Journal of Freshwater Ecology

ISSN: 0270-5060 (Print) 2156-6941 (Online) Journal homepage: https://www.tandfonline.com/loi/tjfe20

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To cite this article: Frank Johansson, Fang Fang & Haigen Xu (2006) Fish Communities in Small and Intermediate Streams in Guangxi Province, China, Journal of Freshwater Ecology, 21:1, 39-45, DOI: 10.1080/02705060.2006.9664094

To link to this article: https://doi.org/10.1080/02705060.2006.9664094

Published online: 06 Jan 2011.

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ABSTRACT

We examined the relationship between fish species composition and environmental and biogeographical variables in 26 small and intermediate streams in the Guangxi Province. The variables estimated were stream width, stream order, vegetation cover, bottom substrate, altitude, longitude, and latitude. Altogether 4,433 specimens of 36 species were collected. *Rhinogobius giurinus* (Gobiidae) and *Opsariichtys bidens* (Cyprinidae) were the most common species, and they were found at 16 of the localities. Species richness was correlated with stream width. Canonical Correspondence Analysis showed that longitude was the only environmental variable that significantly explained community composition of the fishes. Intensive land use is suggested to be a cause off the lack of correlation with other environmental variables. Two fish species assemblages could be distinguished, one eastern and one western.

INTRODUCTION

Fish communities have received considerable attention in the study of community ecology, and the relationships between fish community structure and environmental variables have been the focus in many studies (e.g. Gorman and Karr 1978, Tonn and Magnuson 1982, Maret et al. 1997). For stream fish, several environmental variables are important in structuring fish assemblages. One of the more general patterns is that species diversity increases with habitat complexity and stream size (Gorman and Karr 1978, Paller 1994). However, human impact has caused physical, chemical, and biotic alterations in many stream ecosystems, and this has changed the community structure in these waters (Allen and Flecker 1993).

Fish communities in China are strongly affected by human impacts such as overfishing, draining, and polluting (Li 1996 and 2001, Gawlik, et al. 2001). This should have an impact on the fish fauna, and it is therefore interesting to determine if fish communities in China are correlated with similar environmental variables as has been demonstrated in studies from areas where human impact is less severe. One reason for a different pattern in Chinese fish communities could be that severe disturbance and habitat alterations of streams does not allow all potential niches to be exploited. Therefore the relationships between the fish community and environmental variables may be different from those of more undisturbed systems. Similarly, since human impact is strong it should be valuable to identify unique fish assemblages that are impacted and associate these assemblages with environmental variables.

The aim of this study was to examine the fish fauna in small and intermediate-sized streams in the Xi Jiang subdrainage of the Pearl River (Zhu Jiang) basin in Guangxi Province, China, and relate the patterns found to environmental conditions.

MATERIAL AND METHODS

Guangxi Province covers 240,100 km^2 and is located in southeastern China. Situated on the southeast ring of the Yunnan-Guizhou Plateau, the altitude of Guangxi is high in the northwest and low in the southeast, with the highest point at 2,141 m above sea level. Because of the hilly and mountainous terrain, only about 10% to 15% of the land is cultivated, and up to 39.3% of the province's total territory is covered by forest. Guangxi's climate is tropical and sub-tropical, with the annual average temperature between 16°C and 23°C. The annual rainfall in Guangxi Province is between 1,000 – 2,800 mm, increasing gradually southward.

In March 2003 we collected fishes in 26 small and medium-sized streams and rivers in Guangxi Province, China (Fig. 1). Streams were selected to represent the whole area under investigation. A seine (mesh size 3.0 mm, length 8 m and height 1.4 m) was used to sample the fishes. We selected sites with slow to medium velocity (approximately 0.05-0.3 m/s). Sites with large and rocks and boulders were not sampled because the seine was not effective in this habitat. The procedure might have missed some fish species in the

