Spatial Niche Breadth and Overlap of Main Nekton Species in Autumn Near Dongtou Island

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Abstract: As the basic theory in community ecology, research on the niche breadth and niche overlap is of great significance to understand the position, function of various species and explain the mechanism of interspecific coexistence and competition. We found the main nekton were 5 species of fish, 5 species of shrimp and 2 species of crab in autumn in the sea area near Dongtou Island (DTI). The dominant species are mainly *Harpodon nehereus*, *Portunus trituberculatus* and *Oratosquilla oratoria*, in which the *Harpodon nehereus* and *Portunus trituberculatus* had the high degree of aggregation phenomenon in DTI. The niche breadth of main nekton ranged from 1.08-2.06, and the broad niche species were shrimp *Solenocera crassicornis* (2.06) and fish *Harpodon nehereus* (2.03), which is negative correlated with the index of aggregation intensity. The niche overlap index (Q_{ik}) of main nekton were 66 pairs of species, in which, 32 pairs whose overlap indices were $Q_{ik} > 0.6$ and 23 pairs whose overlap indices were $0.6 \geq Q_{ik} \geq 0.3$. The niche breadth and overlap of main nekton communities were highly positive correlated. The niche overlap may be a necessary factor for interspecific competition between the nekton species. The competition among species may also be affected by the distribution and supply of resources in the coexistence area. The habitat homogenization of nekton community should be considered in studying the niche and ecological restoration.

1 INTRODUCTION

The niche theory was first proposed and defined by Grinnell (1917; 1924), and then Elton (1927) and Hutchinson (1991) successively put forward nutrition niche, multi-dimensional super volume niche and other theories, which improved and developed the niche theory. The niche theory has been widely used in the study of species community structure and function, community interspecific relationship, biodiversity and other aspects. The division of trophic level, functional group and niche has been highly applied to the study of aquatic ecosystem (especially in marine ecosystems) in recent years. Yu et al. (2010) showed that niche breadth could more comprehensively reflect the evenness and change of species biomass at different scales in the central and southern Yellow Sea; Li et al. (2013) believed that the niche of dominant fish species in the Yangtze River Estuary and adjacent waters had obvious seasonal variation and spatial movement trend. Li et al. (2017) found that the niche overlap is different among species and has the relatively independent distribution characteristics in Wenzhou Bay.

Dongtou Island (DTI) is rich in islands and marine resources, which is located in the estuarine area (Oujiang) in the southeastern part of the East China Sea. The sufficient baiting food brought by river runoff supply for nekton to feed, spawn, breed here (Day et al., 2012). There may be overlap and interspecific competition in the niche of main nekton species. Therefore, it is necessary to study the niche of main nekton in estuarine waters. The research on the nekton in Oujiang Estuary (near DTI) and its adjacent waters mainly focused on the community composition, community structure and its relationship with environmental factors (Xu, 2008, 2009; Yan et al., 2018, 2019). And, Li et al. (2013) studied the niche and interspecific association and functional group of major nekton in the spring of Wenzhou Bay. Zhang et al. (2019) found the niche breadth values differed greatly and showed

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significant positive correlation with *IRI* in Yueqing Bay. However, there is no relevant report on the niche breadth and overlap of main zooplankton species in autumn in the sea area around DTI.

This paper studied the niche breadth and overlapping characteristics of the main nekton communities in the coastal waters of DTI in autumn, which can objectively reflect the interspecific relationship and community structure characteristics of the main nekton communities in the coastal waters, reveal the ecological relationship between different species, avoid interspecific competition due to lack of common resources, and maintain ecological balance. The purpose is to provide scientific basis for the research and sustainable utilization of the marine ecosystem.

2 MATERIALS AND METHODS

2.1 Study Area

DTI is located in the southeast coast of the East China Sea, whch is rich in marine resources and has many bay shorelines, and is the second largest fishing ground in Zhejiang (Fig. 1). As the second largest river in Zhejiang Province, the Oujiang River feeds fresh water into the sea near DTI all year round, making the sea rich in bait organisms, which is favorable for fish and other nekton to feed and spawn here.

