

COMMUNICATION

Advances on taxonomy of marine Crustacea in China

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Abstract The researches on taxonomy and phylogeny of the subphylum Crustacea in China, mainly the marine species, are reviewed in the present paper. The researches involved taxonomy, morphology, fauna and zoogeography, phylogeny and systematics. The mentioned groups almost cover all groups of the Crustacea which have been studied by Chinese scholars. This review is of great significance to summarize the achievements in the field of taxonomy and phylogeny on marine crustaceans in China.

Key words Crustacea, taxonomy, phylogeny, China seas.

1 Introduction

Most phyla of the invertebrate animals live in the ocean and freshwaters. Chinese sea area stretches tropical, subtropical, and temperate climatic zones; the marine habitats of the area are diverse and complex, with a variety of types of coasts, estuaries, islands and seafloor topography (Liu, 2008), which makes for an unusually rich marine biota in the area.

Although there are few publications documenting invertebrates in ancient China, they can be traced back to the *Shennong's Herbal Classic*, which dates back to the first and second centuries AD. There were already records of squid and octopus in the monograph. *The Fishery Book* of the Ming Dynasty described in detail many different kinds of squids.

Mr. Huang Nie in the Qing Dynasty can be regarded as the forefather of marine biological classification research in China. With his talent, persistence, and love for nature and creatures, Mr. Nie published a masterpiece in the form of a Chinese marine biological atlas—*The Sea Creatures*. With the perspective of modern biological taxonomy, this monograph covers the groups of subphylum Vertebrata in the phylum Chordata, such as Pisces (fishes), Reptile (reptiles), Mammalia (mammals) and Aves (birds), as well as some groups of invertebrate phyla or subphyla—crustaceans, millipedes, sea spiders and merostomates in the phylum Arthropoda. Furthermore, it discussed the sea cucumbers and sea stars in the phylum Echinodermata; the squids, octopuses, bivalves in the phylum Mollusca; the siphones of the phylum Sipuncula, the nereids of the phylum Annelida; the lingulids of the phylum Brachiopoda; the corals of the phylum Cnidaria; the sea algae—brown algae, green algae and red algae, and the seed plants sea grasses and mangroves. Most of the species depicted in the monograph can be found commonly today. The author's scientific, rigorous, perfect attitude is very worthy of our generation to learn and respect.

Modern taxonomic and phylogenetic studies of invertebrates in China seas can be traced back to the middle of the 20th century. Some western naturalists went to China to collect intertidal and subtidal samples together with some Chinese scholars who had studied as zoologists in Europe, America and Japan. After these Chinese zoologists returned back China, they usually worked in Chinese colleges and studied the taxonomy and faunas independently. For example, Prof. Zhaoqi Yu (Shou-Chie Yu), the first modern taxonomist of crustaceans in China, reported many shrimp crustaceans from the waters of

southern China (Yu, 1930a, b, 1931, 1935a, b, c, 1936, 1938). Prof. Xi Zhang (Si Tchang), one of the founders of the researches on shellfish biology and marine macrobenthic ecology in China, as well as the Institute of Oceanology, Chinese Academy of Sciences, carried out a field biological investigation of intertidal and subtidal zones at Jiaozhou Bay, Qingdao (Tsingtao), Shandong Peninsula in May 1935, leading his group in the Institute of Zoology, National Academy of Peiping. This was the first marine biological expedition in China carried out by Chinese scholars. Based on the collected samples, Prof. Zhang reported many marine species of mollusks, enterobranchians and cephalochords, *etc.* (Tchang, 1933, 1934a, b, c, 1935; Tchang *et al.*, 1940).

It was not until 1949 when the People's Republic of China was founded that systematic and large-scale studies on the taxonomy and systematics of invertebrates in Chinese waters were carried out, especially after the establishment of the Marine Biology Laboratory of the Institute of Hydrobiology, Chinese Academy of Sciences (the predecessor of the present Institute of Oceanology, Chinese Academy of Sciences) in 1950. Under the leadership of Profs. Xi Zhang (Si Tchang), Ruiyu Liu (J.Y. Liu), Zhongyan Qi (Chong-Yan Tsi), and Baoling Wu, the Chinese marine taxonomists started to conduct a comprehensive and systematic faunal survey and taxonomic study of invertebrates from Chinese waters thereafter. The Institute of Oceanology, CAS has been the main force and training base for marine taxonomic research in China. More than 100 monographs and thousands of research papers have been published. Furthermore, a lot of researchers in marine biology and marine ecology have been trained for the country. Since the 1950's, a series of large-scale marine comprehensive surveys in Chinese seas, such as the "National Comprehensive Oceanographic Investigation" (1958–1960), "Sino-Vietnamese Joint survey of Beibu Gulf (Gulf of Tonkin)" (1959–1962), "Resource Investigation of Coastal and Shallow Waters of Shandong Province" (1981–1982), "Marine Investigation of Continental Shelf of East China Sea by Chinese Academy of Sciences" (1976–1978), "Comprehensive Resource Investigation of the Islands of China" (1989–1992), "The investigations of marine biota of Xisha Islands" (1965–1985), "China-South Korea Cooperative Expedition to the South Yellow Sea" (1989–1996), "Nansha Islands Comprehensive Investigations" (since 1985), *etc.*, have been carried out and a large number of samples and data for the comprehensive and systematic studies of marine taxonomy, biota, biogeography and phylogeny have been obtained. As a result, marine invertebrate taxonomy has also developed vigorously in China (Li *et al.*, 2020).

