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Diet Overlap between the Endemic Fish *Anabarilius grahami* (Cyprinidae) and the Exotic Noodlefish *Neosalanx taihuensis* (Salangidae) in Lake Fuxian, China

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Diet Overlap between the Endemic Fish *Anabarilius grahami* (Cyprinidae) and the Exotic Noodlefish *Neosalanx taihuensis* (Salangidae) in Lake Fuxian, China

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ABSTRACT

We studied diet composition and overlap of the exotic noodlefish (*Neosalanx taihuensis*) and the endemic fish *Anabarilius grahami* in a deep, oligotrophic lake in the Yunnan Plateau. *A. grahami* dominated the fish community in Lake Fuxian before the invasion of *N. taihuensis* in 1982, but it is now in the process of extinction, corresponding with an explosive increase in *N. taihuensis* population. Schoener's index (α=0.773) indicate that *N. taihuensis* and *A. grahami* have significant diet overlap, with both fish feeding mainly on zooplankton. An increased proportion of littoral prey, such as *Procladius* spp., Coleoptera, and epiphytes, in the diet of *A. grahami* indicated that this endemic fish shifted its main habitat from the off-shore zone in the late 1980s to the littoral zone at the present. A difference in reproduction between the two fishes, along with the overfishing, may have exacerbated the occupation of *A. grahami*'s pelagic niche by *N. taihuensis*. The endemic species has shown large competitive disadvantage for food and space in the presence of *N. taihuensis*.

INTRODUCTION

Neosalanx taihuensis is a small transparent noodlefish (adult size 41-75 mm) with a widespread distribution, which inhabits lakes in the subtropical middle and lower reaches of the Yangtze River, China (Xie and Xie 1997). As a commercially important freshwater fish, it has been introduced into many lakes on the Yunnan Plateau since the 1980s (Liu 2001a). There is evidence that *N. taihuensis* naturally invaded Lake Fuxian by traveling downstream through the Gehe River in 1982 (Xu et al. 2005). In Lake Fuxian *N. taihuensis* has two reproductive periods – spring (March-May) and autumn (August-October) (Yang 1992).

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There is only very limited information available on the feeding biology of *A. grahami*. Previous studies indicated that the adult *A. grahami* fed mainly on zooplankton such as Cladocera and Copepoda, and sometimes aquatic insects for large-sized adults (NIGLAS 1989). Yang (1992) reported that *A. grahami* less than 140 mm in length fed mostly on zooplankton, while individuals larger than 150 mm preyed on both *N. taihuensis* and zooplankton. In contrast, there have been many studies on the diet of *N. taihuensis* over the past few decades (Gao et al. 1989, Liu and Zhu 1994, He et al. 2000, 2001). *N. taihuensis* is a zooplanktivorous and feeds primarily on zooplankton throughout

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its life span. Therefore, overlapping of prey items between these two species might result in intense interspecific competition.

Food items of *A. grahami* in Lake Fuxian were studied in 1988 and 1991 (Yang 1992) when populations of both *A. grahami* and *N. taihuensis* were coexisting. Currently, however, the endemic *A. grahami* is nearing extinction, and the exotic *N. taihuensis* population has increased dramatically. A critical need exists to understand the trophic interactions, especially diet overlap, between these two species so as to provide scientific basis for the conservation of the endemic *A. grahami* population. Thus, the purpose of this study was to examine the seasonal changes in food items found in the guts of *A. grahami* and *N. taihuensis* from 2002 to 2003. Shift in the diet of *A. grahami* was also evaluated by comparing diet composition between 1989/1990 and 2002/2003.

MATERIALS AND METHODS

Lake Fuxian is an oligotrophic subtropical lake located on the Yunnan Plateau, in southwest China (102°47'-102°57'E,24°17'-24°37'N), covers a surface area of 212 km^2, and has a maximum depth of 155 m. Recently, there were 39 fish species observed in Lake Fuxian, including 25 endemic species (Yang and Chen 1995). The lake is at present dominated by the exotic species *N. taihuensis*. Several other exotic fish species including the topmouth gudgeon (*Pseudorasbora parva*), the Chinese false gudgeon (*Abbottina rivularis*), Pope's goby (*Ctenogobius cliffordpopei*), and the barcheek goby (*Ctenogobius giurinus*), are also present.

All fish were captured by gillnet or pelagic trawl in the western littoral zone of Lake Fuxian. A gillnet with a mesh size of 12 mm was used for weekly sampling of *A. grahami*. More frequent samples (often daily) were taken from commercial catches to obtain more *A. grahami*. The haul net with a mesh size of 5 mm was used three or four times every month to capture *N. taihuensis*. Fish were identified and preserved in 10% formalin for laboratory examination.