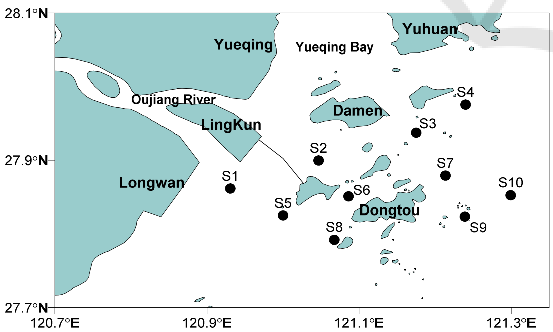

Figure 1: Study area and sampling stations in DTI, China.

2.2 Sample Collection and Data Analysis

The research data was collected through the survey cruise with 10 sampling sites in Autumn (October) of 2019 in the waters around DTI (Fig. 1) (Zhang et al., 2021). We employed an 8-m wide, mouth-opening bottom trawl, with 20 mm cod-end mesh, was towed in mean speed of 3.7 kn for 25 min on average in stepped tows to collect samples. And, we standardized the original survey data of nekton before data analysis.

The dominant species was determined by the Index of Relative Importance (*IRI*): $IRI = (W + N) \times F$ (1) (Pinkas et al., 1971). W is the percentage of a species′ biomass in the total biomass, N is the percentage of a species′ abundance in the total abundance, F is the frequency of a species′ occurrence in all stations. The species with $IRI >$ 1000 were the dominant species; The species with *IRI* value of 100-1000 were important species. We selected the species with $IRI > 100$ and the frequency of occurrence higher than 50% as the main nekton of the study.

The aggregation intensity of main nekton species was determined by the clumping index : $I = S^2/x - 1$ (2); and mean crowding index : $x^* = (S^2 - x + x^2)/x$ (3) (x is the mean of the total number of species, S^2 is the variance) (Lloyd, 1967).

The niche breadth was calculated by Shannon Wiener index (Shannon and Wiener, 1963): $B_i = -\sum_{j=1}^{r}(P_{ij} ln P_{ij})$(4). According to the value of B_i, species can be divided into broad niche species ($B_i \geq 2.0$), medium niche species ($2.0 > B_i \geq 1.0$) and narrow niche species ($1.0 > B_i > 0$) (Doledec et al., 2000). The niche overlap index was calculated by Pianka index (Pianka, 1973): $Q_{ik} = \sum_{j=1}^{r}(P_{ij}P_{kj}) / \sqrt{\sum_{j=1}^{r} P_{ij}^2 \sum_{j=1}^{r} P_{kj}^2}$(5). r is the number in all sampling station; P_{ij} and P_{kj} represent the proportion of individual number of species i and species k in station j to the total number of species. B_i is the niche breadth with the value range in 0-r. The peak B_i value means the high niche breadth. Q_{ik} represents the niche overlap value with the range in 0-1. $Q_{ik} > 0.3$ is regarded as significant overlap, and $Q_{ik} > 0.6$ is regarded as highly significant overlap (Krebs, 1999).

3 RESULTS & DISCUSSION

Our results showed that the main nekton in the sea area near DTI included 5 species of fish (*Harpodon nehereus*, *Coilia nasus*, *Takifugu xanthopterus*, *Chrysochir aureus*, *Collichthys lucidus*), 5 species of shrimp (*Solenocera crassicornis*, *Palaemon gravieri*, *Exopalaemon carinicauda*, *Oratosquilla oratoria*, *Exopalaemon annandalei*) and 2 species of crab (*Charybdis japonica*, *Portunus trituberculatus*) in autumn (Table 1). The dominant species are mainly *Harpodon nehereus*, *Portunus trituberculatus* and *Oratosquilla oratoria*. As the aggregation intensity of dominant species is an indicator reflecting the spatial distribution of nekton. When it is positive, it means that the spatial pattern of the species is non-random to a greater extent, i.e. there is a certain aggregation, and the high positive value means the high aggregation intensity. We found that the *Harpodon nehereus* and *Portunus trituberculatus* were captured in the all sampling stations, implied that there is a large number of aggregation phenomenon of these two species in the sea area, which also can be reflected from the aggregation intensity index (Table 1).