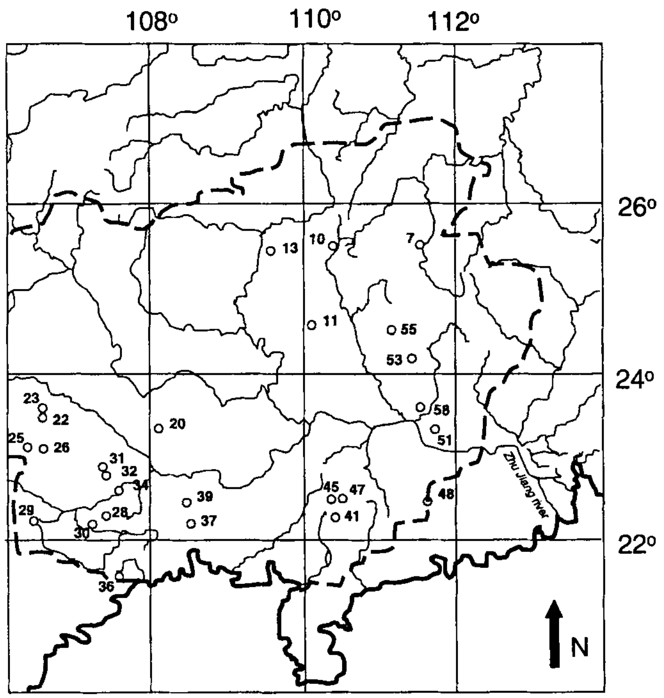

Figure 1. Map showing the 26 localities of small and intermediate streams where fish were collected in Guangxi Province. To facilitate reading of the localities the small and intermediate streams sampled are not shown on the map. The dashed line denotes the Guangxi Province border.

stream, but our purpose was not to provide a complete description of the fish fauna in the streams, but was to relate the fish fauna and environmental variables in the system sampled. Two to four seine sweeps were conducted in each stream, with the mean area fished aproximately 128 m^2 ($\pm$ 17 S.E.). In more complex habitats we conducted additionally sweeps. The depth of seine sweeps varied from 0.3-1.0 m. Fish identified in the laboratory following the most recent systematic revisions of relevant genera whenever possible, but otherwise used Eschmeyer (1998).

Seven variables describing river morphology and geographic position were collected at each site. These were stream width, vegetation cover (divided into 10% categories), altitude, latitude, longitude, stream order, and bottom substrate. Bottom substrate for each site was scored into individual classes: (1) silt (< 1 mm); (2) sand and gravel (1-16 mm); (3) boulder (> 256 mm), cobble (16-256 mm) and silt; (4) boulder cobble, gravel and sand; (5) boulder and cobble; (6) boulder cobble and bedrock.

Canonical correspondence analysis (CCA) using CANOCO (ter Braak and Smilauer 1998) was used to evaluate relationships between species abundances and environmental variables. Stream order and bottom substrate are categorical variables and were therefore entered as dummy variables. Since two fish taxa had very large impact on the analysis, we performed two CCAs, one with and one without these two species. The relationship between environmental and biogeographic variables and species richness was analyzed with stepwise regression setting the least significant predictor to 15 %.

Our estimates of species richness might be biased because they are based on different sample sizes (i.e. fish abundance). To overcome this problem we standardized all samples to a common size and achieved an expected number of species at each locality. We used the rarefaction method in EcoSim (Gotelli and Entsminger 2001) to estimate expected number of species in each sample.

RESULTS

A total of 4,433 specimens of 36 species were collected (Table 1). *Rhinogobius giurinus* (Gobiidae) and *Opsariichtys bidens* (Cyprinidae) were the most common species, and they occurred at 16 of the 26 localities respectively. Nine species were found only at one locality.

The CCA showed that environmental variables explained 57.9 percent of the variation in the abundance of the different fish species, and the first three axes explained 11.3, 10.6, and 7.4 percent of the variation. There was a significant effect of the canonical axes compared to random (P = 0.015), and bottom substrate (P = 0.01) and longitude (P = 0.01) showed a significant effect on the structure of fish abundance. Two taxa, Gobioninae sp. (possibly the genus *Squalidus*) and *Traccatichthys pulcher* (Balitoridae) had a much higher correlation with axis 1 than any of the other taxa and therefore strongly influenced the results of the analysis. For that reason we excluded these two taxa and performed a second CCA.

In the second CCA environmental variables explained 56.4 percent of the variation in fish species abundance, and the first two axes explained 13.2, and 9.0 percent of the variation. There was a significant effect of the canonical axes (P = 0.045). Only longitude showed a significant effect on the structure of fish abundance (P = 0.005) and was correlated with CCA axis 1 (Fig. 2). There was a trend for an effect of altitude (P = 0.06).

