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Distribution characteristics and seasonal seawater changes of fish eggs and larvae in the northern South China Sea

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ABSTRACT

The quality of the marine environment is increasingly affected by human activities, especially the ecological environment of nearshore waters is deteriorating year by year, and the production of fishery resources is constantly decreasing. As a result, fish eggs and larvae have gradually been highly valued in recent years. Through cross-sectional investigation and research on the spring and autumn seasons in the northern waters of the South China Sea, this paper preliminarily explores the distribution characteristics and seasonal changes of fish eggs and larvae in the northern South China Sea. As clearly revealed by the survey and research results, the species and resource density of fish eggs and larvae in spring are higher than those in autumn. Moreover, the high-density areas of fish eggs and larvae are predominantly concentrated in the nearshore waters, with a comparatively small number in the nearshore areas. In spring, there are principally open-sea species, while in autumn, there are nearshore species. After October in the northern part of the South China Sea, the water temperature began to decrease, and fish entered a low peak period of spawning. This study has reference value for the sustainable development of fisheries in the sea area as well as the protection and rational utilization of marine living resources.

Keywords: Northern South China Sea; Fish eggs and larvae; Distribution characteristics; Seasonal changes

1. Introduction

As is known to all, the northern part of the South China Sea is a land sea interaction water body that flows into the South China Sea after the three main streams of the Pearl River – Xijiang River, Beijiang River and Dongjiang River intersect in the delta and pass through the Badaokou Gate. It is also the main receiving water body for land source pollutants in the northern part of the South China Sea, with an annual runoff of about 300 billion·m^3. The sea area belongs to a typical subtropical estuarine ecosystem [1,2].

Over the past 10 y, the species number and individual density of zooplankton in the Pearl River Estuary have not changed conspicuously in recent years [3]. Specifically, in the summer of 2002, a total of 117 species of large zooplankton were discovered, with an average density of 464 ind/m^3. In the summer of 2009, a total of 121 species of zooplankton were identified, with an average individual density of 423 ind/m^3. Although the abundance and individual numbers of zooplankton species do not change noticeably [4–6], there has been a noticeable change in the composition of the number of planktonic animals. In 2002, the proportion of copepods was the highest, accounting for 40% of the total number of zooplankton, while Cladocera only accounted for 19%. But in 2009, the proportion of copepods decreased, accounting for only 16% of the total number of planktonic animals, while Cladocera became the dominant group, with a proportion of 64%. Filter feeding Cladocera ingests a myriad of bacteria and organic debris, which can be used as monitoring organisms for pollution. The increase

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in the number of Cladocera suggests that the zooplankton community in the Pearl River Estuary has responded to the deterioration of water quality. On the other hand, the filtering effect of Cladocera also plays an important role in the self-purification of the sea area [7–9]. Cladocera belong to smaller zooplankton, and the increase in the proportion of Cladocera is one of the reasons why the biomass (wet weight) of zooplankton decreased from 172 mg/m^3 in 2002 to 135 mg/m^3 in 2009. This paper adopts survey data from the spring and autumn seasons of 2010 to 2011 to study the species composition, dominant species, and quantity distribution of fish plankton in the northern South China Sea, and explores their seasonal changes, providing reference for the sustainable development of fisheries in the sea area and the protection and rational utilization of marine biological resources [10–12].

2. Sampling and sample processing

2.1. Survey time and sampling positioning

The survey will be conducted once in spring and once in autumn separately.

The survey covers the northern waters of the South China Sea, from E113° 20′ 23.00″ to E114° 54′ 20.56″, and from N20° 08′ 43.58″ to N21° 53′ 37.47″, with a total of 23 stations set-up as exhibited in Fig. 1.

2.2. Sampling method and sample processing

Fish eggs and larvae are trawled vertically and horizontally once severally.

Samples of fish eggs, larvae, and juveniles in water depths of up to and including 30 m are taken from shallow water I A type of plankton net (with a net mouth area of 0.2 m^2, a net mouth inner diameter of 50 cm, a net length of 145 cm, and a sieve diameter of 0.505 mm) is vertically towed from the seabed to the sea surface once; A large plankton net (with a net mouth area of 0.5 m^2, an inner diameter of 80 cm, a net length of 280 cm, and a sieve diameter of 0.505 mm) was used to vertically trawl fish eggs and juveniles from the seabed to the sea surface at a depth of 30 m [13–15].

Horizontal trawl sampling uses a large plankton net to horizontally tow for 10 min, with a ship speed of 1–2 knots.

The collected samples were fixed with a 5% formaldehyde solution and then brought back to the laboratory for species identification and counting [16,17].

