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Factors on Fish Richness in Native Streams of Fogang Area, Qingyuan, Guangdong Province

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Abstract. Rapid urbanization in the rural areas of Guangdong Province poses varying degrees of threat to the survival of native stream fishes. This study conducted over three years, utilized fishing nets, fish traps, angling techniques and lure-fishing methods to perform a quantitative assessment of stream fish species across 11 representative watersheds within Fogang County, Qingyuan City, Guangdong Province, along the upper reaches of the Pajiang River. In this study, a total of 4 orders, 4 suborders, 9 families, 4 subfamilies, 14 genera and 18 species of fish were collected. The identified species include *Opsariichthys evolans, Opsariichthys bidens, Girella punctata, Acrossocheilus paradoxus, Pangasianodon hypophthalmus, Varicorhinus guangdongensis, Pseudogastromyzon fangi, Betta splendens, Micronemacheilus pulcher, Rhinogobius giurinus, Rhinogobius duospilus, Gambusia affinis, Pseudorasbora parva, Rhodeus ocellatus, Pseudorasbora pumila, Carassius auratus, Channa striata and Gobiocypris rarus*. The dataset comprises 15 indigenous species and three non-indigenous species, namely *the Girella punctata, Gambusia affinis and Channa striata.* Based on comprehensive analysis of field surveys, fishing data and feeding data, it is evident that invasive alien species, environmental changes, water oxygen content and water quality exert significant influences on stream fish richness. Furthermore, variations in channel structure, river beds and coastal environments along the banks also contribute to alterations in species composition and diversity within aquatic ecosystems. Therefore, identifying factors that constrain the abundance of native stream fishes will help to protect the ecosystem as a whole, while restoring diversity and sustainability of the local aquatic communities and improving the living conditions and habitats of local population.

Keywords: Fogang County; Pajiang River Watershed; Indigenous Stream Fish Species; Invasive Species; Biodiversity.

1. Introduction

Research on native stream fish worldwide has yielded significant findings across a diverse range of topics, encompassing fish ecology, habitat requirements and restoration, water quality management, human impacts, river ecosystem management and conservation, as well as the development and application of tools for assessing biological integrity.

In the context of fish ecology, the riverine continuum perspective plays a crucial role in conserving riverine fish and other aquatic organisms. Consequently, several studies have proposed the concept of riverine landscape ecology, which emphasizes research at appropriate scales, cross-scale ecological processes, dominant effects of unique characteristics, unintended consequences of habitat degradation and the significance of ecological connectivity. Additionally, five principles aligning observations and predictions with management actions effectively contribute to studying and protecting river fish populations [1]. Landscape ecology provides valuable insights into how human activities such as agriculture, logging and grazing modify the structural and functional relationships between landscape elements. These alterations subsequently impact the stability of the physical environment while influencing fish populations and their community dynamics through changes in land-water interfaces [2].

Habitat studies differentiate between habitat selection (an organism's preference for a specific habitat), habitat preference (the choice of habitat under controlled conditions) and habitat demand (the

necessity of a habitat for survival and reproduction) by constructing multiple correlated habitat models based on observed data. A bioenergetics-based model is proposed to predict the growth rate of a particular habitat, as well as to extrapolate individual habitat requirements to the population level in order to discern the impacts of different habitat configurations on various fish species [3]. Through comparing fish densities in two rivers with natural flow and highly regulated flow, researchers concluded that human-induced fluctuations in flow height are a significant factor influencing the structure of fish communities, particularly those heavily reliant on specific microhabitat conditions [4].

In terms of water quality management, a study investigating the presence of microplastics in wild fish from the Nandu River in Hainan, China revealed that over 90% of fish samples were found to contain microplastics, exhibiting an average abundance of 3.20 ± 2.60 microplastic particles per fish. Consequently, it can be inferred that there is a widespread occurrence of microplastic pollution among fish inhabiting the Nandu River. However, no significant correlation was observed between the level of microplastic pollution in the water body and its accumulation within fish specimens, suggesting that the uptake process may occur randomly and independently of factors such as fish size, feeding habits or habitat characteristics. Furthermore, when comparing different weight categories among these fishes, it was noted that the concentration of microplastics decreased proportionally with increasing body weight, suggesting an absence of any accumulation pattern associated with organism growth [5].