After 70 years of painstaking efforts by generations of taxonomists, the faunal characteristics of the main groups of Chinese invertebrates have been basically clarified, providing valuable basic data for the study of marine invertebrate diversity in Chinese waters. In 1994, Prof. Zongguo Huang summarized the previous research results of marine organism classification in China and listed 20,278 species of marine organisms in Chinese seas (Huang, 1994), including 2,903 marine species of Crustacea. In 2008, Prof. Ruiyu Liu summarized the previous research results of marine organism classification in China and listed 22,629 species of marine organisms in China seas (Liu, 2008), including 4,320 marine species of Crustacea. In 2010, Prof. Xinzheng Li and his colleagues listed 4,980 common species of macrobenthos belonging to 17 phyla and 418 families respectively from offshore waters of China, including 459 species in Bohai Gulf, 1,166 species in Yellow Sea, 2,346 species in East China Sea, and 3,312 species in South China Sea (Li *et al.*, 2010), in which, about 23% are crustacean species (1,139 spp.). In 2012, Zongguo Huang and Mao Lin mentioned that there were 5,645 marine crustacean species recorded in Chinese seas (Huang & Lin, 2012). In 2015, Prof. Song Sun and his colleagues recorded 346 common species of zooplankton belonging to 7 phyla respectively from offshore waters of China (Sun *et al.*, 2015), in which, more than 80% are crustacean species (289 spp.). The advances and perspectives of research on taxonomy and phylogeny of marine invertebrates in China was reviewed by Li *et al.* (2020). More recently, Prof. Xinzheng Li and his colleagues listed more than 4,300 common species of macrobenthos from offshore waters of China (Li & Gan, 2022a), in which, 2 species are Xiphosurida and 23 species are Pantopoda, and 1,617 species are Crustacea (about 38% of all macrobenthic species).

In recent years, with the continuous enhancement of China's comprehensive national strength, comprehensive oceanographic survey capacity has been greatly improved. Many research institutes and universities have equipped oceanographic research vessels and manned deep-sea submersibles with advanced equipment and carry out regular oceanographic surveys every year. From offshore to high and deep sea, the sample resources of marine invertebrates have been further enriched, which has led to the rapid development of research on the classification and diversity of invertebrates in China. Since Huang & Lin (2012), there are several crustacean groups being reviewed again based on marine materials, *e.g.*, Galatheaidea, Palaemonidae, Pasiphaeidea, Hippolytidae, Alpheidae, Stenopodoidea, Coenobitidae, Paguridae, Diogenidae, Copepoda, *etc.* More and more new species and newly recorded species of Crustacea from Chinese sea, particularly from deep-sea and special habitats and those of small body sized groups, have been discovered and described. The current estimate of the number of reported species from Chinese seas is approximately 6,000 species.

The scientific identification of marine organisms is the basis of marine scientific research and sustainable utilization of sea resources. The continuous innovation of molecular biological technology provides new opportunities for the development of taxonomy. Hebert *et al.* (2003) proposed that the polymorphism of mitochondrial cytochrome C oxidase

subunit I (COI) gene sequence could be used to realize species differentiation at the DNA level, thus DNA barcoding technology came into being. It also provides technical support for rapid and accurate identification of marine invertebrates (Hebert *et al.*, 2003; Yang *et al.*, 2018). At present, the identification of marine species, as well as the studies of phylogenetic relationship and the discovery of cryptic species, have used the combination of different evolutionary rate markup DNA barcode technology. This method is used to not only find the difference of evolutionary relationships showed by different marks and to assist the analysis of diversity of cryptic species, but also compare the effectiveness of these markers as DNA barcode label. The progress of DNA barcoding technology greatly promoted the progress of modern taxonomic research.

The higher classification system of the phylum Arthropoda is still controversial. The generally accepted taxonomic system classifies the phylum into four subphyla: Chelicerata, Crustacea, Hexapoda and Myriapoda. Among them, almost all the species of the subphylum Hexapoda are terrestrial or live in freshwater. Only a few species of the orders Coleoptera and Hemiptera are known living on the sea surface. Almost all species of the subphylum Myriapoda are terrestrial, too, and the taxonomic studies of this group in China are very poor. The subphylum Chelicerata includes three classes, Arachnida, Merostomata and Pycnogonida. Of which, the taxonomic studies in China of the class Arachnida, a terrestrial group, was reviewed by Dr. Shuqiang Li (2020). The taxa of the other two classes of the subphylum: Merostomata and Pycnogonida are all marine species, and the species of the subphylum Crustacea mostly live in sea. Only a few species live in freshwater, and the taxonomic studies of Crustacea in China are based mainly on the marine species (Li & Gan, 2022a, b).