In the laboratory, 1,118 *N. taihuensis* were selected randomly for dietary analyses. As *A. grahami* has been very rare in recent years, only 82 specimens were collected; all were analysed. Each fish was weighed and measured (TL), its entire gut was measured and dissected, and food items were identified and counted. Guts with no food present were also recorded. Unidentified digested food was grouped into the "others" category. Food items of *N. taihuensis* were grouped into the following taxonomic categories: *Bosmina* sp., *Daphnia* sp., *Ceriodaphnia* sp., *Alona* sp., *Chydorus* sp., calanoid copepods, cyclopoid copepods, and others. Food items of *A. grahami* were grouped into the following taxonomic categories: *Bosmina* sp., *Daphania* sp., *Alona* sp., *Chydorus* sp., calanoid copepods, cyclopoid copepods, macroinvertebrate, entomic larvae, and the others.

The diet of each individual specimen was quantified using three indices – percent frequency of occurrence (%F), percent number (%N) and percent volume (%V), following the methods described in Hyslop (1980). The index of relative importance (IRI) for each prey type was calculated as IRI = %F(%N + %V) (Pinkas et al. 1971); the percent IRI (% IRI) for each prey type was divided by the total IRI for all prey items (Cortés 1997). The volume taken up by each food item relative to the whole gut content of each sample were calculated using the method proposed by Hellawell and Abel (1971).

Diet overlap between the two fish was calculated with the Schoener (1970) index in which a value of zero indicates no overlap and a value of 1.0 suggests complete overlap. A diet-overlap value of 0.60 or higher have been considered biologically significant (Wallace 1981). Diet overlap was estimated using the volumetric proportion of food items found in the gut, and the unidentified digested food was omitted from the total in the calculation.

Diet can be affected by changes in prey availability. Therefore, diet overlap should theoretically be calculated by month. However, it was not possible to obtain enough samples of *A. grahami* to encompass all life stages in this survey. Therefore, for comparison, and ignoring prey availability issues, diet overlap between the two fishes was calculated annually using all the diet data combined.

RESULTS

Differences in diet between the two species were evident: *N. taihuensis* fed principally on *Bosmina* sp. and calanoids, whereas *A. grahami* fed mainly on calanoids, and also on cyclopoids, *Bosmina* sp., *Procladius* spp., and Coleoptera (Table 1).

Empty guts of *N. taihuensis* numbered 414 out of 1,118 (37.2%). *Bosmina* sp. dominated the gut contents (54.2%IRI), and calanoids were the second most important food item (42.6%IRI). Prey items of little importance included cyclopoids (1.6%IRI) and other cladocerans (<1%IRI).

Of the 82 *A. grahami* guts examined, all contained prey items. Calanoids (64.5%IRI) comprised the major component of the gut contents, followed by cyclopoids (17.4%IRI) and *Bosmina* sp. (10.0%IRI). *Procladius* spp. (2.7%IRI) and Coleoptera (2.7%IRI) were important foods for *A. grahami* because of their relatively high %V contribution to the diet. On the other hand, although *Bosmina* sp. had a high %F (90.2%), its contribution to the diet of *A. grahami* was minor due to a rather low %V. Other cladocerans were negligible food (<1%IRI). Phytoplankton, especially the epiphytic *Cladophora* sp. and *Stigeoclonium* sp., were present in the gut of all fish, but small zooplankton such as rotifers and nauplia were not found.

Table 1. Dietary composition of *A. grahami* (50.1–198.1 mm total length (TL); mean = 138.9 mm; N = 82; no empty) and the noodlefish *N. taihuensis* (11.7–65.8 mm TL; mean = 39.8 mm; N = 1118; 414 empty) by percent frequency of occurrence (%F), percent number (%N), percent volume (%V), and index of relative importance on a percent basis (%IRI). Others: unidentifiable items.

Prey item	*A. grahami*				*N. taihuensis*			
	%F	%N	%V	%IRI	%F	%N	%V	%IRI
Bosmina sp.	90.2	14.6	1.0	9.97	57.6	79.9	25.1	54.19
Alona sp.	18.3	1.7	0.2	0.25	8.3	0.3	0.2	0.04
Chydorus sp.	23.2	1.5	0.2	0.28	17.5	0.9	0.6	0.24
Daphnia sp.	36.2	4.8	1.7	1.67	20.2	1.9	3.0	0.89
Calanoids	86.6	50.7	54.4	64.51	61.7	13.6	63.4	42.57
Cyclopoids	63.4	21.4	17.4	17.44	20.4	2.2	6.8	1.64
Procladius spp.	31.7	1.5	10.4	2.67				
Coleoptera	25.6	1.3	13.5	2.69				
Others	29.6	1.5	1.0	0.52	23.6	1.2	0.9	0.44

