

Marine zooplankton researches in Vietnam: An overview

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Abstract—Marine zooplankton in Vietnamese waters have been studied since the establishment of the Institute of Oceanography in 1923. A total of 253 species of zooplankton have been reported from the Gulf of Tonkin, with the biomass (wet wt) of about 72 mg m^{-3} on average, which was higher than any other coastal waters of Vietnam. Vietnamese coastal waters from Hue to the Ca Mau Cape have been studied mainly by the Institute of Oceanography, Nha Trang. After the liberation of South Vietnam in 1975, many comprehensive investigations have been conducted in South Vietnamese waters, reporting 211 zooplankton species and the seasonal changes of biomass with peaks in September–December. The Gulf of Thailand was studied in 1979 and 1982–1994, wherein 125 zooplankton species were reported from the coastal waters of Minh Hai and Kien Giang Provinces. The species number of zooplankton was generally higher in the southern than in the northern waters while the biomass was higher in the northern waters.

Key words: Gulf of Tonkin, South Vietnam, Gulf of Thailand, zooplankton species, biomass

Introduction

The mainland of Vietnam has a wide latitudinal range, with the coastline of 3260 km stretching from $8^{\circ}30'N$ to $21^{\circ}20'N$, and the waters along the coasts and those to the offshore involve diverse geographic regions, including the Gulf of Tonkin in the northernmost region and the coastal waters of northern, middle, and southern Vietnam. While these waters are parts of the South China Sea, the coast in the south-westernmost region faces the Gulf of Thailand. Far eastern offshore in the South China Sea there are also groups of islands represented by the Paracel and Spratly Islands. All these waters in different geographic regions encompass various types of pelagic habitats, including estuaries, coral reefs, seagrass beds, coastal to oceanic waters, lagoons, and the waters associated with islands. The coastal waters in Vietnam, particularly in the northern and middle regions, receive strong influence of river waters during the seasons around summer (April–October) owing to the heavy rainfall caused by southeastern monsoon and typhoons. All these geographic and climatic conditions suggest that the biodiversity of marine zooplankton in Vietnamese waters may be considerable.

The research on marine zooplankton in Vietnam was initiated after the establishment of the Institute of Oceanography, Nha Trang in 1923, with the first report published by Rose (1926). Since then, many investigations have been conducted on diverse pelagic habitats. However, many of these results have been published in project reports in Vietnamese

language that are difficult to access by foreign scientists, while several representative studies have been published by foreign researchers in different languages such as English and French. Under this circumstance, here we review zooplankton researches conducted in Vietnamese waters with scopes and outlines of research projects and literature information, including those in Vietnamese language, as a basis for integration of biodiversity information of zooplankton.

The Gulf of Tonkin

The Gulf of Tonkin has been investigated since 1959 as parts of comprehensive national or international projects, which were conducted in larger scales than in the other regions. During 1959–1962 Vietnam and the People's Republic of China cooperated in a study on the Gulf of Tonkin to carry out 26 surveys. The results were published in 1962 in which the Part V dealt with plankton (China–Vietnam Cooperation Survey Team 1962) wherein a total of 253 species of zooplankton (excluding Protozoa) were reported. The average zooplankton biomass (wet wt) of 72 mg m^{-3} in the Gulf was higher than those in the other coastal waters of Vietnam. The peak of zooplankton biomass was recorded in June and September–October. The high biomass region was located in the brackish water area in the western region of the gulf. Spatial and temporal variations in the abundance of some dominant species such as the copepods *Temora discaudata*, *Eucalanus subcrassus*, and *Canthocalanus pauper* were presented. In addition to plankton communities themselves, the relationships between the distribution of dominant species and envi-

ronmental parameters and water currents were studied.

Nguyen V. K. and Dam (1967) listed 125 species of copepods and 16 species of chaetognaths from the Gulf of Tonkin. Based on previous data on Vietnamese waters, Nguyen V. K. (1994) published the book “Subclass Copepoda in the Gulf of Tonkin”, including description, drawings and keys for identification of 100 species, variations in quantitative distribution, ecological characteristics and the relationships between copepod communities and environmental conditions.