3. Results and discussion

3.1. Species composition and distribution

3.1.1. Fish eggs

3.1.1.1. Spring

A total of 15 species of vertical trawl fish eggs were identified (including 1 unidentified fish egg); Among them, the number of *Thryssa mystax* is the highest, accounting for 35.9% of the total number of vertical trawl fish eggs; Next is the *Stolephorus* sp., accounting for 22.6%. 7 species were collected by horizontal trawl (including 1 unidentified fish egg); Among them, the *Upeneus* sp. has the highest number, accounting for 66.0% of the total number of horizontal trawl fish eggs. Among the surveyed stations, P45 station showed 6 types of fish eggs, making it the station with the most types of fish eggs; Next are stations P21, P42, and P44, each showing 5 species of fish eggs [18].

3.1.1.2. Autumn

There are a total of 11 species of vertical trawl fish eggs (including 1 undetermined species). Among them, *Stolephorus* sp. has the highest number of fish eggs, accounting for 52.0% of the total number of vertical trawl fish eggs; Next is the *Upeneus* sp., accounting for 28.2%. 9 species (including 1 unidentified fish egg) were collected by horizontal trawl. Among them, the *Upeneus* sp. has the highest number, accounting for 29.9% of the total number of horizontal trawl fish eggs; The second is the *Carangidae*, accounting for 25.1%. Among the surveyed stations, P44 station showed 5 types of fish eggs, making it the station with the highest number of fish egg types; Next are stations P27, P42, P45, and P49, each showing 4 species of fish eggs.

3.1.2. Larva

3.1.2.1. Spring

A total of 31 species of vertical trawl larvae and juveniles were identified (including 1 unidentified species). Among them, *Carangidae* has the highest number, accounting for 20.0% of the total number of vertical trawl larvae and juveniles; Next are *Gobiidae* and *Stolephorus* sp., accounting for 12.2% and 10.4% separately. There are a total of 24 species of horizontal trawl larvae and juveniles (including 1 undetermined species), among which *Osteomugil ophuyseni* has the highest number, accounting for 43.8% of the total number of horizontal trawl larvae and juveniles; Next are the *Oxyporhamphus micropterus*, *Sparidae*, and *Upeneus* sp., accounting for 20.7%, 12.3%, and 11.4%, severally [19,20]. In the surveyed stations, both P21 and P44 stations showed 10 species, which is the station with the highest number of juvenile fish species; Next are P22 stations and P17 stations, with 9 and 8 types appearing severally.

3.1.2.2. Autumn

There are a total of 27 species of vertical trawl larvae and juveniles (including 1 undecided species). Among them, the *Argyrosomus* sp. has the highest number, accounting for 30.9% of the total number of vertical trawl larvae and juveniles; Next are *Cynoglossidae* and *Sciaenidae*, accounting for 19.3% and 10.5% separately. There are a total of 19 species of horizontal trawl larvae and juveniles (including 1 undetermined larvae species). Among them, the *Stolephorus* sp. has the highest number, accounting for 23.1% of the total number of horizontal trawl larvae and juveniles; Next are *Argyrosomus* sp. and *Sciaenidae*, accounting for 20.9% and 9.9%, respectively. Among the surveyed stations, P30 station has 9 species, which is the station with the highest number of juvenile fish species; Next are P14 stations, with 7 types appearing, respectively.