2 Revision of the taxonomic and phylogenetic studies of Crustacea in China

The subphylum Crustacea, called “the insects of the sea”, is the largest group, with the largest species number, the most morphological diversity and the widest distribution among sea animals. More than 65,000 crustacean species have been reported from all kinds of marine environments. However, due to the insufficient sampling and research, many more species are still unknown. Early reports on the taxonomy of crustaceans in China can be traced back to the 1920s–1930s. Profs. Zhaoqi Yu (S.C. Yu) and Jiarui Shen (C.J. Shen) were the pioneers who reported a variety of shrimps and crabs from coastal China (Shen, 1929; Yu, 1930b, 1931, 1935a, b, c, 1936, 1938). After the founding of the People's Republic of China, under the leadership of Profs. Jiarui Shen, Ruiyu Liu, Zhong Zheng, Yumao Dong, Nanshan Du, Qingchao Chen and Aiyun Dai, taxonomic research of crustaceans in China developed vigorously and is still developing rapidly.

It is difficult to recognize who would be cited as the author of Crustacea. According to Holthuis (1991), it can be traced back as early as 1553, Belon used the name Crustata for lobsters, shrimps and crabs. However, Linnaeus (1758, *Systema Naturae* (10th Edition)) ignored the term “Crustacea” and placed the crustaceous animals together with the spiders, millipedes, *etc.* in his Insecta Aptera. In the *Systema Naturae* (12th Edition), Linnaeus (1767) placed most crustacean species then known in only three genera, *Cancer*, *Monoculus* and *Oniscus*, which were included in his class Insecta. The scope of his Insecta then is equivalent to the Arthropoda as it is now understood. Linnaeus (1758, 1767) did not use the name Crustacea, and some crustacean species today, such as barnacle species, were placed in his “Vermes testacea”. Of course, the scopes of *Cancer*, *Monoculus* and *Oniscus* in the *Systema Naturae* were much more generalized (*sensu lato*) than those today. Before Linnaeus (1767), the names “crustata” or “crustacea” were applied loosely by the older naturalists to those animals possessing a hard exoskeleton. In fact, before Martin & Davis (2001), concerning authorship of the name Crustacea, most carcinologists credit Pennant (1777). Holthuis (1991) noted that the first nomenclaturally available work to use the term Crustacea was actually by Brünnich (1771), who separated the Crustacea (in which he included Chelicerata and Crustacea in the modern sense) from the Insecta Aptera. Subsequently, Pennant (1777) used the term again (Holthuis, 1991; Martin & Davis, 2001). Martin & Davis (2001) followed Holthuis' (1991) suggestion and credited Brünnich (1771) with the authorship of Crustacea.

It is hard to summarise the numerous changes in classification of Crustacea after Pennant (1777) until Calman (1909), who proposed modern higher classification system of the class Crustacea with five subclasses, based on lots of works of comparative anatomy and phylogeny. In the 20th century, the five-subclasses system was commonly used in living crustaceans. In this system, Crustacea was treated as a class of the phylum Arthropoda, and divided into five subclasses, Branchiopoda, Ostracoda, Copepoda, Cirripedia and Malacostraca (Calman, 1909). With the discovery of new crustacean taxa, some new subclasses, such as Cephalocarida, Mystacocarida, Branchiura, Pentastomida, Tantulocarida, and Remipedia, were proposed and added into the Crustacea subsequently (Du, 1987; Martin & Davis, 2001).

In the late 20th century, the higher classification of Arthropoda and the systematic position of Crustacea are very controversial. The old phylum Arthropoda was divided into three (represented by Manton, 1977) or four (represented by Schram, 1978) phyla, and the Crustacea was dealt with as a subphylum or superclass in the old Arthropoda (*sensu lato*).

Ignoring the rank (phylum, subphylum or superclass) of Crustacea, Bowman & Abele (1982) elevated some subclasses of Crustacea to class level, and re-organized other subclasses, proposed a six-class system: classes Branchiopoda, Remipedia, Cephalocarida, Ostracoda, Maxillopoda, and Malacostraca. In the 21st century, with the development of comparative morphology and phylogeny, the higher classification system of crustaceans has undergone great changes. Martin & Davis (2001) recognized the subphylum status of Crustacea in Arthropoda and received the six-class system of Bowman & Abele (1982). In recent years, the rapid developing molecular biological technology has been applied to the phylogenetic research of crustaceans for exploring their origin and evolutionary history. These researches caused further changes to the higher classification system of Crustacea. To date, according to the WoRMS (2022), the new higher classification system of the subphylum Crustacea consists of five superclasses, nine classes and 18 subclasses. They are listed as follows (Li & Gan, 2022b), and the brief changes of the higher classification system of Crustacea are shown in the Table 1.