On the basis of the Integrated Investigation Program in the Western Waters of the Gulf of Tonkin on Living Resources, Dang et al. (1994) reported that the average zooplankton biomass was highest in the western coastal area and the biomass in winter and summer was twice as much as those in spring and autumn.

During 1960–1961, four surveys were conducted by the Vietnam–USSR Cooperative Program, in which the spatial and temporal variations in zooplankton biomass were investigated, reporting the highest biomass in summer and the lowest biomass in spring (Dang et al. 1994).

In 1972, the book “The Fauna of the Tonkin Gulf” (Brodsky 1972) was published, which was a systematic collection of studies on the fauna of the Gulf, wherein Brodsky (1972) dealt with the relation between zooplankton and environmental conditions, while Foraminifera was dealt with by Stshedrina (1972). Nguyen T. C. (1977) reported plankton biomass in the Gulf of Tonkin, with zooplankton biomass of 77 mg m^{-3} in average and of 320,000 tons of total stock.

The northern Vietnamese waters

The northern Vietnamese waters include Ha Long and Cat Ba Bays (Hai Phong–Quang Ninh), the Red River mouth, and the coastal lagoons in Hue. The waters in the river mouth are affected strongly by freshwater flows from the mainland in the rainy season, while the influence is weaker in the dry season, resulting in a large seasonal variation in salinity (5–30 psu).

From the investigation on plankton in the estuaries of the Red River system by Hai Phong Institute of Oceanology in 1970–1972, Nguyen V. K. and Duong (1980) identified 104 zooplankton species (including 10 species newly recorded in the waters) and reported the highest abundance in the dry season (February–April) and the lowest abundance in the rainy season (July–September). Nguyen V. K. and Nguyen T. M. A. (1987) reported 140 species of zooplankton from Quang Ninh–Hai Phong Provinces. On the basis of the results obtained at different sites in the northern coastal waters by IMER during 1990–2003, Nguyen T. T. (2004) reported 206 groups and species of zooplankton.

Central to South Vietnam

Vietnamese coastal waters from Hue to the Ca Mau

Cape have been studied for a long time by the Institute of Oceanography, Nha Trang. Many French scientists contributed to the plankton studies during 1924–1960. Since the establishment of the Institute, the French plankton specialists had implemented small-scale studies and timely published their papers. The first paper was published by Rose (1926) who listed 42 phytoplankton species and 56 zooplankton species in Vietnamese coastal waters. Later Rose (1955, 1957) reported 119 copepod species from Nha Trang Bay, including three new species belonging to the genus *Mazellina* (= *Pseudodiaptomus*). Dawydoff (1929) studied the day-night and seasonal variations in species composition of zooplankton in Nha Trang Bay, and compiled a list of plankton species reported from the Vietnamese waters (Dawydoff 1936). Dawydoff (1952) also studied in detail the environmental conditions affecting differences in plankton biomass between dry and rainy seasons in Nha Trang Bay. Temporal variation in plankton communities as related to environmental conditions was studied by Serene (1937), with a list of zooplankton species from Vietnamese coastal waters. Then Serene (1948) studied in detail zooplankton in Nha Trang Bay, reporting temporal variation in zooplankton biomass of different phyla. Other reports on the zooplankton from Nha Trang Bay include: 11 chaetognath species by Hamon (1956), 21 siphonophore species by Leloup (1956), and variations in plankton biomass by Yamashita (1958). As such, plankton researches in the Nha Trang Bay and the adjacent waters during 1924–1958 were conducted mainly by foreign scientists.

The NAGA Expedition conducted by the United States of America during 1959–1961 was one of the most comprehensive studies in the waters of East and South Vietnam (from 4° to 16°N , expanded to 114°E) and in the whole area of the Gulf of Thailand. Based on 10 surveys by the R/V Stranger, results of many plankton studies were published in NAGA reports (Vol. I–IV). Brinton (1963) reported the plankton biomass in the waters of East and South Vietnam with 150 ml m^{-3} in average, 150 ml m^{-3} in the South China Sea, and up to $200\text{--}700 \text{ ml m}^{-3}$ in the Gulf of Thailand. Lang (1963) reported dominant copepod species in the South China Sea. Species of the following taxa were described and listed from the South China Sea including central/south Vietnamese waters and the Gulf of Thailand: copepods (Fleminger 1963), euphausiids (Brinton 1975), pteropods (Rottman 1963, 1967), siphonophores and chaetognaths (Alvarino 1967). Especially the studies of Rottman (1967), Alvarino (1967) and Brinton (1975) are among the most comprehensive studies on zooplankton taxonomy in Vietnamese waters.