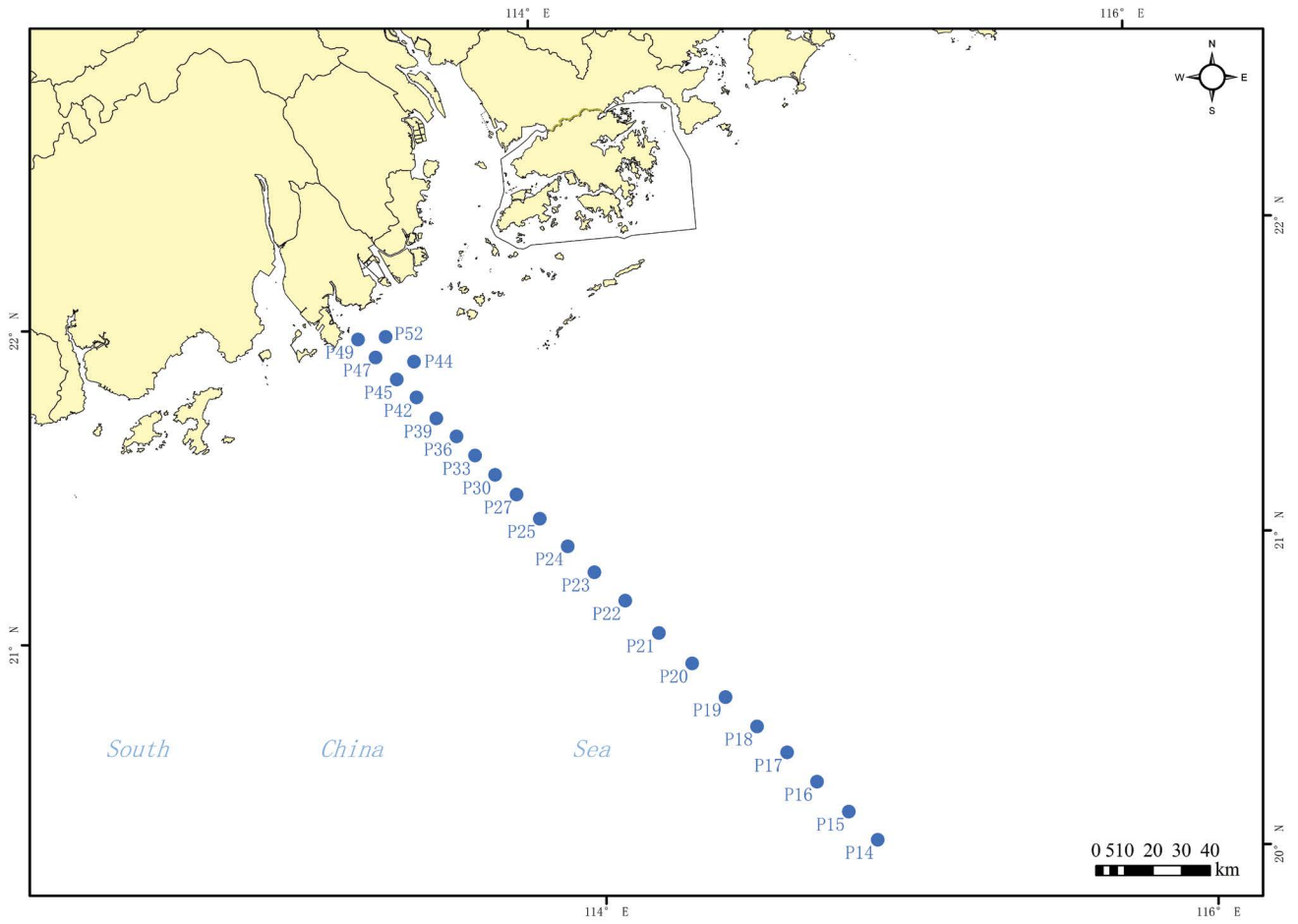

Fig. 1. Researching area and sampling locations.

3.2. Quantity distribution

3.2.1. Fish eggs

3.2.1.1. Spring

1,903 fish eggs were collected during the April survey, of which 397 were collected through vertical trawls, with an average density of 2.89 ind/m^3; 1,506 fish eggs were collected by horizontal trawl.

The changing range of fish egg density is (0–33.00) ind/m^3, with an average density of 2.89 ind/m^3, with remarkable differences in dissimilar regions. The high-density area appears at station P44 at 33.00 ind/m^3; Next are P47 and P45 stations, with 13.96 and 7.23 ind/m^3 separately; The average density of fish eggs at other sites is relatively low. The results indicate that the high-density areas of fish eggs in the surveyed sea area are principally concentrated in the nearshore waters, while the number of fish eggs in the open-sea areas is comparatively small (as exhibited in Fig. 2).

The number of fish eggs collected by horizontal trawling varies greatly from 0 to 570 at each station, with conspicuous differences in dissimilar regions. The horizontal trawl fish eggs are primarily distributed at station P23, with 570 eggs; Next are P44 station and P22 station, with 328 and 182 fish eggs, separately; The number of other stations is relatively small.

3.2.1.2. Autumn

In October, a survey collected 627 fish eggs, of which 78 were collected by vertical trawls, with an average density of 0.61 ind/m^3; 549 fish eggs were collected by horizontal trawl.

The average density of fish eggs is 0.61 ind/m^3, with a range of (0–4.67) ind/m^3 and a noticeable change. The high-density area appears at P52 station, at 4.67 ind/m^3; Next are stations P49, P42, and P44, with values of 2.73, 1.78, and 1.03 ind/m^3, severally; The density of other stations is comparatively low. The high-density area of fish eggs in the surveyed sea area is predominantly concentrated in the nearshore area, while the quantity in the open-sea area is comparatively small as depicted in Fig. 3.

