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Diving into Estuarine Fish Larvae: A Comprehensive Overview

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SUMMARY

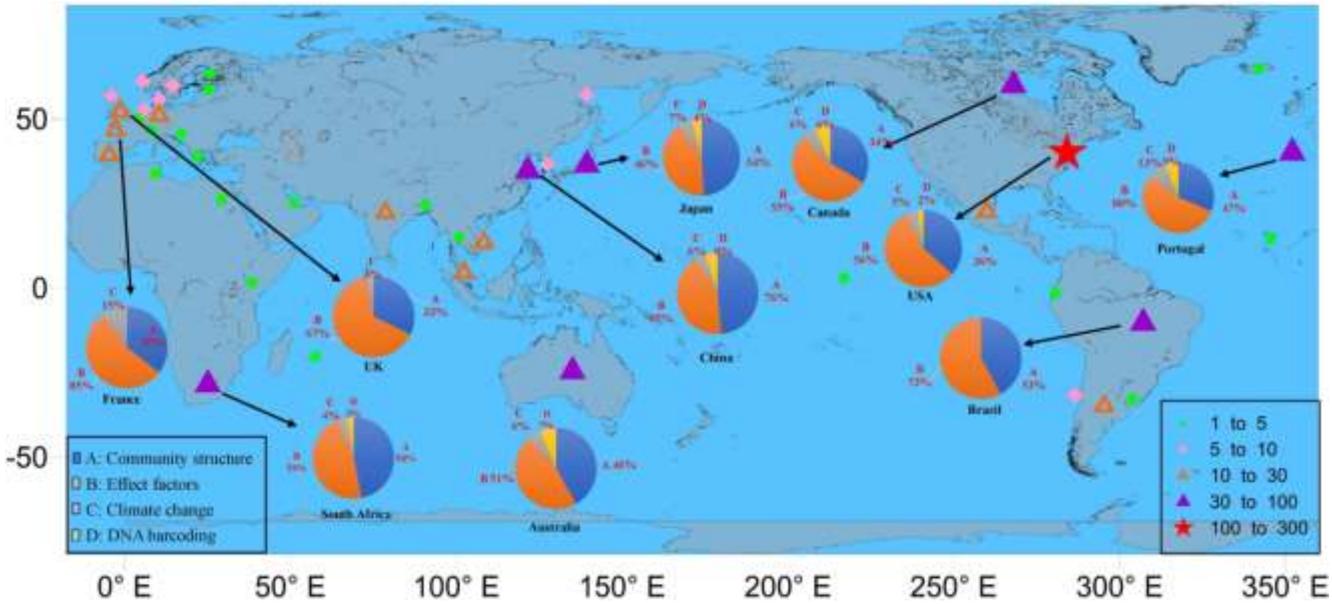
Estuaries represent nutrient-rich environments characterized by a gradient from fresh to salt water, fostering high levels of primary productivity and an abundance of zooplankton. These unique conditions make estuaries ideal nursery grounds for various fish species, as they offer a bountiful food supply for both larval and adult fish. Ichthyoplankton, encompassing fish eggs and larvae, play a crucial role in the recruitment of fish populations. The structure of ichthyoplankton communities in estuaries is primarily influenced by salinity and turbidity. Moreover, the indirect effects of climate change on estuarine ichthyoplankton communities involve alterations in species' spawning times, locations, and hatching periods. Notably, there is a consistent trend towards the poleward movement of spawning sites and earlier spawning times. The advancement of DNA barcoding techniques stands as a valuable addition to conventional taxonomic methods for identifying ichthyoplankton. This development opens up new prospects for systematic taxonomy within this field.