During 1962–1974 there were several studies on marine zooplankton, most of which were published in monographs in Vietnamese language. Hoang (1962a, b, 1963) listed and illustrated 123 protozoan species from Nha Trang Bay. Based

on the collection from the coastal waters from Hue to Ha Tien, Shirota (1963, 1966) reported the occurrence of 982 marine plankton species with their illustrations. During 1971–1974 the CSK Program (Cooperative Study of the Kuroshio and Adjacent Regions) investigated zooplankton in the coastal waters of Phu Yen–Khanh Hoa, the results of which have been partially published (e.g. Nguyen T. D. and Le 1974).

After the liberation of South Vietnam in 1975, many investigations were carried out in South Vietnamese waters. Of these, the program “Comprehensive Investigation in Thuan Hai–Minh Hai Waters” (1978–1980) was one of the most intensive studies, including 11 surveys by the R/V “Bien Dong” and 4 surveys by the R/V “03 Marine Research”. Nguyen V. K. et al. (1991) published results on zooplankton in the waters of Thuan Hai–Minh Hai, listing 211 zooplankton species (including copepods and chaetognaths from South Vietnamese waters) with biomass of 30 mg m^{-3} in average and highest in September and November–December, in addition to the data on zooplankton distribution.

Coastal waters along the central Vietnam, including many bays and lagoons, have been investigated since 1978. During 1978–1979, four surveys were carried out in Binh Cang–Nha Trang Bay (Khanh Hoa Province). Tam Giang (Thua Thien), Thi Nai (Binh Dinh), O Loan (Phu Yen) and Nai (Ninh Thuan) lagoons were also investigated in many surveys. These results were compiled by Dang et al. (2003). Based on the materials collected from the coastal waters of Quang Nam–Da Nang Provinces during 1978–1986, Nguyen D. T. (1998a) reported the occurrence of 182 species of zooplankton which showed the highest biomass in dry season near the coast of Da Nang. Studies on the ecology of estuaries and mangrove areas in South Vietnam were also conducted since 1978 in order to exploit the economic potentials and to protect their environment. Many surveys were conducted in the estuaries of Dong Nai and Me Kong river systems, and in coastal districts of Minh Hai Province, although scientific reports have not yet been published.

Zooplankton specimens were collected in a larger area by R/V Nauka under the Program “Study on the Marine Fish Resource in the Waters of South Vietnam”. The results on zooplankton biomass were printed in the National Atlas (Nguyen V. C. 1996). Also from 1982 up to now, using many research ships of USSR such as “Prof. Bogorov” (1981, 1995), “Academican Nesmeyanov” (1982), and “Sokanski” (1992, 1994), plankton specimens were collected in South Vietnamese waters (Nguyen C. 1997).

From 1991 to 1994, the coastal waters of central Vietnam shallower than 110 m were intensively investigated, with major focus on the upwelling area along southern Central Vietnam. Scientific reports of 5 surveys were published (Nguyen C. 1997), indicating that average abundance and biomass of zooplankton in the waters of northern Central

Vietnam were relatively low (133 inds m^{-3} and 36.4 mg m^{-3}) compared with the waters of southern Central Vietnam (152 inds m^{-3} and 71 mg m^{-3}). On the basis of the plankton samples collected by 34 stations from Central to South Vietnam, Nguyen D. T. (2001a) reported the occurrence of 219 species of zooplankton, which showed higher density in the periphery of the upwelling area and the mixed water area between the high-sea and coastal waters.