The number of fish eggs collected by horizontal trawl varies from 0 to 113, with remarkable changes in dissimilar regions. The horizontal trawl fish eggs are principally distributed at station P19, with 113 eggs; The second stations are P14, P27, and P42, with 83, 63, and 63 fish eggs, respectively; The number of other stations is comparatively small.

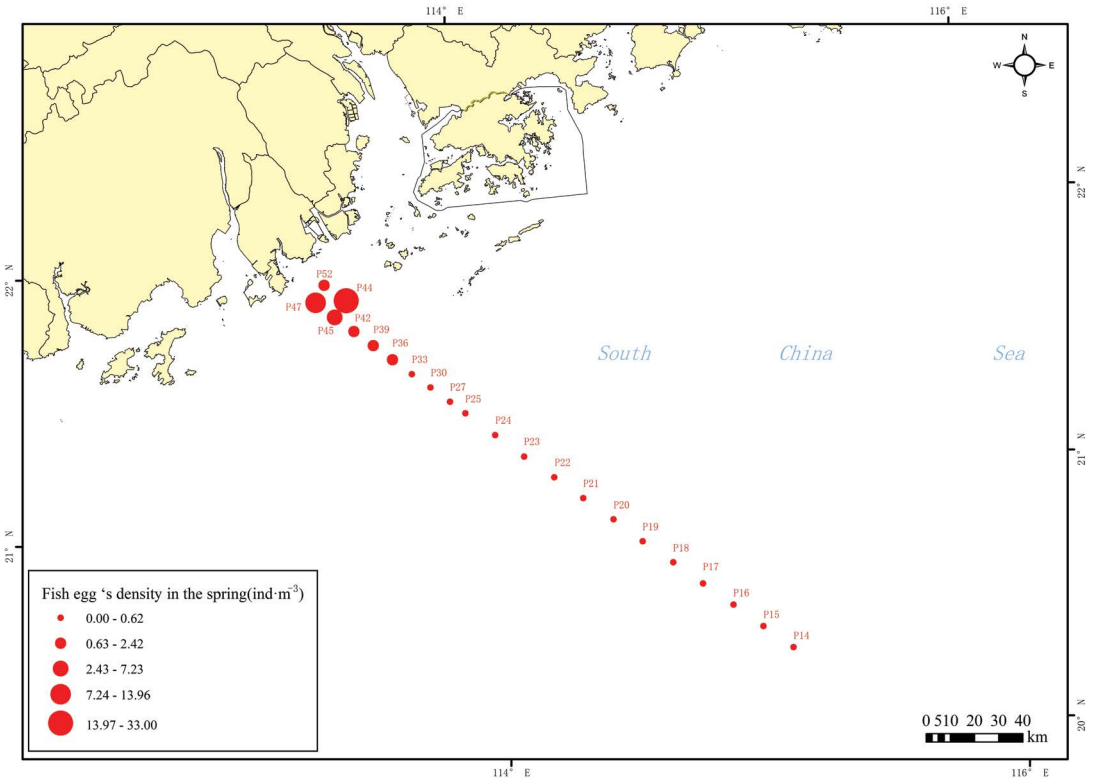

Fig. 2. Distribution condition of the fish egg's density in the spring (ind/m^3).