INTRODUCTION

Estuaries are indeed renowned as the most productive and nutrient-rich ecosystems on our planet. They serve as critical environments where numerous species undergo a portion or the entirety of their life cycle. Among their ecological roles, estuaries stand out as particularly significant foraging and breeding habitats for a wide range of fish species (Sheaves et al., 2015; Xian et al., 2016; Lefcheck et al., 2019). Nevertheless, due to their distinctive geographical positioning, estuaries have been subject to human development and impact for countless millennia. The ichthyoplankton stage, encompassing fish eggs and larvae, holds a pivotal role in shaping the growth and development of estuarine communities, and it is remarkably responsive to environmental fluctuations (Shan et al., 2004). The quantity and survival of ichthyoplankton offer insights into the biomass and interannual dynamics of future fish stocks (Butler et al., 2003; Song et al., 2019). It forms the foundation for fish stock recruitment and the sustainable utilization of fisheries resources (Chambers and Trippel, 1997; Cao et al., 2007). Furthermore, ichthyoplankton, as significant predators and consumers of plankton, especially zooplankton, contribute substantially to the secondary production within estuarine ecosystems (Monteiro et al., 2021). Their role in energy transfer is essential for the functioning of these ecosystems (Wan and Sun, 2006). In essence, ichthyoplankton serve as a critical link in the aquatic food web (Wan and Jiang, 2000). Identifying individual species among ichthyoplankton remains a challenging endeavor (Zhang et al., 2015). Currently, more than 36,058 fish species have been successfully identified in their adult forms (Fricke et al., 2021). However, when it comes to the larval and postlarval stages, only approximately 10% of these species can be reliably identified, and for fish eggs, less than 10% can be accurately assigned to a specific species. This highlights the complexity of distinguishing among ichthyoplankton at their early life stages, underscoring the need for improved techniques and methodologies in this field.

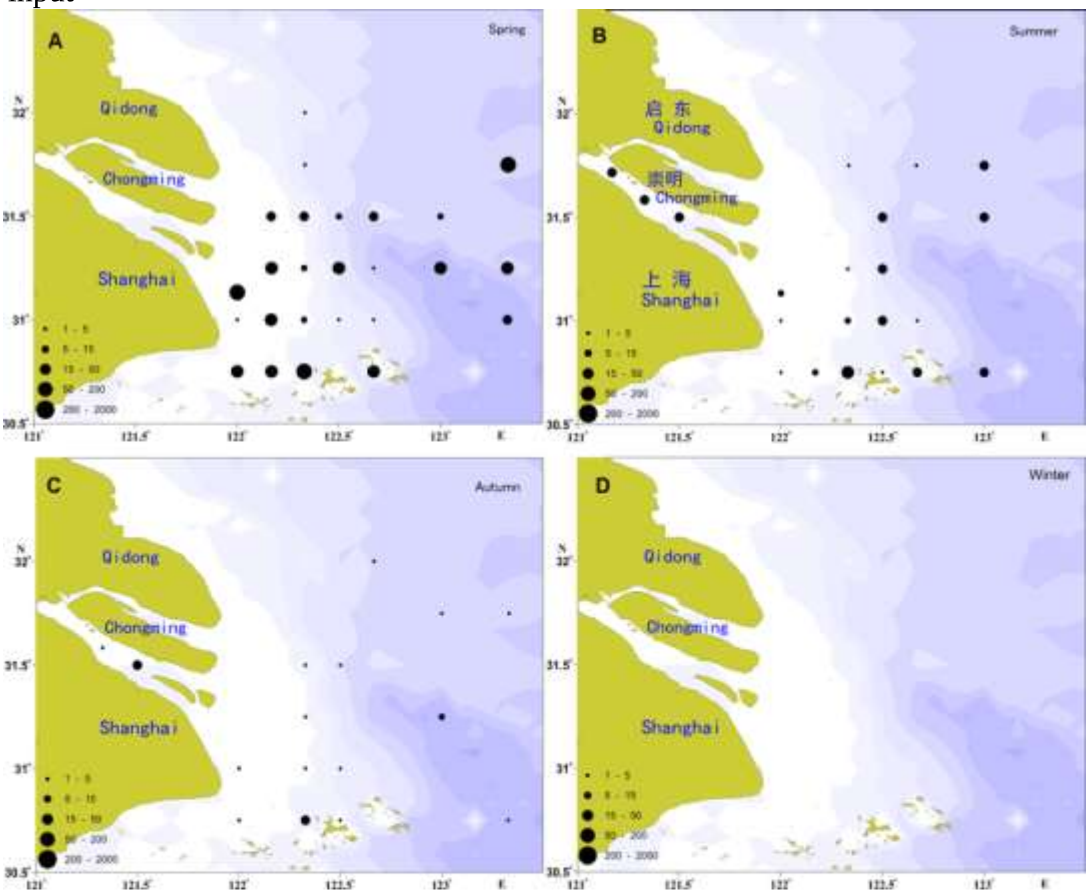
Species Composition of Estuarine Ichthyoplankton

