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Short Note

Diet of bluegill *Lepomis macrochirus* in a South African reservoir during winter and summer

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Alien fishes are considered a major threat to aquatic biodiversity in South Africa, yet relatively little regional information on their biology and ecology is available for many of these species. Seasonal changes in the diet of the bluegill *Lepomis macrochirus* in Howieson's Poort Dam, Grahamstown, were assessed during summer and winter in 2014–2015, using stomach content analysis. In winter, juvenile and adult fish diets were dominated by crustacean zooplankton and insects, respectively. In summer, juvenile fish fed on crustaceans and insects, whereas adults consumed mostly fish eggs, indicating a potential impact by these invasive fish on native fish through oophagy.

Keywords: dietary shift, non-native fish, prey groups, stomach contents

South Africa is considered to be a fish-invasion hotspot (Leprieur et al. 2008), with alien fishes now present in all major South African river systems (Ellender and Weyl 2014). However, there is relatively little local information on the biology and ecology of many alien species. Bluegill, *Lepomis macrochirus* Rafinesque, 1819 (Centrarchidae), was first introduced into South Africa from the USA in 1938 as a fodder fish for bass (Ellender and Weyl 2014). The species has populations in the Eastern Cape, Western Cape and KwaZulu-Natal, and have been evaluated as "fully invasive", using the Blackburn et al. (2011) criteria, in that they are surviving, dispersing and reproducing at multiple sites in South Africa (Ellender and Weyl 2014). Although *L. macrochirus* was evaluated as a high-risk invasive species in South Africa (Marr et al. 2017), that evaluation was based on impacts documented outside Africa, as there is no published information available on the impacts of this species on the aquatic environment in South Africa. Elsewhere, *L. macrochirus* predation has been shown to decrease the abundance of certain invertebrates (Mittelbach 1988) and the species can outcompete native fish species for food (Marchetti 1999). For example, in California, *L. macrochirus* outcompetes Sacramento perch *Archoplites interruptus* for food, resulting in slow growth of this native fish (Marchetti 1999). Since the impacts of alien species have been shown to be context-dependent (Ricciardi and Atkinson 2004), an understanding of the diet of *L. macrochirus* in the South African context is important, for which research could help to determine the potential impact of the species on native fauna. The aim of the current study was to describe the diet of *L. macrochirus* in a small impoundment in the Eastern Cape, South Africa.

Lepomis macrochirus were collected from Howieson's Poort Dam (33°23.21' S, 26°29.07' E), an approximately 16.3 ha water supply reservoir constructed in 1929–1931, during summer (December 2014 and February 2015) and winter (June–July 2015) using a multi-method approach, including fyke nets, gillnets and a seine net, to sample all *L. macrochirus* size classes adequately. A total of 81, 69, 54 and 62 *L. macrochirus* were collected during December, February, June and July, respectively. After capture, fish were immediately euthanised with an overdose of the anaesthetic eugenol (clove oil) and kept on ice until they reached the laboratory that same day. In the laboratory, each fish was measured to the nearest mm for fork length (FL), and the stomach of the fish was then removed by dissection and fixed in 10% formalin before being transferred to 70% ethanol for storage.

In the laboratory each stomach was dissected and the contents were analysed according to the procedures outlined by Wassermann et al. (2011). Contents were emptied into a dissecting tray and, with the exception of fish eggs and fish, were identified to family level under a dissecting microscope following the identification guides of Gerber and Gabriel (2002). Prey counts were based on heads, as other parts were often digested. The volume of each prey taxon was determined using an indirect volumetric method, whereby prey items were squashed under a glass slide to a uniform depth within a custom-made 5 mm-deep dissecting tray with 1 mm × 1 mm grid markings and the volume was

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calculated as the grid-area covered. As recommended by Hyslop (1980), data were quantified via the index of relative importance (IRI, Pinkas et al. 1971), using the formula equation *IRI* = (%*N* + %*V*) x %*F*, where %*F* is the frequency of occurrence (number of stomachs containing a prey taxon expressed as a percentage of all stomachs sampled), %N is the numerical abundance of each prey taxon expressed as a percentage of all prey identified and %V is the volume of each prey taxon expressed as a percentage of the total volume of all prey. The index of relative importance (IRI) values were then expressed as the proportion of the sum of IRI values calculated for all prey items (%IRI). As is common practice in gut content studies, IRI was calculated only for identifiable prey taxa (cf. Weyl et al. 2010; Wasserman et al. 2011).