In terms of the impact of human activities, there are two categories of factors influencing the community composition and habitat suitability of fish in streams: biological factors and abiotic factors. Among the biological factors, predation, competition and species interactions play significant roles. As for abiotic factors, twelve variables including temperature, water depth and flow rate, sediment type, cover availability, water flow patterns, chemical properties of water bodies, land use practices, urbanization levels, sediment accumulation rates caused by human activities or natural processes such as erosion or deposition events triggered by climate change effects or introduction of alien species into ecosystems due to tourism and sports-related activities have been identified. These human-induced changes have had detrimental impacts on fish populations [6]. Furthermore, some studies have also considered spatial heterogeneity and dynamics as additional influential factors alongside biological and abiotic aspects when discussing fish diversity. The effects of geographic regions, different abiotic conditions at various scales, stability within physical systems and spatial connectivity were examined [7]. In a study conducted from 1977 to 1979, the autumn wild salmon population in the Lewis River, Washington was analyzed to identify several positive factors that distinguish it from other Columbia River populations. These findings provided a scientific foundation for effective management and conservation strategies for this specific population [8]. A study examining the recovery of fish communities in temperate streams after natural and human-induced disturbances focused on low gradient third or fourth grade streams. Data collected from 49 sites revealed that species composition, species richness and total density were restored within one year in systems with over 70% recovery rate. However, long-term disturbances such as mining, logging and riverization required a recovery time ranging from five years to more than fifty-two years. On the other hand, fish communities demonstrated strong resilience towards pulse disturbances like floods and droughts but exhibited weaker recovery abilities when faced with long-term disruptions [9]. Studies have also investigated the impact of specific human engineering structures on fish communities, such as the influence of low head dams in China's Qingyi River tributaries. It was found that sediment heterogeneity, tributary location and dam height significantly affected fish species richness in these tributaries [10].

Finally, the application of the Biointegrity Index (IBI) in water resources management and the challenges and adjustments encountered when applying IBI in different regions are discussed. Due to its strong ecological foundation and inherent flexibility, IBI exhibits significant potential for direct biological monitoring [11].

In contrast to foreign studies on stream fish that prioritize theoretical aspects, domestic research on stream fish in China is characterized by a strong emphasis on national and regional contexts. Each study focuses on the diverse fish communities found in different regions of China, encompassing their distribution patterns, ecological behaviors and conservation recommendations.

For instance, in July 2012, the Guilongshan Provincial Nature Reserve in Fujian Province collected a total of 19 fish species from 5 orders, 8 families and 16 genera in July 2012, primarily belonging to the cypriniformes order. The majority of the fish found in this area are mountain stream species that inhabit the benthic zone and exhibit omnivorous feeding habits. The dominant species include Perca fluviatilis,Distoechodon tumirostris and Epiplatys boulengeri. This research proposes effective measures for combating illegal fishing activities as well as addressing issues related to water conservancy construction and water pollution [12]. A study focusing on the protection of fish resources in streams located in northwest Jiangxi highlights the impacts of habitat changes, pollution and overfishing on fish diversity. It also suggests removing abandoned water conservancy facilities while emphasizing the importance of ecological preservation and safeguarding residents' interests [13].

The fish composition and habitat status in the nature reserve of Hainan Island primarily consist of small mountain stream fish, with Cyprinidae spp. being the dominant group. The decline in fish resources can be attributed to habitat loss and overfishing as the main factors [14,15]. Studies on stream fish in Guangdong and Guangxi mainly focus on mountainous forest areas in western Guangdong, central and northern Guangxi. Among these regions, streams in western Guangdong exhibit abundant fish resources. However, with societal development and advancements in science and technology, human interference with nature has intensified, resulting in a decrease in wild fish populations along with a noticeable trend towards miniaturization that threatens species diversity. Additionally, there has been a contraction of species distribution areas leading to fragmented habitats [16]. In central and northern Guangxi's six nature reserves, the fish resources primarily comprise lineages of ancient Tertiary primitive fish taxa as well as subtropical warm water fish species. Unfortunately, due to unregulated hunting practices without proper management measures, these once-rich fish resources now face significant threats [17]. These aforementioned studies provide valuable data for comprehending the current state and challenges faced by stream fish communities across different regions of China while also offering a scientific basis for formulating effective conservation strategies.