Subphylum Crustacea Brünnich, 1771

Superclass Branchiopoda Latreille, 1817

Class Branchiopoda Latreille, 1817

Subclass Phyllopoda Latreille, 1817

Superclass Remipedia Yager, 1981

Class Remipedia Yager, 1981

Subclass Remipedia Yager, 1981

Superclass Cephalocarida Sanders, 1955

Class Cephalocarida Sanders, 1955

Subclass Cephalocarida Sanders, 1955

Superclass Oligostraca Zrzavý *et al.*, 1997

Class Ichthyostraca Zrzavý *et al.*, 1997

Subclass Branchiura Thorell, 1864

Subclass Pentastomida Diesing, 1836

Class Mystacorarida Pennak & Zinn, 1943

Subclass Mystacorarida Pennak & Zinn, 1943

Class Ostracoda Latreille, 1802

Subclass Myodocopa Sars, 1866

Subclass Palaeocopa Henningsmoen, 1953

Subclass Platycopa Sars, 1866

Subclass Podocopa Sars, 1866

Superclass Multicrustacea Regier *et al.*, 2010

Class Hexanauplia Oakley *et al.*, 2013

Subclass Copepoda Milne Edwards, 1840

Subclass Tantulocarida Boxshall & Lincoln, 1983

Class Thecostraca Gruvel, 1905

Subclass Ascothoracida Lacaze-Duthiers, 1880

Subclass Cirripedia Burmeister, 1834

Subclass Facetotecta Brygier, 1985

Class Malacostraca Latreille, 1802

Subclass Eumalacostraca Grobben, 1892

Subclass Hoplocarida Calman, 1904

Subclass Phyllocarida Packard, 1879

The following is a brief introduction of the taxonomic research progress mainly of the marine crustacean groups in China. The order and names of the groups take into account both the traditional and the newest classification system. The superclass Remipedia is very scarce and only reported from Australia and Indian Ocean. The superclass Cephalocarida is scarce, too, and only reported from North and South Atlantic Ocean, the North, South Pacific Ocean and the Mediterranean Sea. Neither of them are recorded in China.

Table 1. The changes of higher classification system of Crustacea.

Class Crustacea (Calman, 1909)	Phylum/Subphylum/Superclass Crustacea (Bowman & Abele, 1982; Martin & Davis, 2001)		Subphylum Crustacea (WoRMS, 2022; Li & Gan, 2022b)	
Subc. Branchiopoda	C. Branchiopoda		Superc. Branchiopoda	
	C. Remipedia		Superc. Remipedia	
	C. Cephalocarida		Superc. Cephalocarida	
Subc. Ostracoda	C. Ostracoda		Superc. Oligostraca	C. Ostracoda
	C. Maxillopoda	Subc. Mystacocarida		C. Mystacocarida
		Subc. Pentastomida		C. Ichthyostraca
		Subc. Branchiura		Subc. Pentastomida
		Subc. Copepoda		Subc. Branchiura
Subc. Copepoda		Subc. Tantulocarida	Superc. Multicrustacea	C. Hexanauplia
		Subc. Thecostraca (or Cirripedia)		Subc. Copepoda
Subc. Cirripedia				Subc. Tantulocarida
				C. Thecostraca
				Subc. Cirripedia
				Subc. Facetotecta
				Subc. Ascothoracida
Subc. Malacostraca	C. Malacostraca			C. Malacostraca

2.1 Superclass Branchiopoda

Only one class is contained in the superclass. Zheng & Chen (1966) carried out the first taxonomic study on marine cladocerans (Branchiopoda) in China, and the book *Biology of Marine Cladocera*, published by Zheng & Cao (1987), is a systematic summary monograph of the researches on marine cladocerans in China. Qingchao Chen and Kaizhi Li listed 35 species of 20 genera in 9 families of Branchiopoda from China seas in Liu (2008).

2.2 Superclass Oligostraca

Chen (1978, 1982) firstly reported ostracod crustaceans (class Ostracoda in Oligostraca) from offshore China of the East China Sea. Subsequently, Qingchao Chen, Jianqiang Yin *et al.* carried out investigations and studies on planktonic ostracods in the northern South China Sea and Nansha Islands (southern South China Sea) (Chen *et al.*, 1983, 1989; Yin & Chen, 1991). Chen & Lin (1995) published the book *China Marine Ostracoda*, in which, 133 ostracod species from China seas were reported, with morphological descriptions and illustrations. Qingchao Chen and Jianqiang Yin listed 178 species of 51 genera in 4 families of Ostracoda from China seas in Liu (2008). In their list, the Ostracoda was dealt as a subclass of the class Maxillopoda.

The other two classes, Mystacocarida and Ichthyostraca, of the superclass are poorly studied in China.