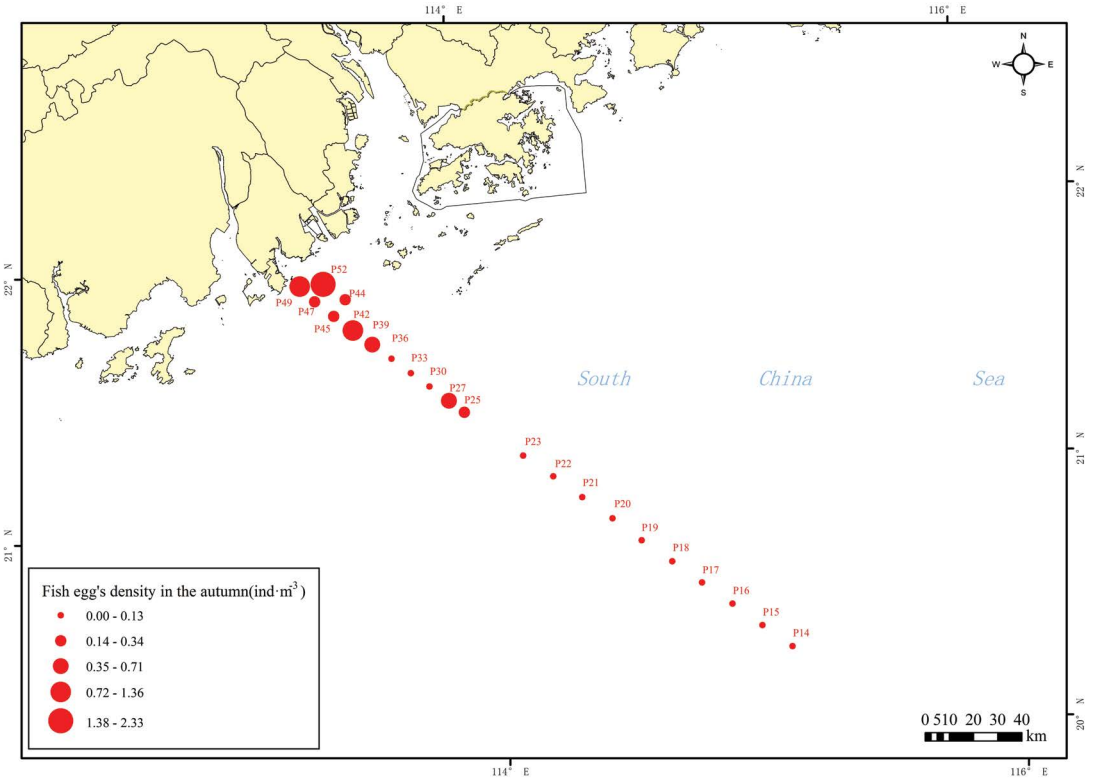

Fig. 3. Distribution condition of the fish egg's density in the autumn (ind/m^3).

3.2.2. Larva

3.2.2.1. Spring

A total of 721 larvae and juveniles were collected during the April survey, of which 97 were collected through vertical trawls, with an average density of 0.54 ind/m^3; 624 tails were collected by horizontal trawl.

The changing range of juvenile fish density is 0–1.96 ind/m^3, with an average density of 0.54 ind/m^3, with significant changes at each station. High density areas occur at stations P47, P52, P44, and P45, with values of 1.96, 1.88, 1.86, and 1.72 ind/m^3, severally; Next is P49 station, which is 0.83 ind/m^3. The high-density areas of juvenile fish in the surveyed sea area are predominantly concentrated in the nearshore waters, while the number of juvenile fish in the open-sea areas is comparatively small (as depicted in Fig. 4).

The changing range of the number of larvae and juveniles collected by horizontal trawls is 0–172, with conspicuous changes at each station. Among them, P52 station and P44 station have the highest number, with 172 and 168 separately; Next are stations P20, P19, P21, and P18, with 68, 61, 45, and 30 tails, severally; The number of other stations is relatively small.

3.2.2.2. Autumn

A total of 180 juvenile fish were collected during the October survey, of which 89 were collected through vertical trawls, with an average density of 0.47 ind/m^3; 91 tails were collected by horizontal trawl.

The density of juvenile fish varies from 0 to 4.34 ind/m^3, with an average density of 0.47 ind/m^3, indicating a striking change. The high-density area appears at P52 station, at 4.34 ind/m^3; Next are stations P36, P49, and P39, with values of 1.44, 1.35, and 1.29 ind/m^3, severally; The density of other stations is comparatively low. The survey results reveal that the high-density areas of juvenile fish in the sea area are chiefly concentrated in the nearshore area, while the quantity in the open-sea area is comparatively small, as illustrated in Fig. 5.

The changing range of the number of larvae and juveniles collected by horizontal trawls is (0–18), with little change. Among them, P49 and P52 stations have the highest number, both with 18 tails; Next are stations P27 and P33, both with 13 tails; The number of other stations is comparatively small.

3.3. Dominant species

3.3.1. Spring

In the April survey, *Carangidae* and *Upeneus* sp. account for a large proportion.

3.3.1.1. Carangidae

Carangidae fish are economically valuable species. The survey results suggest that *Carangidae* principally includes the blue round scad and other species of the scad family.

In the April survey, both *Carangidae* fish eggs and juvenile fish appeared. The average density of *Carangidae* fish