Numerically, the major items of *N. taihuensis* diet including the cladocerans *Bosmina* sp. and *Daphnia* sp. and calanoids. *Bosmina* sp. comprised the largest part of the diet from November to March, but its proportion decreased dramatically in April. Then, the proportion increased steadily beginning in May, to reach more than 70% in September. Relative abundance of *Daphnia* sp. increased in the fish diet from February to May, remained low from July to September, and then increased to a maximum in October. Calanoids also comprised a substantial proportion of the gut contents of *N. taihuensis* over the study period (especially in April and October), ranging from 1.6% to 76.2%. Cyclopoids only appeared in the fish diet from February to June with the maximum proportion in March (6.1%). Other zooplankters such as *Chydorus* sp., *Ceriodaphnia* sp., and *Alona* sp. were only consumed occasionally by *N. taihuensis*, with proportions never exceeding 2.5%.

Based on Schoener's index, there was significant annual diet overlap between *A. grahami* and *N. taihuensis* (α=0.773).

DISCUSSION

The diet of *A. grahami* reported in this study was quite different from the previous survey. In 1989/1990, *A. grahami* and *N. taihuensis* coexisted in Lake Fuxian. Cladocerans and *N. taihuensis* comprised the major proportion of the diet of *A. grahami*, along with a substantial amount of calanoids and cyclopoids, with only small numbers of *Procladius* spp. and Coleoptera (Yang 1992). Today, however, *N. taihuensis* was not observed in the gut contents of *A. grahami*, and cladocerans were only a minor part of the diet. The increased proportion of littoral species (i. e., *Procladius* spp., Coleoptera, and epiphytes) in the food items indicates that *A. grahami* altered its habitat from the pelagic zone in the late 1980s to the littoral zone at present. This is probably due to the competitive stress posed by *N. taihuensis*, which occupied the pelagic zone habitat and consumed most prey that had previously been available to *A. graham*. Two factors might have triggered the occupation of pelagic niche by *N. taihuensis*. There is a significant difference in reproductive ability between these two species. The relative fecundity of *N. taihuensis* (>1,200 oocytes/g bw) is much greater than that of *A. grahami* (<300 oocytes/g bw) (Yang and Chen 1995). *N. taihuensis* is also short-lived, with a spawning population made up of recruit spawners (0^+ age group), and has a high population growth rate. Secondly, overfishing of *A. grahami* represents a serious threat due to its extremely high price in local market (>1,600 yuan per kg). Overfishing of *N. taihuensis* is also very harmful to *A. grahami* since the mesh size of gillnets or trawls for *N. taihuensis* are so small (5 mm) that they can trap most larvae and juveniles of *A. grahami*.

The diet of *N. taihuensis* in Lake Fuxian in the present study was generally in agreement with results from other lakes (Gao et al. 1989, Liu and Zhu 1994, He et al. 2000, 2001). It is noteworthy that t *N. taihuensis* in Lake Fuxian displayed different feeding behavior between the spring and autumn spawning seasons. This contrasts with results reported for the same species in other lakes (Liu and Zhu 1994, He et al. 2000) as well as for other freshwater salangids such as *N. oligodentis* and *N. pseudotaihuensis* (Yin et al. 1997, Liu 2001b).

Schoener's index (α=0.773) indicates that *N. taihuensis* and *A. grahami* had great diet overlap, with both species feeding mainly on zooplankton. Food availability for *A. grahami* in Lake Fuxian was consistently low due to the scarcity of prey in this oligotrophic environment (Yang 1994). Current results and previous studies (Chen 1956, Yang 1992) indicate that *N. taihuensis* and *A. grahami* have significant diet overlap that there is a high potential for significant niche competition. The decline of the endemic *A. grahami* in Lake Fuxian over the past two decades indicates a great competitive disadvantage for prey and space command with *N. taihuensis*.

Lake ecosystems in the Yunnan plateau have been shown to be quite vulnerable, as these lakes are usually isolated and the food webs are relatively simple (Xie and Chen 2001). For instance, in the early 1950s, two planktivorous Chinese carp species, bighead and silver carp, were introduced into Lake Xingyun for the purpose of aquaculture. Before the introduction of these carp, about 50% of fish yield from the lake consisted of the endemic barbless carp (*Cyprinus pellegrini*). However, since the introduction of the exotic carp, the proportion of barbless carp in the total fish yield declined to 20% in the 1960s, to 10% in the early 1970s, and finally to less than 1% since the 1980s (Xie and Chen 2001). In China, the disastrous impacts of exotic fish have been especially striking in many plateau lake ecosystems in recent decades. The invaders have suppressed and in some instances completely eliminated the native or endemic species.