2.3 Superclass Multicrustacea

2.3.1 Subclass Copepoda (class Hexanauplia)

This is a group of small-bodied crustaceans containing a lot of species and huge individuals both in plankton and in benthos. It is the main group of zooplankton, as well as of meiobenthos, and plays an important role in the circle of material and flow of energy in marine ecosystem. Therefore, the taxonomic research of Copepoda is very important. The systematic study on copepod taxonomy in China was started in the 1950's. Shen & Bai (1956) reported firstly 22 copepod species from the spawning fields of mackerel in northern China. A series of early taxonomic papers and monographs published by Jiarui Shen, Qingchao Chen, Zhong Zheng, Guangshan Lian and other experts laid a foundation for taxonomic research on marine plankton copepods in China (Shen & Lee, 1963; Chen & Zhang, 1965; Zheng *et al.*, 1965, 1982; Lian & Lin, 1978a, b; Lian & Qian, 1984). Subsequently, a series of atlases and lists were published to update the number of species of plankton copepods in China (Chen, 1986; Shu & Han, 1993; Shih & Young, 1995; Zhang *et al.*, 2010; Lian *et al.*, 2018). Compared with the taxonomic studies on plankton copepods, the taxonomic studies on benthic and parasitic copepods in China are relatively poor, the papers are much fewer (Shen & Bai, 1956; Zheng *et al.*, 1965; Chen *et al.*, 1974; Zhang & Li, 1976). The taxonomy of marine benthic copepods was not to be systematically studied until the 21st century. Fanghong Mu firstly conducted a taxonomic study on benthic copepods from the Bohai Gulf. Subsequently, Lin Ma and Qinghe Liu carried out

taxonomic studies on benthic copepods and finished their theses for doctoral degrees in 2011 and 2019 respectively, and subsequently reported some species from Chinese seas. Qingchao Chen listed 1 species of 1 genus in 1 family of Branchiopoda and 698 species of 191 genera in 71 families of Copepoda from China seas in Liu (2008). He placed Copepoda in the class Maxillopoda.

2.3.2 Subclass Cirripedia (class Thecostraca), the barnacles

The taxonomic study of this organism group in China was first reported by Ren & Liu (1978, 1979). Since the late 1980s, Xianqiu Ren has reported the cirripeds from coastal waters of China. A monograph of the superorder Thoracica, one of the series monographs of the *Fauna Sinica*, was published by Liu & Ren (2007) and described in detail the morphological characteristics, ecological habits and geographical distribution of 198 species of thoracican cirripeds from Chinese seas. Xianqiu Ren and Ruiyu Liu listed 198 species of 74 genera in 21 families of the Infraclass Cirripedia. They put Cirripedia in subclass Thecostraca of the class Maxillopoda in Liu (2008). B.K.K. Chan & Lee (2007) reported 52 species of barnacles from the intertidal zone to deep-sea around Taiwan Island, with discussion of their diversity and ecological characteristics.

2.3.3 Subclass Hoplocarida (class Malacostraca)

Only one order, Stomatopoda, is contained in the subclass. Liu & Wang (1962) firstly reported the fauna of stomatopod crustaceans in China. Subsequently, Liu (1975) described stomatopod species from Xisha Islands, Dong *et al.* (1983) reported stomatopods from coast East China Sea, Wang & Liu (1998) and Sun & Yang (1998) studied the species and fauna of stomatopods in the northern South China Sea and Nansha Islands (southern South China Sea), respectively. Ah Yong *et al.* (2008) described 63 stomatopod species of 28 genera in 9 families of 5 superfamilies from Taiwan Island and adjacent areas, showing a high species diversity of stomatopods in waters off Taiwan. Yongliang Wang and Ruiyu Liu listed 104 species of 42 genera in 12 families of the subclass Hoplocarida from Chinese seas in Liu (2008).

2.3.4 Orders Mysida and Lophogastrida (superorder Peracarida, subclass Eumalacostraca, class Malacostraca)

Taxonomic studies on the orders Mysida and Lophogastrida began in the 1950's in China (Shen, 1955) when a new variety, *Acanthomysis longirostris* var. *sinensis* Shen, 1955, was described. Since the 1980s, Shaowu Wang and Ruiyu Liu carried out systematic taxonomic studies on the two orders in China. They published one of the series monographs *Fauna Sinica* (Liu & Wang, 2000), in which, 112 species of 43 genera in 4 families in Chinese seas were reported. They recognized Mysida and Lophogastrida as suborders of the order Mysidacea. Ruiyu Liu listed 103 species of 43 genera in 2 families of the order Mysida, and 8 species of 4 genera in 2 families of the order Lophogastrida from Chinese seas in Liu (2008).

2.3.5 Order Amphipoda (superorder Peracarida, subclass Eumalacostraca, class Malacostraca)

Yu (1938) firstly described two species of amphipods in Tanggu, Tianjin, marking the beginning of the taxonomy of amphipods in China. After that, there was barely any systematic research on amphipods in China until the 1990s. In the 1990s, Xianqiu Ren carried out a systematic taxonomic study on the suborder Gammaridea in the China seas and published finally two volumes of the series monographs of the *Fauna Sinica* (Ren, 2006, 2012), in which, 373 species of 129 genera in 38 families were reported in total. A volume of plankton amphipod suborder, Hyperiidea, in the series *Fauna Sinica* was published by Chen & Shi (2002) based on their systematic taxonomic studies for years, described 120 species of 41 genera in 14 families. Xianqiu Ren listed 373 species belonging to 130 genera in 38 families of the order Amphipoda in China seas in Liu (2008).