Oryzias latipes (Adrianichthyidae) and *Rasbora steineri* (Cyprinidae) were positively associated with CCA axis 1 reflecting an eastern distribution of these species, since axis 1 was associated with longitude. *Acrossocheilus labiatus* (Cyprinidae) was negatively associated with CCA axis 1 reflecting a western distribution of this species. Two more or less distinct fish assemblages could be distinguished which were associated with longitude. One assemblage is positively associated with axis 1 and hence has a more eastern distribution. One of the most common species in this assemblage is *Zacco platypus* (Cyprinidae). The other assemblage is negatively associated with axis 1 suggesting a western distribution of these species. Typical species of this assemblage were *Metzia formosae* and *M. lineata.*

The stepwise regression analysis showed that stream width was the only significant predictor of species richness ($P = 0.005$, $r^2 = 0.30$; Fig 3). The stream localities with the highest richness were 28, 55 and 29 which had 14, 12 and 11 species, respectively. Species richness was not related to effort ($P = 0.86$, $r^2 = 0.001$) and consequently the fact that we might have sampled a larger area in large rivers does not confound our species richness relationship.

Table 1. Fish species collected from 26 small and intermediate streams in Guangxi province, China, 2003. N denotes number of streams in which each species was found.

Species	N	Species	N
Rhinogobius giurinus	16	*Gnathopogon walterstorffi*	2
Opsariichthys bidens	16	*Microphysogobio elongates*	2
Rhodeus ocellatus	11	*Oreochromis niloticus*	2
Puntius semifasciolatus	10	*Squalidus* sp.	2
Rhinogobius wui	9	*Mastacembelus armatus*	2
Gambusia holbrooki	9	*Xenocyprioides* sp.	2
Zacco platypus	8	*Rasbora steineri*	2
Oryzias latipes	7	*Parazacco spilurus*	2
Nemacheilus fasciatus	6	*Gnathopogon argentatus*	1
Carrasius auratus	5	*Acheilognathus barbatulus*	1
Metzia formosae	5	*Hemibarbus umbrifer*	1
Macropodus opercularis	5	*Paraprotomyzon multifaciatus*	1
Pseudorasbora parva	4	*Cobitis sinensis*	1
Rhinogobius brunneus	4	*Mugilogobius myxodermus*	1
Metzia lineata	3	*Hemiculter leucisculus*	1
Hemigrammocypris lini	3	*Acrossocheilus labiatus*	1
Traccatichthys pulcher	3	*Protomyzon sinensis*	1
Gobionine sp.	3	*Hypseleotris swinhornis*	1

DISCUSSION

As far as we know, our study is the first to examine the fish fauna quantitatively in small to intermediate streams in this region. Our study suggests that two fish species assemblages can be found in the province, one eastern and one western, though there was some overlap. This pattern could reflect historical factors such as evolution or dispersal of fish species because the assemblages are restricted to different drainages. The fish communities were not associated with any of the environmental variables we measured but could be associated to other unmeasured variables. One potential factor could be land use or vegetation (Maret et al. 1997). Currently we have only limited data on these factors.

We found that stream width was the only environmental variable that affected species richness. This pattern is well documented in the literature (Rahel and Hulbert 1991, Maret et al. 1997). A larger stream width could imply more habitats available and therefore more fish species. However neither bottom substrate nor vegetation cover, which are expected to affect habitat diversity, had a significant influence on species richness. Locality 28 was the most species rich of all localities with 14 species. Interestingly this locality did not have the greatest stream width. Seven localities had greater stream width. The nearby locality 29 was also species rich (11 species). Hence this area might be one with high fish diversity in Guangxi Province.

Other studies have found that stream width, altitude, habitat structure, and stream order are associated with fish community structure in small to intermediate streams (Gorman and Karr 1978, Rahel and Hubert 1991, Paller 1994). We did not find similar patterns in our study. Stream width was, however, associated with richness. The streams showed show large variation in variables such as bottom substrate and vegetation cover and therefore there was a potential that these factors could affect fish community structure. One explanation for the absence of an influence on environmental variables could be fishing pressure. Fishing pressure is very high in small streams in China (Duan et al. 1995) and many studies have shown that fish assemblages consist of few and only small species (Chen and Cao 1995, Le et al. 1995). It is therefore likely that many of the niches used by large fish species are used by the small species as well. Hence variation in environmental factors such as bottom substrate and vegetation cover that allows large and small species to coexist is probably of minor importance in many of the streams we sampled. As a consequence, community structure may be similar even if sites differ in habitat structure such as bottom substrate and vegetation cover.