Estuaries, serving as the meeting points where rivers merge with the ocean, represent critical zones of land-sea interactions (Zhuang, 2006). They are characterized by a rich abundance of nutrients and food resources, creating favorable conditions for fish breeding (Huang et al., 2017). Consequently, the species and population of ichthyoplankton found in estuaries are closely tied to the unique environmental characteristics and material inputs present (Shan et al., 2004). Ichthyoplankton communities in estuaries are distinct from those in other marine areas, primarily due to the intricate interplay between freshwater runoff and tidal currents (Whitfield, 1994). One common feature of these communities is the coexistence of both rare and highly abundant species. In warm water estuaries, dominance is often observed among Gobiidae, which inhabit estuaries, as well as Clupeidae and Engraulidae, which seasonally lay their eggs within estuaries.The species composition of ichthyoplankton communities is known to vary in response to the specific environmental conditions within each estuary (Shan et al., 2004).



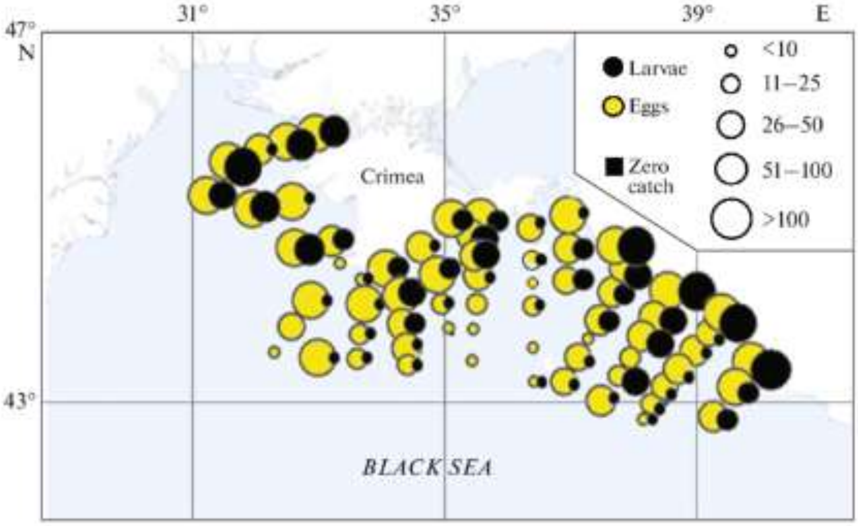
Temporal and Spatial Distribution of Ichthyoplankton

It is intricately influenced by the complex and dynamic physical, chemical, and hydrological conditions characteristic of these environments (Harris and Cyrus, 1995; Hettler and Hare, 1998). The composition and abundance of ichthyoplankton communities in estuaries change over time and across different locations in response to varying fish reproductive seasons and environmental factors .Seasonal variations are prominent in the composition, abundance, and spatial distribution of ichthyoplankton communities (Harris et al., 1999). Generally, the highest abundance of estuarine ichthyoplankton is observed during the spring or summer months because these seasons align with the reproductive periods of most fish species. Spring sees a higher number of fish eggs, while larvae and juveniles become more abundant in the summer. Moreover, the seasonal distribution of ichthyoplankton is closely associated with environmental factors like temperature, salinity, depth, chlorophyll a, and freshwater input