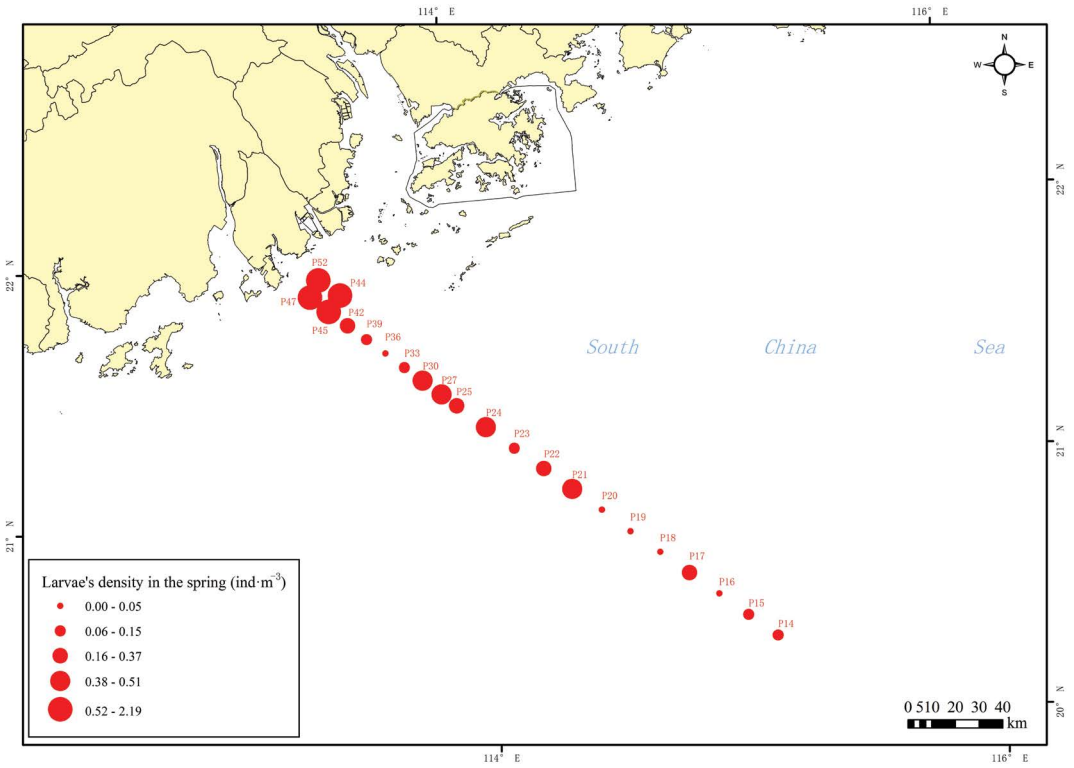

Fig. 4. Distribution condition of the larvae's density in the spring (ind/m^3).