Another explanation for the absence of a strong association between environmental factors and community structure of fish could be introduced fish species. If predation from introduced species is strong on some strong competitors, niche expansion will occur for those fish species not affect by predation. They will occupy a broader niche spectrum, and

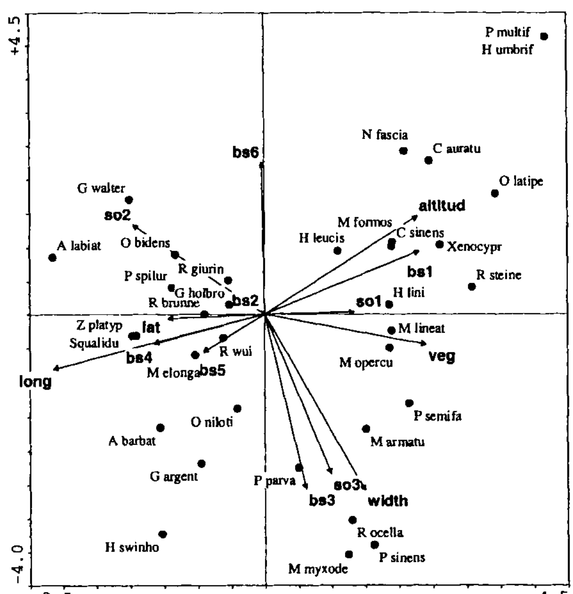

Figure 2. Result from CCA showing position of fish taxa along CCA axes 1 and 2 in relation to the environmental variables (arrows). See Table 1 for identification of fish species names. Environmental variables are abbreviated as: altitud = altitude, long = longitude, lat = latitude, width = stream width, veg = vegetation cover, so = stream order, bs = bottom substrate.

the fish community will thus be homogeneous. A similar effect could be caused if the introduced species are strong competitors which occupy many niches and hence present in many streams and habitats. This effect has been suggested in other studies (Maret et al. 1997). Non-indigenous fish species that we encountered were *Gambusia holbrooki* and *Oreochromis niloticus*. *Gambusia holbrooki* was ranked as the fifth most common species in our study, occuring in nine out of 26 localities. *Oreochromis niloticus,* however, was only found in two localities. We might have missed the large individuals, but small fry are very likely to be caught by our method. The small-sized mosquito fish (*G. Holbrooki*) might have contributed more to the disconnection between environmental factors and fish community structure than *O. niloticus*. However, since no high number of large introduced fish species were found in our field survey, we suggest the impact from introduced fish species to be less strong than the over fishing explanation.

Increasing stream order could be mirrored in altitudinal changes in community composition that are believed to be an effect of biotic zonation or cumulative addition of species downstream (Rahel and Hubert 1991). The absence of a stream order or altitude effect in our study could be due to the low gradient of stream orders. With the exception of one third order stream, all of the strams we sampled were either first or second order. Other studies have, however, found changes in fish communities along a stream order gradient similar to ours (Rahel and Hubert 1991). The absence of a stream order effect could therefore also be due to high fishing pressure.

Admittedly our collecting method could not guarantee to catch all fish species in the streams investigated. About 200 fish species can be found in the province (Anonymous 1981) and we caught about 20 % of these species. Given that we only sampled small and intermediate streams and no large rivers, lakes or swamps, we suggest that we captured the fish diversity in the systems upon which we focused. In addition, our purpose was not to provide a complete survey of the fish species community. Instead our focus was on the relationship between environmental variables and fish community composition. Though other studies in other parts of the world have found that the environmental variables we investigated do influence fish community structure, we did not find similar patterns overall. We found that the fish fauna was very similar with respect to most environmental variables, and we believe that this is due to human impact.

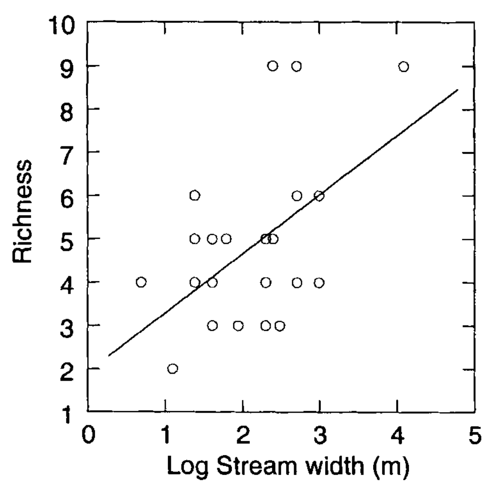

Figure 3. Relationship between species richness and stream width for the 26 localities collected.

ACKNOWLEDGEMENTS

Zhao Yahui, Zhang Chunguang (IZB) and Peng Zuogang (IHB) helped in various ways to collect fishes in the field. Göran Englund gave valuable comments on an earlier draft of this article. Permissions for collecting were issued by the Chinese Academy of Sciences and the State Fishery Bureau. This study was funded by the European Commission, INCO-DEV programme, project ECOCARP, contract number ICA4-CT-2001-10024.

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Received: 20 May 2005 Accepted: 26 September 2005