The present study investigates the richness and influencing factors of stream fish in 11 representative waters located in the upper reaches of Pajiang river, Fogang County, Qingyuan, Guangdong Province. The study is divided into three parts: firstly, an introduction to the current status of stream fish richness in Fogang area based on fishing data. Secondly, an analysis of the living habits and habitat requirements of stream fish through indoor rearing practices. Finally, a discussion on three factors affecting fish abundance in streams including industrial factors, agricultural factors and temperature and climate factors. Through this research framework, we aim to provide a preliminary understanding of the status quo and challenges regarding stream fish abundance in Fogang area for relevant departments while offering guidance for effective conservation strategies.

2. The Study of Indigenous Stream Fish in the Fogang Region

2.1. A Comprehensive Analysis of Stream Fish Abundance in the Fogang Region

In August 2020, the *Guangdong multitude of verdant undulations Master Plan (2020-2035)* was approved by the provincial government, signifying that river control has become an integral component of ecological civilization construction. Fogang, Qingyuan, situated in northern Guangdong, will leverage its ecological advantages to establish picturesque rivers encompassing mountain streams.

The research focus of this paper lies in the assessment of stream species richness in 11 representative water bodies situated within the upper reaches of Pajiang River, Fogang County, Qingyuan City, Guangdong Province. The study duration spans three years. By utilizing fishing techniques such as angling, fish cage, fishnet and lure fishing, we compare the variations in fish catch over these three years to effectively illustrate the survival challenges faced by stream species in this particular region.

During this study, a total of 4 orders, 4 suborders, 9 families, 4 subfamilies, 14 genera and 18 species of fish were collected. The identified species include *Opsariichthys evolans, Opsariichthys bidens, Girella punctata, Acrossocheilus paradoxus, Pangasianodon hypophthalmus, Varicorhinus guangdongensis, Pseudogastromyzon fangi, Betta splendens, Micronemacheilus pulcher, Rhinogobius giurinus, Rhinogobius duospilus, Gambusia affinis, Pseudorasbora parva, Rhodeus ocellatus, Pseudorasbora pumila, Carassius auratus, Channa striata and Gobiocypris rarus*. The data encompassed fifteen native species and three invasive non-native species: *Girella punctata, Channa striata and Gambusia affinis*. Based on the author's field investigation,it was observed that among the 11 water areas surveyed (Shanglian Village, Wangtian Village, Lianyao Village, Shitan Village and Xitian Village), the water area in Xingzhuli is characterized by its vast expanse and turbid water quality. The substrate at a lower elevation primarily consists of silt, while the riparian vegetation predominantly comprises grasses. Numerous indications of human-made construction are evident in the surrounding area,with a significant presence of individuals. The fish density in this area is moderate,with a predominance of single species including *Girella punctata, Gambusia affinis and Opsariichthys bidens*. The water areas of Jingzai village, Shiguwa village, Anzai village and Tandong village stand in stark contrast as they boast expansive stretches with pristine water quality. The low-lying streambeds exhibit minimal vegetation on both sides, primarily consisting of shrubs and grasses. These areas have experienced limited human impact, resulting in a remarkable abundance and diversity of fish species such as *Opsariichthys evolans, Opsariichthys bidens, Acrossocheilus paradoxus*. The Shandong Village River basin is characterized by its narrowness, with sections situated amidst mountainous terrain. Both banks are adorned with lush vegetation predominantly consisting of mixed forests. The riverbed is relatively shallow and predominantly composed of stones, while human settlements remain scarce with minimal signs of human influence. Fish density within this basin is moderate. Although species richness is comparatively lower, it supports unique fish species that are absent from other river basins, such as *Pangasianodon hypophthalmus, Pseudogastromyzon fangi*.