Comparison with the aggregation intensity index, the spatial niche reflects the evenness of species spatial distribution (Yu et al., 2010), and it is a negative correlated with the index of aggregation intensity (I, x^*). For instance, *Portunus trituberculatus* and *Oratosquilla oratoria* were the relatively low niche species, while their indices of aggregation intensity (I=15342.02, 15771.32; x^*=20701.22, 20763.66) were extremely high (Table 1, Fig. 2). As the niche theory is one of the basic theories to explain the mechanism of interspecific coexistence and competition in communities. The calculation of niche breadth and niche overlap is of great significance to understand the position and function of various species in the community and the relationship among species (Yu et al., 2010; Zhang et al., 2019). Niche breadth is an important index to evaluate the environmental adaptability and resource utilization of species, and its value depends on the ecological adaptability, interspecific competitiveness and distribution range of species (Soberon and Peterson, 2005). We found that the niche breadth of main nekton ranged from 1.08-2.06 in DTI (Fig. 2). The broad niche species were shrimp *Solenocera crassicornis* (2.06) and fish *Harpodon nehereus* (2.03), while other species were the medium niche species. The niche breadth segmentation is not obvious, contrary to Zhang et al (2020). The larger the value of niche breadth, the higher the ability of the species to use its resources, and the species could more easily adapt to environmental changes and broadened the scope of activities (Liu et al., 2018). The niche breadth of *Harpodon nehereus* was relatively high (2.03) with the high proportion of quantity (Table 1), indicated the species has the widest distribution and is more adaptable to environmental changes, able to make better use of environmental resources and at an absolute advantage in the competition in the investigated sea area.

The overlap value of ecological niches reflects the similarity and competition between species for the utilization of same resource (Liu et al., 2018; Wathne et al., 2000). When the overlap value was greater than 0.6, the overlap between species pairs was significant, and the overlap between species pairs and stations was high (Wathne et al., 2000). In the sea area near DTI, the results indicated the niche overlap index (Q_{ik}) of main nekton were 66 pairs of species, in which, 32 pairs whose overlap indices were Q_{ik} > 0.6 (accounting for 48.48% of the total species pairs) and 23 pairs whose overlap indices were $0.6 \geq Q_{ik} \geq 0.3$ (accounting for 34.85% of the total species pairs), and only 11 pairs whose overlap indices were < 0.3 (accounting for 16.67% of the total species pairs) (Table 2). The niche breadth and overlap of the main nekton communities were highly positive correlated (Fig. 2, Table 2). For example, the broad niche species shrimp *Solenocera crassicornis* and fish *Harpodon nehereus* were significantly overlapped with most species. Actually, niche overlap may be a necessary factor for interspecific competition between the nekton species. For instance, the niche overlap of crab *Portunus trituberculatus* and fish *Collichthys lucidus* is significant (Q_{ik} = 0.99) (Wathne et al., 2000), although there are some differences in the habitats between sub-benthic *Collichthys lucidus* and benthic *Portunus trituberculatus*, their competition in food resources is fierce as they both feed on benthos. Nevertheless, the niche overlap of *Solenocera crassicornis* and *Exopalaemon annandalei* is not significant (Q_{ik} = 0.18), due to the fact that the feeding spectrum of *Solenocera crassicornis* are more than that of *Exopalaemon annandale*. As a result, we believed the overlap value and competition degree of interspecific pairs are not necessarily positive correlated. The competition among species may also be affected by the distribution and supply of resources in the coexistence area. Furthermore, the high spatial niche overlap in this study also reflects the reality of the high degree of habitat homogeneity in the nekton community in DTI, which should be considered in ecological restoration.

Table 1: The Index of Relative Importance (*IRI*), index of aggregation intensity of main nekton species in DTI.

