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Synergy between Dominant Aquatic Plants and Fish in Rivers in Yangzhou City

Jinqing Wang*

Department of Animal Nutrition and Fisheries, Shandong Vocational Animal Science and Veterinary College, China

***Corresponding author:** Jinqing Wang, Ph.D, Associate professor, Department of Animal Nutrition and Fisheries, Shandong Vocational Animal Science and Veterinary College, Yishan Agriculture Technology Co., Ltd, Yangzhou 225624, Yangzhou City, China, Tel: +86-17660718689; Email: jinqwang@163.com

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Research Status and Level at Home and Abroad

Large aquatic plants are closely related to fish communities and aquatic environment, and their interaction determines the stability of aquatic ecosystems. Tugend and Allen [1] studied the changes of plant and fish communities in the ecological restoration area of Kissimmee Lake, Florida. The results showed that fish diversity and richness were the highest in the year with the highest water level, and that water depth and plant coverage ratio were significantly positively correlated with fish community variables, which indicated that water environment, plant characteristics and fish were potentially closely related.

Assessment of fish community structure is an effective way to understand the integrity of biological flora in a river and an important tool for qualitative environmental quality. Many studies have linked fish community structures to environmental degradation caused by human disturbances, such as agricultural and urbanization processes [2]. For example, the number and biomass of individual fish are used to reflect the biomass and energy of the system, while the number of species reflects habitat diversity and fish behavior. Arajo (1998) and Arajo, et al. (2003) studied the tributary of Paraba do Sul (about 80 km) in Brazil using the Biological Community Integrity Index (IBI). It was found that the water near the city was affected by a large number of organic and industrial pollutants, and the overall quality of fish communities was very poor.

When fish species are small, aquatic plants can be used as biological indicators to detect ecological conditions. Hatzenbeler, et al. [3] compared the effects of fish and aquatic plants on the assessment of Lake Ecological health, and found that aquatic plant communities were more sensitive to lake shore development than fish communities. All these provide an effective way to accurately evaluate ecosystem health. Domestic and foreign research fields related to this issue include biology, ecology, environment, aquatic products, etc.

Since 1993, research has been deepening, mainly from the following aspects:
(1) Aquatic plants: Aquatic plants are important physical structural elements in water. As primary producers, aquatic plants not only directly provide food for aquatic animals, but also provide important habitat conditions for their reproductive behavior (courtship, mating, oviposition and development). In recent years, many researchers have paid attention to the growth of aquatic plants. Kohler, et al. [4]. The 82nd Annual Conference of Pennsylvania College (Grantville, PA, USA) reported the diversity and abundance of aquatic plants in a carbonate spring ecosystem. Xie, et al. (2004) reported on the improvement of water quality by aquatic plants in fish cage culture areas at the 29th International Conference on the Theory and Application of Lahti (FINLAND) [5].

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The Important Role of Aquatic Plants in the Aquatic Environment

Aquatic plants increase the structural complexity of the aquatic environment, provide resources for the food web, and promote the diversity and stability of aquatic animals. Usually, plant-growing habitats support higher fish density than non-plant areas, and aquatic plants reduce the risk of fish predation [6]. The responses of fish and phytoplankton to plants are significantly different. The abundance of phytoplankton and benthic omnivorous species decreases with the increase of plant coverage, while the number of plant-loving fish population increases rapidly in the growing season. Overall, aquatic plants have a positive effect on the environment and most of the organisms.

Most studies have shown that medium-density plants are conducive to the survival and reproduction of fish. The biomass level of fish in the river with 20-70% coverage of aquatic grasses is twice and four times higher than that in the sparse (< 20%) or over-dense (>70%) areas [7]. Indicators such as catch per unit effort, species richness and species diversity of juvenile fish larvae are higher in medium plant coverage than in low and high plant coverage waters. Medium plant coverage is particularly important for early life stages of fish [8]. Because it is very difficult to observe fish directly in dense aquatic plant growing areas, few studies have been conducted to define and quantify the structural complexity of plants on the scale of fish perception. By analyzing the regional distribution of aquatic plants and predicting the behavior and distribution of fish on a large scale, it is helpful to guide the management strategy of fishery resources on a large scale [9].

Aquatic vegetation increases environmental complexity, potentially affecting predator-prey interspecific relationships. According to the biomass of large plants, fish communities are significantly different: the highest contribution occurs in the area of maximum plant biomass, while the higher contribution (mainly fish density) occurs in the area of medium plant coverage. In the normal range of oxygen, temperature and pH, the changes of fish community are mainly explained by plant density. Measures to reduce the density of large plants in reservoirs may lead to dramatic changes in fish communities, resulting in decreased fish density, biomass and abundance using Egeria habitats [10]. Other studies have shown that in the presence of predators (micropterus salmoides larvae), mosquito-eating fish (Gambusia holbrooki) chose Hydrilla verticillata, broadfin gill (Poecilia latipinna) chose H. verticillata under natural plant density conditions, while marginal sunfish (Lepomis marginatus) did not have consistent habitat selectivity [11,12]. Aquatic plants also alter fish feeding. When scientists studied soil properties, fish predation, interactions between aquatic plants and phytoplankton, zooplankton community structure, they found that large aquatic plants reduced fish feeding on phytoplankton [13]. Aquatic plants can influence the reproductive behavior of fish. Goldfish and crucian carp spawn actively on aquatic plants, and plant depletion caused by the construction of artificial riverbanks and lakeside zones may inhibit fish reproduction [14].