Therefore, *the Girella punctata*, a highly prevalent and abundant alien species, is distributed across eight water bodies: Shanglian Village, Wangtian Village, Lianyao Village, Shitan Village, Xitian Village, Xingzhuli Village, Jingzai Village and Anzai Village. The proportion of fish caught in 2022 accounted for approximately 23% of the total fish population and increased to 32% in 2024. Consequently, the inundation of *Girella punctata* in aquatic environments leads to a significant decline in both the abundance and diversity of native fish species. Belonging to *the Cichlidae spp.*, the *Girella punctata* has proliferated in southern China's waters due to its remarkable adaptability and reproductive capacity. This omnivorous predator exhibits a preference for tranquil aquatic environments where adult fish can attain sizes ranging from 15 to 30 cm. Upon reaching sexual maturity, male individuals develop red jaws along with territorial behavior, enabling the *Girella punctata* to rapidly establish itself as an invasive alien species and dominate the ecological niche within streams.

What measures can be implemented to safeguard indigenous stream fish populations from the proliferation of invasive species in their current habitat? The survey findings indicate that invasive alien species are more prevalent in the middle and lower sections of the waterway, while native stream fish thrive in the upper sections. This distribution pattern can be attributed to the exceptional adaptability of three invasive species -*Girella punctata, Channa striata and Gambusia affinis* -to low-oxygen environments. Furthermore, Channa striata is classified as a member of *the Labyrinth spp.* group which possess the ability to respire oxygen from atmospheric sources, thereby exhibiting enhanced adaptability to their surroundings. In contrast, native stream fish primarily belong to

oxygen-dependent families such as *Gobiidae spp., Balitoridae spp. and Opsariichthys spp.*. This demonstrates their comparatively limited adaptability compared to their invasive counterparts. Consequently, in downstream areas characterized by weak currents and low oxygen levels due to anthropogenic overfishing and environmental degradation along waterways, the available living space for native stream fish is further restricted.

In order to gain a more comprehensive understanding of the living habits and survival requirements of fish in their natural streams, the author conducted an experiment by raising several fish species in artificial breeding environments. The primary objective of this study was to investigate the behavior and needs of fish in their natural habitat, with the ultimate goal of providing valuable insights for conservation and management efforts. This process involved not only placing stream sand and stones from the original watershed into the fish tanks but also artificially simulating the rapids and slow flow areas found in the native streams. Such an approach aimed to closely replicate the conditions present in natural habitats, thereby facilitating a more accurate assessment of fish behavior and requirements.

In order to maintain the water quality in the aquatic environment, the author has implemented a robust and efficient filtration system comprising filter cotton, a sedimentation tank, biochemical culture filter material and vegetation filtration. Additionally, one-third of the stream water is replaced with fresh water in the fish tank on a weekly basis. The author has carefully selected several common and representative fish for breeding, including *Opsariichthys evolans, Opsariichthys bidens, Acrossocheilus paradoxus, Pangasianodon hypophthalmus, Varicorhinus guangdongensis, Pseudogastromyzon fangi.*

The fish will select areas with higher water flow for feeding, exhibiting the strongest activity and appetite at a dissolved oxygen level of five milligrams. In terms of water quality, fish exhibit peak activity levels when the pH level ranges between 6.5 and 7, while maintaining ammonia nitrogen concentrations below 0.2 mg per litre. Beyond this threshold, indigenous stream fish experience respiratory distress leading to eventual mortality. Notably, *the Pangasianodon hypophthalmus, Varicorhinus guangdongensis and Pseudogastromyzon fangi* display low tolerance towards elevated temperatures. They exhibit signs of respiratory distress when exposed to water temperatures exceeding 28 degrees Celsius and succumb at temperatures surpassing 30 degrees Celsius.

2.2. Three Factors on the Abundance of Fish in Streams

By analyzing catch numbers and feeding data, we have identified three primary factors that pose the most significant threat to the survival of native stream fish.

The first factor is the industrial impact. In order to facilitate irrigation of their farmland, residents residing near the Pajiang river have deliberately modified the river's structure. They have not only constructed dams in the river but also erected cement embankments on both sides of its banks. Consequently, this has resulted in detrimental alterations to the stream's natural configuration and deprived native fish of their beloved rapids.