For further analysis, *L. macrochirus* specimens were categorised into winter (June–July) and summer (December and February) samples of three size classes, representing young-of-year (YOY 26–70 mm FL), juveniles (71–140 mm FL) and adults (>140 mm FL). To assess differences among *L. macrochirus* size classes across seasons, a community analysis approach was employed whereby %IRI values were analysed in Primer 6 by using a cluster analysis based on the Bray–Curtis similarity index (Clarke and Gorley 2006).

The total sample comprised 266 specimens of *L. macrochirus*, including 116 fish collected in winter and 150 in summer. Although algae and plants were occasionally present in the stomachs of all size classes, invertebrates dominated the diet of *L. macrochirus* in the current study. Prey comprised a total of 10 taxa in winter and 14 taxa in summer. The %F and %IRI for all prey encountered in stomachs of young-of-the year (YOY), juvenile and adult fish in summer and winter are summarised in Table 1. Seven prey groups, comprising Calanidae, Daphniidae, Libellulidae, Araneidae, Pyralidae, Chironomidae and Dytiscidae, were encountered in both seasons. Analysis of %IRI demonstrated that there was a clear shift in diet with size class in winter. In this season the diet of YOY fish was dominated by zooplanktonic crustaceans of the family Chydoridae (%IRI = 74.9) and Daphniidae (%IRI = 20.3); juvenile diet was dominated by crustaceans of the family Sididae (%IRI = 92.9) and Ostracoda (%IRI = 6.9); whereas adult fish consumed mostly insects (Libellulidae %IRI = 80.4 and Chironomidae %IRI = 16.4). During winter Araneidae and Cyprididae contributed the least (%IRI = 0.1) to the diet of YOY. Libellulidae, Chironomidae and Dytiscidae made the lowest contribution (%IRI = <0.1) to the diet of juvenile fish, whereas Cyprididae contributed the least (%IRI = 3.3) to that of adult fish. Diet shifts were also clearly evident in summer, when YOY fish fed mainly on Daphniidae (%IRI = 93.9), juveniles fed on Daphniidae (%IRI = 34.3) and fish eggs (%IRI = 64.36), whereas adult *L. macrochirus* fed mostly on fish eggs (%IRI = 98. 8) (Table 1). Araneidae contributed the least to adult fish diet in summer (%IRI <0.1), whereas Ceratopogonidae, Ecnomidae and Naucoridae all contributed %IRI <0.1 to that of juvenile fish. YOY fish diets comprised numerous prey taxa, such as Oligoneuriidae, Ceratopogonidae, Chironomidae, Gyrinidae, Ecnomidae and Pyralidae that contributed relatively little to the overall diet (%IRI <0.1). Community analysis (CLUSTER) demonstrated that the effects of season on diet were more pronounced for larger sized fish (Figure 1).

Table 1: Gut contents of three *Lepomis macrochirus* size classes sampled from Howiesons Poort Dam in winter 2015 (YOY *n* = 59, juveniles = 66, adults = 25) and summer 2014 (YOY *n* = 38, juveniles = 42, adults = 36). YOY = 26–71 mm FL, juveniles = 71–140 mm FL, adults = >140 mm FL. Frequency of occurrence (%F) was calculated as the number of stomachs containing a given prey taxon, expressed as a percentage of all stomachs sampled. Percentage index of relative importance (%IRI) was calculated as a percentage of the total IRI from all dietary categories

Taxa	Winter						Summer					
	YOY		Juveniles		Adults		YOY		Juveniles		Adults	
	%F	%IRI	%F	%IRI	%F	%IRI	%F	%IRI	%F	%IRI	%F	%IRI
Calanidae	7.89	1.11	0.00	0.00	0.00	0.00	18.64	2.21	3.03	0.09	0.00	0.00
Daphniidae	13.15	20.28	0.00	0.00	0.00	0.00	37.29	93.89	10.61	34.30	0.00	0.00
Sididae	5.29	0.80	4.76	93.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chydoridae	21.05	74.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprididae	2.63	0.05	7.14	6.95	2.78	3.27	0.00	0.00	0.00	0.00	0.00	0.00
Araneidae	2.63	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.03
Libellulidae	0.00	0.00	0.38	0.04	16.67	80.36	10.17	0.36	4.55	0.06	0.00	0.00
Chironomidae	7.89	1.87	0.38	0.04	5.56	16.37	5.09	0.04	6.06	0.27	0.00	0.00
Pyralidae	5.26	0.89	0.00	0.00	0.00	0.00	1.70	0.02	0.00	0.00	0.00	0.00
Naucoridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	0.01	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	18.64	3.09	4.55	0.61	0.00	0.00
Gyrinidae	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00	0.00	0.00	0.00	0.00
Ecnomidae	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.01	1.50	0.02	8.00	0.17
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.05	0.00	0.00	0.00	0.00
Ceratopogonidae	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.01	0.03	0.02	0.00	0.00
Oligoneuriidae	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.02	0.00	0.00	0.00	0.00
Dytiscidae	0.00	0.00	2.38	0.03	0.00	0.00	0.00	0.00	1.52	0.15	0.00	0.00
Teloganodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.03	0.07	8.00	0.55
Fish eggs	0.00	0.00	0.00	0.00	0.00	0.00	5.08	0.29	24.24	64.36	36.00	98.78
Fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	0.34