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LITERATURE CITED

Chen, N. S. 1956. Preliminary study on *Neosalanx tangkahkeii taihuensis* Chen. Acta Hydrobiol. Sinica 2: 324–332. (In Chinese with an English abstract).

Cortés, E. 1997. A critical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch fishes. Canadian Journal of Fisheries and Aquatic Sciences 54: 726–738.

Gao, L., D. Zhuang, M. Che, L. Chen, and J. Zhang. 1989. Test study of introducting *Neosalanx taihuensis* Chen into Lake Dianchi. Science Limnology Sinica 1: 79–88. (in Chinese).

He, W., G. Hao, Y. You, Z. Guo, and X. Zhang. 2000. Comparison of feeding biological capacity for *Neosalanx taihuensis* of different latitude. Chinese Qinghai Journal of Animal and Veterinary Sciences 30: 11–12.

He, W., G. Hao, Y. You, G. Hu, and B. Wang. 2001 . Study on forage organ feeding habits of *Protosalanx hyalocranius* and *Neosalanx taihuensis* Chen. Chinese Qinghai Journal of Animal and Veterinary Sciences 31: 12–13.

Hellawell, J. M. and R. Abel. 1971. A rapid volumetric method for the analysis of the food of fishes. Journal of Fish Biology 3: 29-37.

Hyslop, E. J. 1980. Stomach contents analysis—a review of methods and their application. Journal of Fish Biology 17: 411-429.

Liu, Z. W. 2001a. The introduction of icefish, *Neosalax taihuensis* Chen, in China with special reference to the subtropical lakes of the Yunnan Plateau (Southwest China). Verh International Verein Limnology, 27: 3877–3880.

Liu, Z. W. 2001b. Diet of the zooplanktivorous icefish Neosalanx pseudotaihuensis Zhang. Hydrobiologia 459: 51–56.

Liu, Z. W. and S. Q. Zhu. 1994. Feeding behaviour of *Neosalanx taihuensis* Chen in Lake Dianchi. Acta Zool. Sinica 40: 253–261. (In Chinese with an English abstract).

NIGLAS (Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences), 1989. Fuxian Lake, pp. 286. Oceanpress, Beijing, P R China. (in Chinese).

Pinkas, L., M.S. Oliphant, and L.K. Iverson. 1971. Food habits of albacore, bluefin tuna and bonito in California waters. California Dep. Fish Game Fish Bulletin 152: 1–105.

Schoener, T. W. 1970. Non-synchronous spatial overlap of lizards in patchy habitats. Ecology 51: 408–418.

Wallace, R. K. Jr. 1981. An assessment of diet-overlap indexes. Transactions of the American Fisheries Society 110: 72–76.

Xie, P. and Y. Chen. 1999. Threats to biodiversity in Chinese inland waters. Ambio 28: 54–61.

Xie, P. and Y. Chen. 2001. Invasive carp in China's plateau lakes. Science 294: 999–1000.

Xie, Y. H. and H. Xie. 1997. Classification system and biology of populations of salangidae. Chinese Journal of Fisheries 10: 11–19.

Xu, J., S. Li, and P. Xie. 2005. Differences in $\delta^{13}C$ and $\delta^{15}N$ of particulate organic matter from the deep oligotrophic Lake Fuxian connected with the shallow eutrophic Lake Xingyun, People's Republic of China. Bulletin of Environmental Contamination and Toxicology 74: 281–285.

Yang, J. X. 1992. Origin and evolution of some biological characters of *Anabarilius*

grahami as referred to geography development of Fuxian Lake. Zoological research 13: 353–360.
Yang, J. X. 1994. The biological characters of fishes of Fuxian Lake, Yunnan, with comments on their adaption to the lacustrine environments. Zoological research 15: 1–9.
Yang, J. X. 1996. Alien and indigenous fishes in Yunnan: the study on impact fashion and extent. Page 129-138. *In*: Wang S. and Y. Xie (eds.), Conserving China's biodiversity. China Environment Science Press, Beijing (in Chinese).
Yang, J. X. and Y. Y. Chen. 1995. The biology and resource utilization of the fishes of Fuxian Lake, Yunnan. Yunnan Science and Technology Press Kunming, China (in Chinese).
Yin, G., K. Cao, Z. Yu, and S. Gong. 1997. Reproduction, feeding habit and growth of icefishes in Lake Wang. Journal of Lake Science 9: 63–70. (In Chinese with an English abstract).

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