2.3.6 Order Isopoda (superorder Peracarida, subclass Eumalacostraca, class Malacostraca)

The earliest isopod taxonomic report in China was Shen (1929), in which, a new isopod species *Dynoides dentisinus* from the coast of northern China was described. However, early taxonomic studies on Isopoda were only separate reports of individual species. Wei (1991) recorded the morphology and distribution of isopods in coastal Zhejiang Province. At beginning of the 21st century, Dr. Xinzhen Li and Prof. Ruiyu Liu with their students started a systematic taxonomic study on both free-living and parasite species of the order in Chinese seas. Haiyan Yu and Jianmei An finished their theses for master or doctorate degrees in 1999 to 2006 respectively, reported 81 species of 37 genera in 7 families of the suborder Flabellifera and 42 species of 24 genera in 1 family of the parasitic isopods (An, 2011). Haiyan Yu and Jianmei An listed

174 species of 99 genera in 12 families of the order Isopoda in China seas in Liu (2008).

2.3.7 Order Euphasiacea (superorder Eucarida, subclass Eumalacostraca, class Malacostraca), the krills

Cai (1982, 1989) reported krill species from the southern Yellow Sea and East China Sea. Zhang & Chen (1991) reported krill species from the South China Sea and its adjacent areas. The monograph *Marine Krill Biology* published by Zheng *et al.* (2011), provides a comprehensive discussion and elaboration on the morphology, ecology, individual biology, resource development, utilization and protection of krill. Qingchao Chen listed 48 species of 7 genera in family Euphausiidae of the order in China seas in Liu (2008).

2.3.8 Order Decapoda (superorder Eucarida, subclass Eumalacostraca, class Malacostraca), the shrimps, lobsters and crabs

Decapoda is the commonest group of Crustacea, as well as the most successful crustacean group adapting to environments. It is distributed in all habitats of the world, seas, freshwaters, and even terrestrial environments. To date, more than 10,000 species have been reported worldwide.

(1) Suborder Dendrobranchiata. Liu (1955) published a monograph *Economic Shrimps from Northern China*, reported 40 species of 21 genera in 10 families, laying the foundation for systematic taxonomic research on marine shrimps in China. In the book, two families, Penaeidae and Sergestidae, with six genera and seven species belong to the suborder Dendrobranchiata were reported, then these two families were put in the suborder Natantia. Liu & Zhong (1988) published a monograph named *Penaeoid Prawns from the South China Sea*, reported 86 species of 27 genera in 4 families of the superfamily Penaeoidea from the South China Sea.

(2) Caridea, in Suborder Pleocyemata. The earliest taxonomic report of Decapoda in China was Yu (1930a), which described a new species of Palaemonidae, *Leander Gravieri* Yu, 1930 (= *Palaemon gravieri* (Yu, 1930)), a very common species in the Yellow Sea and East China Sea. However, broader systematic taxonomic study of Decapoda did not begin until 1950's. In Liu (1955), 29 species of 13 genera in 6 families were reported in tribe Eucyphidea (=Caridea), similarly as on the suborder Dendrobranchiata, this work laid the foundation for systematic taxonomic research on marine caridean shrimps in China. Li *et al.* (2007b) published a monograph of the series *Fauna Sinica, The Palaemonoidea*, which is the first volume of the series on the infraorder Caridea, reported 155 species of 39 genera in 3 families of the superfamily Palaemonoidea from the Chinese waters both seawaters and freshwaters. In this monograph, the research history and the evolution process of the higher classification system of the infraorder Caridea were described and discussed. Subsequently, the systematic taxonomic studies on the superfamilies Crangonoidea, Alpheoidea and Pasiphaeoidea were respectively carried out by Qingxi Han, Peng Xu, Dongling Cui, Yaqin Wang, Yanrong Wang with their supervisors, and a series of works were subsequently published (*e.g.*, Han *et al.*, 2007; Han & Li, 2017).

(3) Anomura, in Suborder Pleocyemata. Yang (1983) firstly reported the anomurans from Xisha Islands. Chao Dong and Dong Dong started their systematic taxonomic studies on superfamily Galatheoidea in infraorder Anomura since 2007 for their degree theses. 71 species of 19 genera in families Galatheididae and Chirostylidae, and 62 species of 12 genera in family Porcellanidae from China seas were reported. Lichan Xiao and Yuanyuan Han successively carried out taxonomic studies on families Diogenidae, Coenobitidae, and Paguridae of superfamily Paguroidea for their master degree theses. A series of works were published subsequently (*e.g.*, Dong & Li, 2015, 2018; Dong *et al.*, 2016, 2017, 2019).