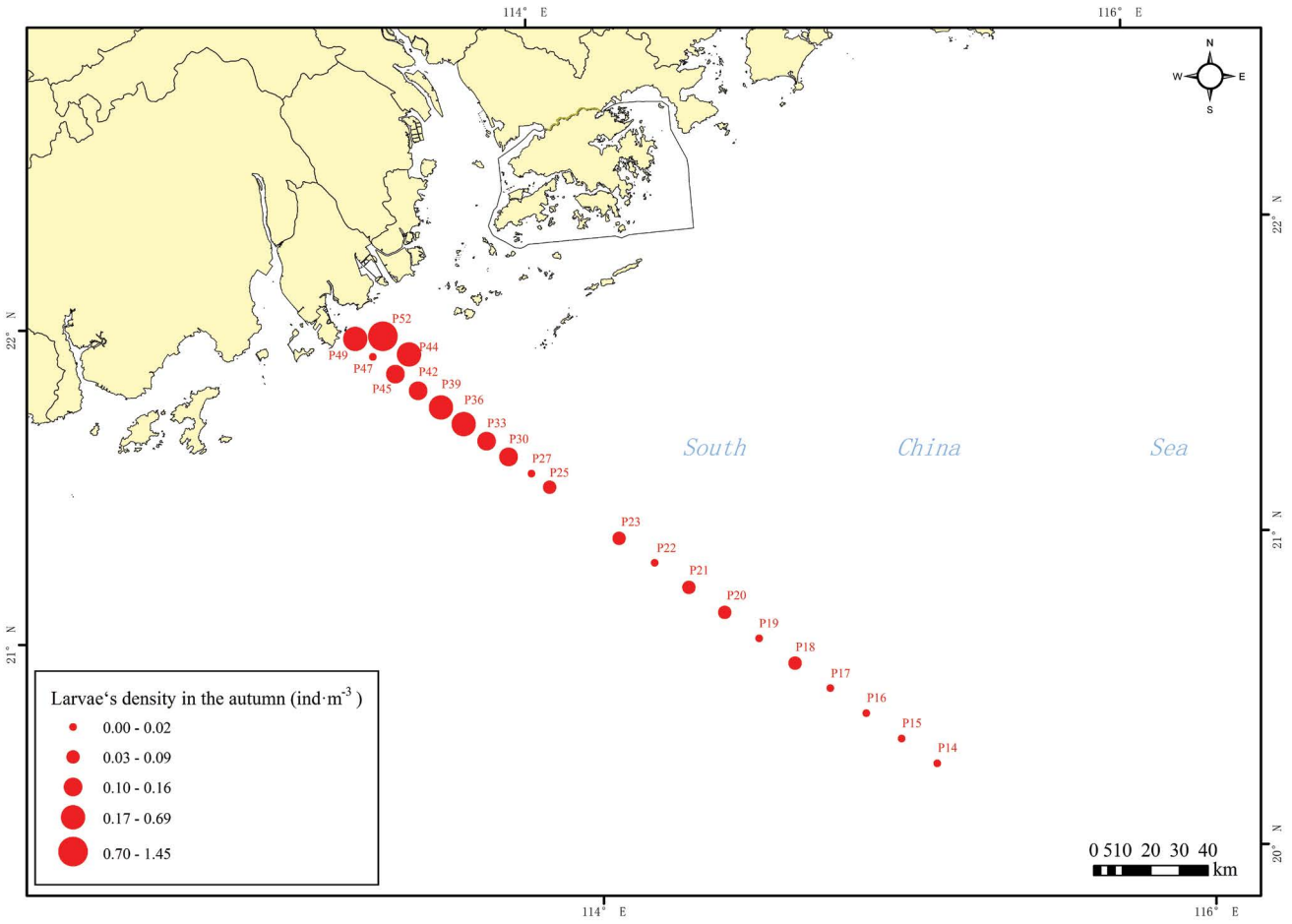

Fig. 5. Distribution condition of the larvae's density in the autumn (ind/m³).

eggs in the surveyed sea area is 2.26 × 10⁻² ind/m³. *Carangidae* fish eggs collected by vertical trawls appeared at stations P47, P14, and P15, with densities of 0.30, 0.14, and 0.10 ind/m³, separately. A total of 19 *Carangidae* fish eggs were collected by horizontal trawls, primarily occurring at station P21, which had 18 eggs. The average density of *Carangidae* larvae and juveniles in the surveyed sea area is 0.11 ind/m³. The *Carangidae* larvae and juveniles captured by vertical trawls predominantly appeared at stations P52, P44, and P21, with densities of 0.63, 0.56, and 0.32 ind/m³, separately. Only one *Carangidae* juvenile fish was caught by the horizontal trawl, appearing at station P17.

3.3.1.2. *Upeneus sp.*

In comparison, *Upeneus* sp. fish belong to species with higher economic value [21].

In this survey, both eggs and larvae of *Upeneus* sp. were found. The average density of fish eggs in the survey area of *Upeneus* sp. is 8.91 × 10⁻² ind/m³. *Upeneus* sp. fish eggs collected by vertical trawls principally appeared at stations P36, P22, and P23, with densities of 1.00, 0.45, and 0.40 ind/m³, separately. A total of 994 *Upeneus* sp. fish eggs were collected by horizontal trawls, chiefly appearing at stations P23, P44, and P22, with 376, 248, and 178 fish eggs, severally. The average density of *Upeneus* sp. larvae and juveniles in the surveyed sea area is 0.17 × 10⁻² ind/m³. *Upeneus* sp. larvae and juveniles captured by vertical trawls appeared at station P17, with a density of 0.04 ind/m³. Only 71 *Carangidae* larvae and juveniles were captured by horizontal trawls, predominantly at stations P21, P44, and P22, with 31, 17, and 12 fish, severally.

3.3.1.2.1. *Autumn*

The species with higher numbers in this survey include *Sciaenidae* and *Stolephorus* sp.

3.3.1.3. *Sciaenidae*

Sciaenidae fish are economically valuable species. The *Sciaenidae* found in this survey primarily include *Argyrosomus* and *Sciaenidae*, etc. [8].

In the October survey, only juvenile fish were found in *Sciaenidae*. The average density of *Sciaenidae* larvae and juveniles in the surveyed sea area is 0.20 ind/m³, with *Argyrosomus* having an average density of 0.15 ind/m³ and *Sciaenidae* having an average density of 0.05 ind/m³. The *Sciaenidae* larvae and juveniles captured by vertical trawls chiefly appeared at P52 station, with a rate of 2.00 ind/m³; Next are

stations P44 and P36, with densities of 0.69 and 0.63 ind/m^3, separately. 28 *Sciaenidae* larvae and juveniles were captured by horizontal trawls, including 19 *Argyrosomus* and 9 *Sciaenidae*. The *Sciaenidae* larvae and juveniles captured by horizontal trawls primarily appeared at stations P33, P27, and P49, with 9, 8, and 7 fish, severally [23,24].

