the course of the study. In comparison, a study by Thorburn *et al.* (2014) in the Fitzroy River reported that large *N. graeffei* (>150 mm) were significantly more reliant on terrestrial inputs than small *N. graeffei* (<150 mm), which predominantly consumed aquatic invertebrates and vegetation. Additionally, the study reported temporal diet variation for larger class sizes of *N. graeffei*, where terrestrial inputs constituted a significantly larger proportion of the diet during the wet season (80%), compared to the early dry (62%) and late dry (56%) seasons (Thorburn *et al.* 2014). Terrestrial invertebrates were the most important terrestrial input for large *N. graeffei*, constituting the largest proportion of the diet during the early dry season (56%), compared to the wet (50%) and late dry (41%) seasons. Terrestrial vegetation, such as fruits, were also an important input for large *N. graeffei* during the wet season, forming 30% of the total diet, compared to only 6% and 11% during the early dry and late dry seasons, respectively (Thorburn *et al.* 2014).

These findings indicate that terrestrial inputs form an important food source for large size classes of *N. graeffei* within dryland rivers. The present study provides the first report on the consumption of the spinifex hopping-mouse (*Notomys alexis)* by large *N. graeffei* (>350 mm) in the Ashburton River during the early dry season.

Methods/Materials

The Ashburton River is one of the largest dryland rivers in Australia, stretching 560 km, and draining an area of 66,850 km^2 (Water and Rivers Commission 2005). It has an extremely variable flow regime that is characterised by periods of little to no flow punctuated by significant flood events, generated by monsoon lows and tropical cyclones (Grootemaat 2008), which deliver almost 90% of the river's annual rainfall during the wet season (January to June) (Bureau of Meteorology 2016).

As part of a larger study on the health of native catfish in northern Australia, 18 *N. graeffei* (weight 140-1495 g, TL 24.5-51 cm) were collected from the Ashburton River in July 2015, during the early dry season. Sampling was conducted over two days, along one section of the Ashburton River (between -21.777684, 114.981715 and -21.778783, 114.983289), using a combination of gill nets and baited lines.

Fish were euthanised by prolonged immersion in an anaesthetic bath of isoeugenol (AquiS). Sex, weight, and total length (TL) measurements were recorded for each individual. As part of a standard post-mortem, the gastrointestinal tract was removed from each fish, and the stomach contents examined.

Results

Small mammals, at various stages of digestion, were found within the stomachs of eight *N. graeffei* (weight 525-1495 g, TL 353-510 mm), constituting approximately 95% of the total stomach contents. In two of the catfish (1495 g, 510 mm, and 695 g, 395 mm), the remains of three small mammals were present in each stomach.

In most cases, the mammals were at an advanced stage of digestion; however three specimens were placed in formalin and identified at the Western Australian Museum (WAM). Here, the specimens were washed, preserved in ethanol, and registered as WAM M64824, M64825 and M64826. M64824 was the least digested of the three specimens, and displayed external features typical of the spinifex hopping mouse *Notomys alexis* Thomas 1922 (Fig. 1), including long and thin hind legs, an upper body of brown coloured hair, with a light grey-white underbelly, and a tuft of white hair at the end of a long tail (Van Dyck *et al.* 2013). M64825 and M64826 were too heavily digested to identify based on external features, however the skull morphology and dentition of these individuals was also consistent with sub-adults of *N. alexis.*

Discussion

This is the first report of *N. alexis* ingestion by any fish species and first report of high levels of terrestrial mammal consumption by any Australian catfish. This is in contrast to previous studies which report terrestrial mammals as an infrequent dietary item for *N. graeffei*, contributing a recorded maximum of 4% to total diet (Pusey *et al.* 2010; Thorburn *et al.* 2014). The dominance of *N. alexis* within the diet of *N. graeffei* sampled, suggests that terrestrial mammals may be consumed at much higher rates, and be a more valuable prey item to *N. graeffei* in dryland rivers, than previously believed. Terrestrial vertebrates in the diet of northern Australian fishes are reported in the catfishes *Neoarius leptaspis* (Bleeker, 1862) (Bishop *et al.* 2001) and *N. graeffei* (Thorburn *et al.*, 2014), as well as mouth almighty *Glossamia aprion* (Richardson, 1842) (Thorburn *et al.* 2014), and several species of *Hephaestus* (Davis *et al.*, 2010), and may be an undervalued resource to food webs in northern Australian dryland rivers.

The mechanism that makes *N. alexis* available to *N. graeffei* in the Ashburton River is unknown. Excluding reports of catfish beaching themselves to ambush pigeons (Coucherousset *et al.* 2012), most predation of terrestrial vertebrates by fishes occurs opportunistically, necessitating the introduction of terrestrial prey into the aquatic habitat. Both *N. graeffei* and *N. alexis* are nocturnal (Watts and Kemper, 1989), increasing the potential for predator-prey interactions between these species. Although many fishes gain opportunistic access to small mammals as they attempt to cross a body of water, the elongate hind legs and tail of *N. alexis* are specialised for saltatory locomotion, and there are no reports of *N. alexis* intentionally spending time in the water (Watts and Kemper, 1989). However, *N. alexis* has been reported to construct deep burrow systems in the sand of river banks (Thompson and Thompson, 2007), predisposing *N. alexis* to predation by *N. graeffei*. As *N. alexis* often lives in small colonies within a single burrow system (Watts and Kemper, 1989), collapse or flooding of one or multiple burrows along the Ashburton River could inadvertently introduce individuals into the water, providing *N. graeffei* with the opportunity to ingest individual rodents pre- or post-mortem.

Predation of small terrestrial mammals by fishes increases with greater prey abundance, and forms an episodically important resource for some fish populations (Lisi *et al.* 2014). In Australia, populations of *N. alexis* will often increase within three to ten months after periods of rainfall (Dickman *et al.*, 1999), and in some seasons are present in 'plague' proportions. Although there is no data on the population dynamics of *N. alexis* in the Pilbara region during the period of sampling for this study, fish were collected during the early dry season - a time of expected population growth for *N. alexis.* Studies indicate that *N. graeffei* will alter its diet in response to temporally available resources (Jardine *et al.* 2012; Thorburn *et al.* 2014), and these findings suggest that *N. graeffei* may consume large quantities of terrestrial vertebrates when available. However, additional dietary studies of *N. graeffei* are required to elucidate the widespread importance of terrestrial vertebrate subsidies in dryland rivers, and expand our understanding of aquatic-terrestrial linkages in arid and semi-arid environments in Australia. This knowledge is of timely importance, as recent climate projections indicate that northern Australia will experience increased temperatures, longer warm spells and increased intensity of extreme rainfall events within this century (CSIRO and Bureau of Meteorology 2015). These factors have the potential to disrupt flooding patterns and flow regimes, leading to ecosystem changes that are likely to threaten the biodiversity of dryland rivers in Australia.

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Figure 1: Specimen M64824, identified as a Spinifex Hopping-mouse *Notomys alexis*