(4) Astacidea, Thalassinidea and Stenopodidea, in Suborder Pleocyemata. Zhao Zhang, Wenliang Liu and Qiwu Jiang carried out taxonomic and zoogeographical studies on infraorders Astacidea, Thalassinidea and Stenopodidea from Chinese seas for their degree theses, respectively. A series of works were published subsequently (*e.g.*, Zhang & Liu, 2006; Liu & Liu, 2012, 2013, 2014; Jiang *et al.*, 2015).

(5) Brachyura, in Suborder Pleocyemata, the crabs. In the early 1930s, Prof. Jiarui Shen started crabs taxonomic research in China. The monograph *Crab Fauna in northern China*, published by Shen (1932), is the earliest work about branchyuran crustacean taxonomic study in China. In this article more than 100 crab species were reported, with detailed descriptions and illustrations. More than 200 species of crabs were recorded in the second crustacean volume of *Animal Atlas of China*, edited by Shen & Dai (1964). Prof. Aiyun Dai with her colleagues published monograph *Crabs of the China Seas* (Dai *et al.*, 1986; Dai & Yang, 1991), systematically reported 601 species of 213 genera in 26 families of branchyuran crustaceans from China seas, laying a foundation for systematic taxonomic research on crabs in China. Later, Huilian Chen, Siliang Yang and Wei Jiang made comprehensive and systematic studies and summary of the infraorder Brachyura in China (*e.g.*, Chen & Sun, 2002; Yang *et al.*, 2012).

In Liu (2008), Ruiyu Liu listed 167 species of 42 genera in 7 families of the suborder Dendrobranchiata, and 49 species of 20 genera in 2 families of infraorder Palinuridea (suborder Pleocyemata); Ruiyu Liu & Zhongli Sha listed 167 species of 30 genera in 3 families of the superfamily Alpheoidea (infraorder Caridea, suborder Pleocyemata); Ruiyu Liu & Wenliang Liu listed 77 species of 31 genera in 14 families of the infraorders Astacidea and Thalassinidea (suborder Pleocyemata); Xinzheng Li listed 276 species of 78 genera in 16 families of the superfamilies Crangonoidea, Nematocarcinoidea, Oplophoroidea, Palaemonoidea, Pandaloidea, Pasiphaeoidea, Processoidea, Psalidopodoidea, Stylodactyloidea (infraorder Caridea, suborder Pleocyemata), and 3 species of 3 genera in 2 families of the infraorder Stenopodidea (suborder Pleocyemata); Yongliang Wang listed 299 species of 72 genera in 12 families of the infraorder Anomura (suborder Pleocyemata); Siliang Yang listed 1073 species of 383 genera in 61 families of the infraorder Brachyura (suborder Pleocyemata).

2.4 Deep-sea crustacean taxonomic researches in China

Dong (1988) published a monograph *Deep-sea Crustaceans from the East China Sea*, reporting 85 crustacean species of shrimps, crabs, anomurans, isopods and cirripeds in 31 families of 4 orders, including 4 new species and 50 new recorded species, based on samples collected from the Deep-sea of East China Sea, mainly continental slope. This monograph was the earliest work on deep-sea crustaceans' systematical taxonomic research in Chinese seas. Since 1996, Dr. Xinzheng Li and his collaborators have systematically sorted out species of the superfamilies Palaemonoidea and Pandaloidea in infraorder Caridea and other crustacean groups from Indo-Pacific, reported many taxa including new genera and new species (Li, 2004, 2006a, b, c, 2007, 2008, 2009, 2015, 2017; Li & Bruce, 2006; Li & Davie, 2006; Li & Poupin, 2009, 2012; Li & Chan, 2013; Li *et al.*, 2007a, 2008, 2012; Han *et al.*, 2007; Rajkumar *et al.*, 2009; Mitsuhashi *et al.*, 2010, 2012; Jiang *et al.*, 2015; Dong & Li, 2015, 2018; Dong *et al.*, 2016, 2017, 2019, 2021a, b; Kou *et al.*, 2018a, b, 2019; *etc.*). In recent years, with the application of advanced deep-sea equipment such as manned deep-sea submersibles (*e.g.*, the “Jiaolong”, “Shenhaiyongshi” and “Fendouzhe” submersibles, Li, 2015, 2017) and ROV (*e.g.*, the “Faxian”), many new crustaceans, as well as other marine groups, have been reported. Ren & Sha (2014, 2015) and Sha & Ren (2014, 2015a, b; Sha *et al.*, 2018) established a new family, Probathylepadidae, of superorder Thoracica, and described several new species of the infraclass Cirripedia based on samples from the West Pacific. Kou *et al.* (2019) reported a new record of the deepest record of the order Lophogastrida based on a sample caught at 7,526m in the Mariana Trench, and published a new genus and a new recorded species of the order Mysida, as well as discussing the evolutionary history of the deep-sea mysids (Kou *et al.*, 2018b, 2020). Liu & Sha (2015) reported a new species of family Antarcturidae (order Isopoda) from the Okinawa Trough at 2,115m depth. Kou *et al.* (2017) reported a new species of family Cirolanidae (order Isopoda) from the South China Sea at 898m depth. Many new species and new recorded species of the order Decapoda were reported by Chinese scholars in recent times. Li (2015) reported two new recorded caridean species from the cold seep, “Jiaolong Cold-Seep”, close to the Site F, at northeastern South China Sea southwest to Taiwan Island. Wang *et al.* (2015) and Wang & Sha (2016, 2017) reported one new species of family Palaemonidae and two new species of Alvinocarididae (infraorder Caridea). Xu *et al.* (2016) reported a new species of family Thoridae (infraorder Caridea) from the Magellan Seamount. The deep-sea spongicolid shrimps usually live as a commensal with hexactinellid sponges. Jiang *et al.* (2015) reported a species of family Spongicolidae from the cold seep at northeastern South China Sea southwest to Taiwan Island. Xu *et al.* (2017) and Kou *et al.* (2018a) described new species of genus *Spongicoloides* (family Spongicolidae), respectively, based on samples from seamounts of the West Pacific. Dong & Li (2015, 2018) and Dong *et al.* (2016, 2017, 2019, 2021a) reported many squat lobster species including at least 16 new ones from the deep sea of West Pacific.