3.3.1.4. Stolephorus sp.

The *Stolephorus* sp. belongs to the Anchovy family and is a mid to upper-level fish that predominantly feeds on copepods and diatoms. It is a low economic value fish in the nearshore area [25–27].

In the October survey, both *Stolephorus* sp. fish eggs and juvenile fish appeared. The average density of *Stolephorus* sp. fish eggs in the surveyed sea area is 0.25 ind/m^3. *Stolephorus* sp. fish eggs collected by vertical trawls primarily appeared at stations P52 and P49, with densities of 1.82 and 3.67 ind/m^3, separately. A total of 41 *Stolephorus* sp. fish eggs were collected by horizontal trawls, which only appeared at stations P49 and P52, with 28 eggs and 13 eggs, separately. The average density of *Stolephorus* sp. larvae and juveniles in the surveyed sea area is 0.03 ind/m^3. *Stolephorus* sp. larvae and juveniles captured by vertical trawls only appeared at P52 station, with a density of 0.67 ind/m^3. Only 21 *Stolephorus* sp. larvae and juveniles were collected by horizontal trawls, most of which appeared at P52 and P49 stations, with 17 and 3 fish, separately [28–30].

4. Conclusion

- During the spring survey, a total of 53 species of fish eggs and juvenile fish were collected, including 15 species of fish eggs and 44 species of juvenile fish. There are a total of 44 species of fish eggs and juvenile fish surveyed in autumn, including 12 species of fish eggs and 39 species of juvenile fish. The number of fish eggs, larvae and juveniles in spring is more than that in autumn, but the range is not large. As a consequence, it is considered that spring is the growth and development period of fish eggs, larvae and juveniles in the northern South China Sea, but there is little change in fish species in the sea area as a whole.
- The average density of fish eggs in spring is 2.89 ind/m^3, and that of larvae and juveniles is 0.54 ind/m^3; In autumn, the average density of fish eggs is 0.61 ind/m^3, and that of larvae and juveniles is 0.47 ind/m^3. The survey results demonstrate that not only is the density of fish eggs and juvenile fish resources higher in spring than in autumn, but the high-density areas of fish eggs and juvenile fish are chiefly concentrated in the coastal waters, with a comparatively small number in the coastal areas.
- The species that appear in spring surveys are mostly *Carangidae* and *Upeneus* sp., which have higher economic value. Among other non-major species, there are also Goldfish, *Sparidae*, *Sciaenidae*, *Citharidae*, *Mugil cephalus*, and Hairtail, which have higher economic value. The survey results illustrate that fish eggs and larvae are primarily divided into nearshore and offshore species. The nearshore species are predominantly distributed in the survey stations north of P39 station, while the open-sea species are distributed in the survey stations south of P39 station. Among them, nearshore species principally include *Osteomugil ophuiseni*, *Sparidae*, *Sciaenidae*, *Stolephorus* sp. and *Sardinella* sp., while open-sea species chiefly include *Lantern fish*, *Flying fish*, and *Bregmacerotidae*.
- The species found in autumn surveys are mostly common in the South China Sea. The main species are *Sciaenidae* and *Stolephorus* sp. Among them, *Sciaenidae* has higher economic value, while other non-major species have higher economic value, such as Goldfish, *Carangidae*, Tuna, Tongue sole, Scorpion, *Mugil cephalus*, and Hairtail. The survey results demonstrate that fish eggs and larvae are principally divided into nearshore and offshore species. The nearshore species are predominantly distributed in the survey stations north of P30 station (E113° 45.44′, N21° 25.46′), while the open-sea species are distributed in the survey stations south of P30 station. Among them, nearshore species primarily include *Mugil cephalus*, *Sciaenidae*, *Stolephorus* sp. and *Sardinella* sp., while open-sea species chiefly include Lantern fish, Flying fish, and *Bregmacerotidae*.
- Compared with the results of the spring survey, the number of species, density of fish eggs and larvae decreased to varying degrees in autumn. The density of fish eggs decreased remarkably, while the number of species and density of larvae and juveniles did not decrease strikingly; The main species in the two surveys showed striking changes, with open-sea species in spring and nearshore species in autumn. These changes are principally as a result of seasonal factors. After October, the water temperature in the South China Sea begins to decrease, and fish enters the low peak period of spawning.
- The investigation demonstrates that the species and quantity of fish eggs in the northern South China Sea are decreasing. It is recommended to further strengthen the protection measures during the spawning period of fish eggs and carry out appropriate fishery resource release activities to prevent further threats from the decline of the ecological environment and species resources.

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