Aquatic plant communities have significantly changed the physical and chemical conditions of the water body and have an impact on fish. Oxygen and temperature variability within plants provide shelter for fish. When oxygen is scarce in deep water, large plant areas, especially surface areas, provide suitable conditions for fish [6]. Studies on the development of aquatic weeds in the Corff River (Brittany, France) show that large plants can dramatically change habitat conditions, reduce water flow velocity by about 60%, and reduce the transport capacity of water to salmon [15]. There are mosaic conditions in aquatic plant areas, including temporary physical and chemical microhabitat mosaic patches. In these patches, physical and chemical conditions are unstable, and fish must constantly change their microhabitats to avoid being trapped by inappropriate conditions in the daily physical and chemical environment reorganization process [6].

Aquatic plants also have some negative effects on fish. In large-scale plant-intensive areas, the high-density respiration of plants at night can cause anoxia in water and affect the respiration of fish. When plants occupy the whole water body, fish growth is inhibited and slowed down due to the depletion of food resources [9]. But plants can also alter the abiotic properties of water bodies, creating physical and chemical conditions that fish cannot tolerate at high densities [6]. Studies in lakes and rivers in North America have shown a positive correlation between nutrient status (e.g., measured total phosphorus concentration) and fish stocks. Consequently, eutrophic rivers generally support higher fish production than eutrophic habitats, and overconsumption of nutrients by primary aquatic plants is not conducive to algae development and fish production [7].

Aquatic plants have other functions. Fish meal substitution for aquatic feed: Fish can selectively feed on animal and plant proteins according to different protein levels, which will help reduce protein input and contribute to the effective utilization of low-quality, plant protein-based feed [16]. Researchers extracted a natural plant substance called De odorase from the fleshy plants

of Cymbidium genus. The concentration of ammonia nitrogen and nitrate nitrogen in the pond water treated with De odorase gradually decreased after 45 days, increasing dissolved oxygen, alkalinity and plankton concentration in the water [17]. Herring oil can be used as an alternative to petroleum products to kill carnivorous respiratory insects, while corn oil is an effective control agent at a higher rate of use [18].

The Interaction between Aquatic Plants and Fish is Frequently Related to the Problem of Invasion

The invasion of weed species (Elymus athericus) in the salt marshes of Mont-Saint-Michel Bay (France) has resulted in significant changes in vegetation coverage, possibly altering the habitats of many invertebrates, which constitute food items for several species of fish, such as Dicentrarchus labrax and Pomatoschistus M. Inutus) [19]. The invasion of Elymus athericus changed the larval function of salt marshes to fish. Gastric contents analysis showed that the proportion of empty stomach fish from invasive plant areas was significantly higher than that from native plant areas. The importance of major food items of tongue-toothed perch has undergone an important change: Half-terrestrial species O. gammarella dominated the food of tongue-toothed perch before invasion, while marine bran shrimp (Neomysis integer) dominated the food of tongue-toothed perch after invasion. The same trend has also been observed in beach shrimp and tiger fish, where the main food items have shifted from *O. gammarella* to Hediste diversicolor. This nutrient transformation can be explained as follows: in the invasive community, *O. gammarella* has lower accessibility and acquirement than in the natural community. Through observations throughout northern Europe, the invasion of *E. athericus* may disturb the nutritional function of natural salt marshes to fish. At the same time, the preliminary study of *E. athericus* invasion is strong evidence that the invasive species are an urgent problem in conservation biology.

When the invasive weed *Hymenachne amplexicaulis* was used to replace the floating and submerged vegetation in Fitzroy River, the plant community and the large invertebrate community changed. In this study, the species *Xiphophorus maculatus* (Swordtail) was introduced into Hymenachne habitat, which accounted for 75% of the total catch, while only 0% of the local plants. As an important factor affecting the composition of fish and large invertebrates, the change of vegetation structure is very complex and has potential impact on the habitat value of seabirds in wetlands [20].

Fish abundance and community composition of native and non-native plants in Lake Izabal, Guatemala, after the establishment of hydrilla. Although Hydrilla has a negative impact on native plants, river access and other uses, it provides a useful habitat for fish communities and may be harmless to the composition of fish communities in Lake Izabal, Guatemala [21].

With the increase of latitude and elevation, soil water evaporation, temperature and precipitation decreased, species density and local and non-local species decreased accordingly. Local species of birds and plants are highly positively correlated with non-native species. Birds and plants can be accurately predicted at the urban level, but fish communities at the river level are difficult to predict. Local and exotic plants, birds and fish are always located at low altitudes, near the coast, and in areas with high precipitation and plant yields. We conclude that humans facilitate the initial colonization and invasion of alien species, while the subsequent diffusion and distribution are determined by environmental factor [22].

Plant invasion and the exclusion of indigenous species involve the transformation of plant habitats, which will inevitably change the physical and chemical environment, primary production and food resources of the entire aquatic community, and then affect the fish community [23-35].

In summary, large aquatic plants are the most dominant plant components in water environment, especially in fresh water. According to their distribution and biomass, they can play a decisive role in the physical and chemical environment of the waters. Fish is the most dominant component of animals, as the top consumer, at the top of the food chain, controlling energy flow. This study focuses on the two most important components in the water area, focusing on the interaction between them. Essentially, it focuses on the factors that determine the material cycle and energy flow in the aquatic ecosystem, and stands at the forefront of the aquatic ecosystem, enriches and develops the basic ecology, which has profound theoretical significance.

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