3 Fauna Sinica of marine Crustacea in China

The published volumes of crustaceans in the series of *Fauna Sinica* are: suborder Hyperiidea of order Amphipoda (Chen & Shi, 2002); suborder Gammaridea of order Amphipoda (Ren, 2006, 2012); order Mysidacea (Liu & Wang, 2000); superfamily Palaemonoidea of order Decapoda (Li *et al.*, 2007b); family Portunidae of order Decapoda (Yang *et al.*, 2012); sections Dromiacea, Archaeobrachyura and superfamilies Dorippoidea, Leiucosioidea, and Calappoidea of section Eubrachyura of infraorder Brachyura in order Decapoda (Chen & Sun, 2002); superorder Thoracica of infraclass Cirripedia (Liu & Ren, 2007). The other volumes of crustacean groups are in preparation or in press.

4 Molecular systematic researches on Crustacea in China

Since 2000, with the rapid progress of molecular biological technology, new theories, techniques and methods have been applied to the phylogenetic research of crustaceans. Many graduate students in China worked on phylogenetic relationships of crustacean groups using molecular methods, many research results have been published (*e.g.*, Fan *et al.*, 2004; Kou *et al.*, 2013). Because this field is developing very quickly and a lot of papers have been published recently, it can be reviewed in future for a separate paper.

5 Summary and prospects

The systematic researches of taxonomic, systematic, biogeographic studies of marine living organisms did not develop until 1950. In that year, the Department of Marine Biology of the Chinese Academy of Sciences was established, and the systematic taxonomic research and field investigate of marine organisms were formally started in China. After the bottleneck period from the late 1980s to 2000, with the development of modern biological technology and the national demand for marine life science, the taxonomic and systematic researches of marine living organisms in China has entered a rapid development period, talent growing stronger and stronger, new theories, methods and technology being applied to the researches, and more and more research teams joining the field of study. However, comparing with that of international advances, or with the situation of terrestrial organism groups in China, the development of marine biology in the country is still on a comparatively less-developed level. There are still many groups not been studied, especially those with small body-size or less economic value from Chinese seas. Indeed, the application of advanced biological technologies has accelerated the unbalanced development of taxonomic researches among marine organism groups; however we are facing a very important and complicated situation with opportunity and challenge. In order to preferably develop marine taxonomy in China, the following suggestions are put forward for the reference of colleagues and decision-makers of marine science development.

Strategically, we should seize the opportunity of new rounds of marine biodiversity research, starting with a high point and trying our best to obtain high-quality results. Based on basic research, it is strived for theoretical breakthrough and sustainable development.

In the research groups, the deep-sea crustaceans and the small groups should be given attention. The deep-sea crustaceans have novel life systems and ecology. The small groups are often the main contributors to ecosystem health and marine ecosystem functions and services. These small organisms may disturb and impact the big ocean, then are the giants in ocean in terms of biomass. They have more advantages and are more important in adapting to climate change and new environments than the big body size living organisms.

Methodologically, the combination of morphology and molecular biology is necessary. Molecular systematics is a magic tool to solve the evolution of living systems and the state of marine biodiversity. For example, the DNA barcoding technology can be applied in the rapid species identification and diagnosis of the state of marine biodiversity.

In team building, a comprehensive, systematic, stable and capable research team is very necessary.

It is a fascinating world where the vast ocean is home to thriving marine life. Marine taxonomy is the basic subject of marine life science and even marine science, which has a long way to go. I hope a stable taxonomic team of marine taxonomists in China can be maintained and developed who can produce high level research results, and new talents particularly young scientists will join the team continuously.

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