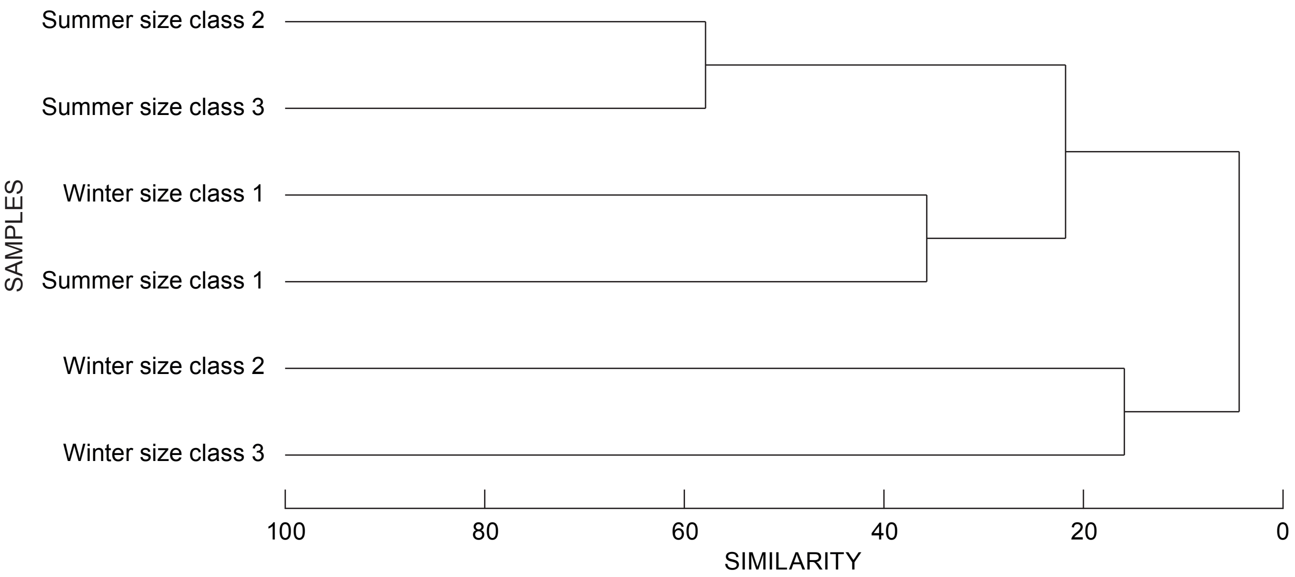

Figure 1: Dietary similarities (%IRI) among three size classes of *Lepomis macrochirus* sampled from Howieson's Poort Dam during winter and summer seasons in 2014–2015. Clustering method = group average, size class 1 = YOY (26–71 mm FL), 2 = juveniles (71–140 mm FL), 3 = adults (>140 mm FL)

Overall, the results of the current study demonstrate that *L. macrochirus* in this impoundment were generalist feeders. This is similar to their feeding ecology in their native range (Dewey et al. 1997; Olson et al. 2003). The large proportion of fish eggs in their diet in summer indicates that the fish are most likely utilising prey relative to their availability. Neff (2003) report that cannibalism of eggs is common in *L. macrochirus*. It is therefore likely that the observed oophagy was a result of cannibalism, whereby *L. macrochirus* were feeding from conspecific nests. Oophagy by *L. macrochirus* also has relevance for their potential impact on African fishes, many of which also construct nests in sandy and rocky habitats (Ribbink et al. 1983).

The potential for *L. macrochirus* to raid nests and forage on the eggs of native fishes therefore warrants further investigation, especially because this might be one of the mechanisms for the observed negative impacts of this species on native fish abundance (Maezono et al. 2005). Future studies should compare the diet of *L. macrochirus* with that of other fish species in systems where *L. macrochirus* is invasive. In addition, comparative studies on the foraging efficiencies, interference competition and intra-guild predation of *L. macrochirus* and native species would add to the understanding the invasion impact of *L. macrochirus* in aquatic systems in the South African region.

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