Spatial Distribution Marking of Ichthyoplankton

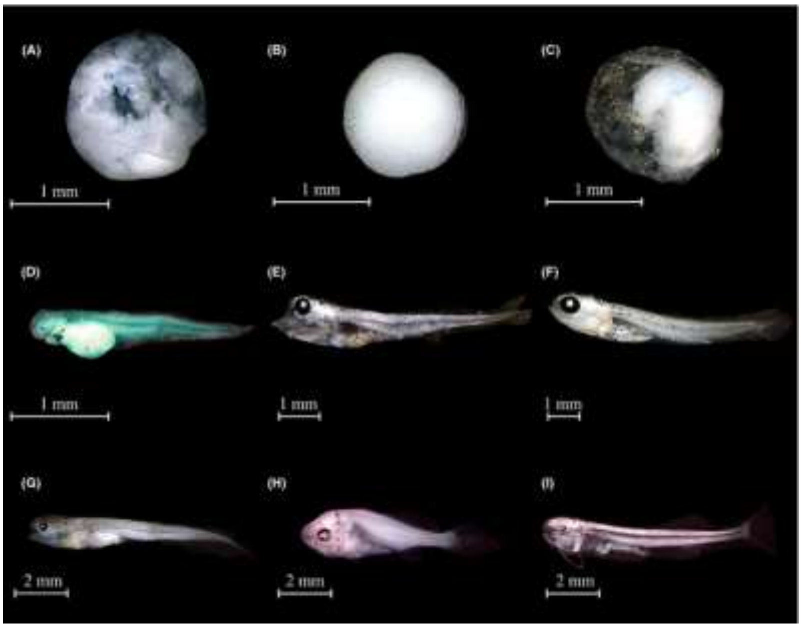
It is marked by horizontal heterogeneity and vertical stratification, influenced by ecological habits, physiological changes, and external environmental factors such as prey availability, light, runoff, and tides. Horizontal distribution varies based on species composition and abundance in different regions, along with the ecological classification of species in those areas. Brackish water species dominate in spring and are typically found in the lower River channel and nearby marine areas with specific temperature and salinity ranges. In autumn, coastal species become more prevalent, followed by brackish water and inshore species, while freshwater ichthyoplankton are less common. The lower estuary generally hosts marine-spawning fish, while the upper estuary is a habitat for estuarine-spawning fish.



Vertical distribution patterns also vary, linked to species preferences and the water structure, including changes and fluctuations. For example, the herring family is often found in the upper and middle layers of estuaries, while Gobiidae primarily inhabit the bottom of estuarine and coastal waters (Muhling et al., 2007). Vertical migrations of larvae and juveniles can be a strategy to avoid cold and low-salinity surface waters (Ramos et al., 2006) and to utilize two-layer circulation patterns to maintain dynamic balance and avoid being washed out of the estuary.

DNA Barcoding in the Identification of Ichthyoplankton

The application of DNA barcoding in the identification of estuarine ichthyoplankton has proven to be a valuable tool in addressing the challenges associated with traditional morphological classification methods. DNA barcoding is a molecular biology technique that identifies species by analyzing standardized short gene fragments (Chu et al., 2019).



One of the most significant advantages of DNA barcoding is its ability to accurately identify individuals at various development stages and species that may have high morphological similarity or lack sufficient morphological classification data (Liu et al., 2021). This is particularly valuable in the context of ichthyoplankton, where species can be challenging to distinguish based on traditional morphological characteristics. For instance, researchers have successfully used DNA barcoding to differentiate between fish eggs with similar morphological features but belonging to different species, such as Hyporhamphus sajori and Strongylura anastomella (Bian et al., 2007).

CONCLUSION

Ichthyoplankton, as a critical component of marine ecosystems, have garnered significant attention due to their role in the recruitment of fish populations and their impact on ecosystem energy flow. Their diversity, abundance, and distribution are influenced by a range of environmental factors, both temporal and spatial, making their study challenging yet essential for understanding the dynamics of estuarine ecosystems and beyond. The use of DNA barcoding techniques has emerged as a powerful tool to address the limitations of traditional morphological classification, enabling more accurate species identification, even at early developmental stages. This advancement provides opportunities for the development of systematic taxonomy, as it facilitates automation and standardization of sample identification processes, making it accessible to both experts and non-professionals. Overall, ichthyoplankton research has significantly contributed to our understanding of fish populations, ecosystem health, and the impacts of environmental changes. As technology and methodologies continue to evolve, ichthyoplankton studies will likely play a pivotal role in fisheries management, conservation efforts, and the broader field of marine biology.

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