Recently, under the Multilateral Cooperative Project among five Southeast Asian countries (Indonesia, Malaysia, Philippines, Thailand and Vietnam) and Japan, the zooplankton fauna in Nha Trang and Qui Nhon has been intensively studied, resulting in a discovery of the new large copepod, *Tortanus vietnamicus* (Nishida and Cho 2005), and description of the contrasting patterns in abundance, community structure, species richness between the Thi Nai Lagoon and surrounding coastal waters (Nguyen C. and Trinh 2006).

Gulf of Thailand

The Gulf of Thailand has not been studied intensively. Except the NAGA Expedition, four surveys were carried out in 1979, 1982, 1993 and 1994 (Nguyen V. K. 1997), showing that phytoplankton biomass in the Gulf was high while zooplankton biomass was low. Nguyen V. K. (1997) listed 125 zooplankton species in the coastal waters of two provinces Minh Hai and Kien Giang (on the side of the Gulf of Thailand) with low biomass (21 mg m^{-3}). On the basis of fishery oceanographic and biological data on zooplankton collected in the Gulf of Thailand during 1997–1999, Nguyen D. T. (2001b) found that the zooplankton biomass had linear relationship with temperature in the upper 10 m.

Spratly Islands

Spratly Islands comprise a coral archipelago in the midst of South China Sea with very unique ecological characteristics. Nguyen V. K. (1998) identified 216 zooplankton species based on specimens collected at 24 stations, seven species being firstly reported in Vietnam. The waters around Bach Ho, Rong, Daihung, and Binh Thuan oil wells were investigated during 1993–1995 by Center for Petroleum Safety and Environment. Nguyen D. T. (1998b) analyzed the samples collected in the crises in 1994 and 1996, identified 228 species of zooplankton, and noted relatively high values of diversity (H') and evenness (J) in the zooplankton community in this region. On the basis of a research project during 1993–1997, Nguyen T. C. et al. (2001) reported occurrence of 299 species of zooplankton in this area, dominated by the copepod *Eucalanus subcrassus* and the chaetognath *Sagitta enflata*.

Trends in species richness and biomass

Based on the data on Vietnamese waters, the book “Fauna of Vietnam-Subclass: Copepoda” was published by

Nguyen V. K. (1998, 2001), including descriptions, drawings and identification keys of 207 species.

Nguyen T. C. (2003) summarized the data from different projects conducted by national institutions of Vietnam during the past 40 years, reporting 657 zooplankton species (except protozoans) in Viet Nam waters. Among the coastal waters of Vietnam, 236 species have been recorded from the Gulf of Tonkin, representing 36% of the total number, while 605 species from the South Vietnamese waters, representing 92% of the total.

In another project, Nguyen T. C. (1989) studied the spatial variations in zooplankton biomass in Vietnamese waters, indicating the average biomass of zooplankton in the Gulf of Tonkin of 80-120 mg m⁻³, which was higher than in the surrounding waters while the central waters of Vietnam (south of the Gulf of Tonkin) showed the lowest values of less than 40 mg m⁻³.

On the basis of collections by the M/V SEAFDEC, Jivaluk (2000) investigated the composition, abundance, and distribution of zooplankton in Vietnamese waters in the South China Sea in April–June, and reported higher biomass and abundance of zooplankton in the studied area than in the Gulf of Thailand in the same period, and in the northern and southern waters than in the central water of Vietnam.

In recent years the utilization of data accumulated to date has been facilitated in order to set up mathematical models for estimating primary production and forecasting fishery activities. Doan (1997) reported the results of the project “Modeling of the distribution of plankton and primary production in the waters of southern Central Vietnam”, contributing to setting up forecast methods of the changes of marine resources.

Future prospects

In summary, during the past 80 years in which the country had passed through several wars, many studies on plankton have been implemented by both Vietnamese and foreign scientists. A lot of valuable plankton data have been collected though these surveys, but the utility such as maintenance, analysis and exploitation of these data was not enough, and their contributions to the fishery also were not yet focused on properly. Most of their results were published as reports/documents of each program, but not distributed widely among academic worlds, due partly to insufficient equipments and study methods, and partly to Vietnamese language used in most of these reports. For more efficient use of these precious information in future researches, active contributions by Vietnamese, as well as foreign scientists, and cooperative researches with foreign countries are expected.

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