Nekton species	Code	*N*	*W*	*F*	*IRI*	*I*	*x**
Solenocera crassicornis	*SC*	3.75	0.24	90.00	359.25	365.82	1438.97
Harpodon nehereus	*HN*	29.77	19.93	100.00	4970.16	4918.26	13432.16
Charybdis japonica	*CJ*	2.01	2.52	90.00	407.29	900.78	1474.41
Coilia nasus	*CN*	1.36	4.19	80.00	443.99	480.45	869.97
Palaemon gravieri	*PG*	1.93	0.14	70.00	145.01	784.42	1336.05
Takifugu xanthopterus	*TX*	0.95	1.46	70.00	169.37	436.10	709.15
Exopalaemon carinicauda	*EC*	1.87	0.38	70.00	157.84	1065.73	1601.38
Chrysochir aureus	*CA*	1.34	1.35	60.00	161.66	1001.63	1384.85
Portunus trituberculatus	*PT*	18.74	19.29	100.00	3803.04	15342.02	20701.22
Oratosquilla oratoria	*OO*	17.46	7.34	80.00	1984.02	15771.32	20763.66
Collichthys lucidus	*CL*	4.45	4.72	60.00	550.33	5586.78	6858.89
Exopalaemon annandalei	*EA*	2.17	0.07	70.00	156.53	3191.12	3810.50

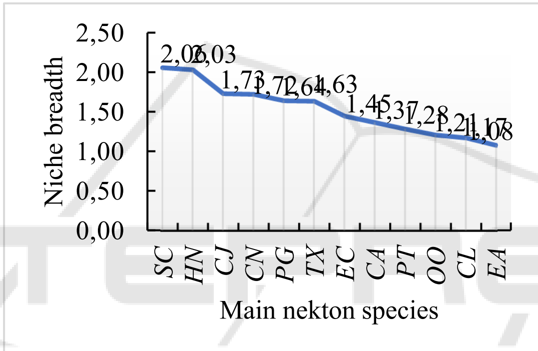

Figure 2: Variation of niche breadth of main nekton species in DTI. The codes are same to Table 1.

Table 2: Niche overlap index of main nekton species in DTI. The codes are same to Table 1.

Q_{ik}	*HN*	*CN*	*TX*	*CA*	*CL*	*SC*	*PG*	*EC*	*OO*	*EA*	*CJ*	*PT*
HN	1.00											
CN	0.88	1.00										
TX	0.52	0.54	1.00									
CA	0.56	0.34	0.24	1.00								
CL	0.82	0.73	0.37	0.46	1.00							
SC	0.83	0.78	0.70	0.45	0.46	1.00						
PG	0.76	0.75	0.62	0.20	0.81	0.64	1.00					
EC	0.75	0.70	0.40	0.34	0.68	0.75	0.85	1.00				
OO	0.82	0.66	0.39	0.60	0.96	0.52	0.78	0.74	1.00			
EA	0.27	0.40	0.08	0.54	0.25	0.18	0.18	0.14	0.20	1.00		
CJ	0.68	0.35	0.41	0.85	0.57	0.61	0.44	0.56	0.75	0.12	1.00	
PT	0.83	0.70	0.38	0.52	0.99	0.48	0.78	0.66	0.98	0.22	0.65	1.00

4 CONCLUSIONS

The main nekton in the sea area near DTI included 5 species of fish, 5 species of shrimp and 2 species of crab in autumn. The dominant species are mainly *Harpodon nehereus*, *Portunus trituberculatus* and *Oratosquilla oratoria*, in which the *Harpodon nehereus* and *Portunus trituberculatus* had the high degree of aggregation phenomenon in the sea area. The niche breadth of main nekton ranged from 1.08-2.06, and the broad niche species were shrimp *Solenocera crassicornis* (2.06) and fish *Harpodon* *nehereus* (2.03), which is negative correlated with the index of aggregation intensity. The niche overlap index (Q_{ik}) of main nekton were 66 pairs of species, in which, 32 pairs whose overlap indices were $Q_{ik} > 0.6$ and 23 pairs whose overlap indices were $0.6 \geq Q_{ik} \geq 0.3$. The niche breadth and overlap of the main nekton communities were highly positive correlated. The niche overlap may be a necessary factor for interspecific competition between the nekton species. The competition among species may also be affected by the distribution and supply of resources in the coexistence area. Next, we should consider the habitat homogenization of nekton community in studying the niche and ecological restoration.

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