In addition, to facilitate the local economic development, the Fogang County government has introduced a certain amount of foreign investment to establish factories by leveraging cost-effective land and labor as well as a range of preferential policies. The objective is to mobilize local funds for collaborative establishment of furniture production centers. For instance, in 2017, Red Apple Furniture Co., LTD., which is wholly owned by legal entities from Hong Kong, Macao and Taiwan, was established. In the same year, Shanggong Furniture Processing Factory was also established. Additionally, Zhiwei Furniture Manufacturing Co., LTD. was founded in 2004. All of these companies are located near the Pajiang river and have been discharging sewage and garbage into the water, resulting in an excessive presence of harmful substances. Consequently, this has disrupted the acid-base balance in the water and led to poisoning that caused death among native fish species.

From a geographical analysis, Fogang County is situated in the central part of Guangdong Province and shares borders with Conghua District of Guangzhou, Xinfeng County of Shaoguan City, Yingde

City and Qingcheng District of Qingyuan City. Throughout its long history of urban zoning changes, Fogang County has been a subject of contention between Guangzhou, Foshan, Shaoguan and Qingyuan for ownership. In 1958, Fogang County merged with Conghua County and was renamed as Conghua County under the jurisdiction of the Shaoguan Administrative Office. Subsequently in 1959, it was transferred from Conghua County to Foshan Special Administration Office before coming under the jurisdiction of Guangzhou in 1960. However, in 1961 it regained its status as an independent county when it separated from Conghua County and reverted back to being called Fogang County. Finally in 1983 and again in 1988 respectively, Fogang County came under the jurisdictions of Guangzhou and then Qingyuan City where it remains today.

Therefore, a significant number of individuals from developed cities such as Guangzhou, Foshan, Dongguan, Shenzhen and other areas in the Pearl River Delta have been attracted to Fogang County for real estate investment and recreational activities. Consequently, this has led to the development of diverse and vibrant local tourism resources. The area is well-connected with a comprehensive network of highways, including the provincial highway S245, county roads 277 and 317 which run parallel to the Pajiang River, Beijing-Hong Kong and Macao Expressway G4, National Highway G106, as well as county roads 270, 271, 272, 278, 280, 336, 346 and 361 that intersect with the Pajiang River. Moreover, attractive real estate options at affordable prices have enticed external buyers like Aoyuan and Country Garden Qingquan City as well as Huangsheng New City. Additionally, there are comfortable accommodation facilities such as Sunbolo Tourist Resort and Country Garden Resort along with several small to medium-sized farm restaurants scattered around the Pajiang river like Shuangyinglou Restaurant, Julongzhuang Hotel, Suifeng farmhouse Restaurant etc., ensuring a pleasant stay for visitors. Furthermore,a variety of amusement facilities have been established along the riverbanks including parks like Broken Bridge Flower Embankment Waterfront Park. The development and application of tourism resources not only disrupt the fundamental river structure but also generate a substantial amount of domestic waste, thereby impairing water quality and habitat for stream fish.

The second factor is agriculture. In order to secure their own survival interests, the residents of villages near Pajiang river engage in deforestation and vegetation clearance on both sides, resulting in the destruction of aquatic organisms' habitats and subsequently reducing the population of small aquatic creatures such as water flies, larvae and daphnia which are essential food sources for native fish. Furthermore, residents also engage in excessive fishing practices, often employing illegal methods like electrocution that directly diminishes the population of indigenous species. Even unintentionally, introduction of foreign species disrupts the balance within the original stream ecosystem by encroaching upon ecological niches occupied by native species and further restricting their living space.

Finally, climate and temperature exert a significant influence. Currently, various data indicate that the climate has been gradually warming across different regions of China in recent years. For instance, the average temperature in Guangdong in 2021 reached 23.0°C, which is 1.1 °C higher than the usual year and represents the highest recorded since meteorological records were established in 1951. Moreover, the average number of high-temperature days soared to a record-breaking 42.9 days, surpassing the usual count by 25.4 days [18]. In 2022, Guangdong Province experienced an average temperature of 23.2°C, marking a slight increase of 0.1°C compared to the yearly average from 1991 to 2020 [19]. Furthermore, during autumn in most parts of China in 2023, temperatures were observed to be approximately one degree Celsius higher than those recorded during corresponding periods [20]. As cold-blooded creatures, fish are highly susceptible to water temperature fluctuations as it directly impacts their metabolic rate and growth rate, thus altering their reproductive patterns as well as overall survival rates within streams.

The agricultural development has concurrently led to a reduction in vegetation along the riverbanks, thereby depriving native fish of their essential resting and spawning habitats. The absence of vegetation cover exposes the water surface to direct sunlight, resulting in a rapid increase in water temperature that poses survival challenges for certain native fish species intolerant to high

temperatures. As different fish species exhibit varying degrees of adaptability to temperature, the competitive advantage of stream-dwelling fish within specific habitats undergoes alterations, consequently impacting community structure.

Studies have indicated a significant increase in the occurrence of spring and autumn droughts in Fogang County since the beginning of the 21st century, suggesting an anticipated rise in alternating periods of partial flooding and partial droughts in the future, accompanied by an escalation in instances of drought-flood mutations [21]. Increases or decreases in precipitation directly impact river and lake water levels, consequently influencing fish habitat size and quality. Droughts specifically result in water body shrinkage, reducing available fish habitats, while floods cause physical destruction to fish habitats.

From 1852 to 1955, the management of the Thames River in the United Kingdom underwent a transition from pollution control to ecological restoration. Subsequently, starting in 1975, there was a proposal to promote collaborative water and shore management alongside industrial upgrading and economic model transformation [22]. In comparison with the developed countries in the Western world, Guangdong province lags behind in terms of its concept and level of river and lake water treatment across the entire region. The results of a national investigation on black and smelly water bodies jointly released by the Ministry of Housing and Urban-Rural Development and the former Ministry of Environmental Protection in 2016 indicate that urban areas within Guangdong province had the highest number of such polluted bodies nationwide. It wasn't until 2018 during the Fourth Plenary Session of the 12th session of Guangdong Provincial Party Committee that regulations for river network management were proposed. This initiative introduced new ideas and concepts for water control: leveraging the provincial river chief system, establishing a high-level comprehensive leading group for water control, strengthening coordination between government departments and society at large, all aimed at building a beautiful green-watered Guangdong with picturesque banks [23].

In order to restore the diversity of fish in the streams of Pajiang River, it is imperative for the government, enterprises and residents to enhance their awareness on fish species protection. They should also prevent the introduction of exotic species and reduce competition among native fish species. Additionally, measures must be taken to minimize damage caused by industrial construction on river courses, preserve rapids and slow-flow areas within them, protect water quality in river basins as well as vegetation and ecosystems along both sides of these basins. Fisheries administration management should be strengthened while artificial overfishing methods such as river barrier nets, electric fishing equipment or drugs must be prohibited. The coexistence between human beings and natural species needs to be balanced so that mutual benefits can be achieved. Ultimately, creating a green environment with clear waters will lead us towards an ecological world where lucid waters and lush mountains are invaluable assets.

3. Conclusion

In this study, the richness and influencing factors of stream fish in 11 areas of the upper reaches of Pajiang river in Fogang County, Qingyuan City, Guangdong Province over the past three years were investigated. Additionally, an analysis was conducted on the composition, influencing factors and protective measures for stream fish. The research findings indicate a declining trend in the richness of stream fish in the upper reaches of Pajiang river year by year. The study identified various factors affecting fish species diversity within these waters including changes in river structure and soil due to industrialization, poor water quality resulting from factory sewage and tourism activities, invasive alien species introduced through agricultural processes, reduction in small aquatic organisms and water oxygen content, rising water temperatures caused by environmental damage along the banks as well as increasing environmental temperature due to climate change alternating between droughts and floods. Considering the regional characteristics of the territory, it is recommended to enhance the awareness of local governments, enterprises, factories and village residents regarding stream fish

resource conservation. Additionally, there should be an emphasis on conducting comprehensive biological research on indigenous stream fish species and implementing robust protection measures. This includes dismantling industrial cement dams, promoting afforestation initiatives for increased green vegetation cover and curbing illegal fishing practices such as river barrier nets, electric fishing devices and drug-induced methods in order to restore the original ecological environment.

Although this study contributes to a preliminary understanding of the current situation and challenges faced by fish abundance in streams in the Fogang Area, as well as provides guidance for formulating effective conservation strategies, it is important to note that the survey site is limited to only 11 areas and does not encompass the entire Pajiang river basin. Furthermore,there are inaccuracies and lack of clarity in the data analysis. Specifically, further strengthening and improvement are needed regarding how specific influencing factors affect the response information on fish abundance.

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