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Research on the seasonal variation of zooplankton community in Daya Bay, South China Sea

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Changes in zooplankton composition, abundance, and some species in response to environmental variation were investigated over four seasons (2020) in Daya Bay. In total, 129 taxa of zooplankton (16 groups of planktonic larvae and 20 indeterminate species) were identified. Zooplankton communities exhibited a significant seasonal shift in abundance and taxonomic composition. The maximum number of zooplankton species was recorded in winter (72 species) and the lowest in spring (42 species). However, the abundance was highest in spring (1,372.01 ± 1,071.14 individuals/m^3) and lowest in autumn (50.93 ± 34.05 individuals/m^3). Pearson correlation analyses demonstrated that the zooplankton abundance and the variations of indicator species were obviously correlated with environmental parameters (*e.g.*, salinity, temperature, pH, and chlorophyll-*a*). Based on specificity and occupancy analysis, a total of eight species were selected as indicator species. It is noteworthy that some kollaplankton (such as *Dolioletta gegenbauri* and *Doliolum denticulatum*) could potentially cause disaster to the nuclear power plant cooling system because of their relatively large body size and huge blooms in spring. In addition, *Centropages tenuiremis* blooms in spring and *Penilia avirostris* blooms in summer could attract assemblages of larval or adult pelagic fish, which would also threaten the cooling system security in Daya Bay. In conclusion, our results suggest that zooplankton communities and some species may be considered as favorable indicators of the marine environment.

KEYWORDS

zooplankton, indicator species, Daya Bay, nuclear power, disaster-causing organism

Introduction

Coastal waters, which lie at the transition zones between oceans and continents, are the most relevant to human society. They also support rich fishing grounds and provide economic benefits due to their relatively higher productivity (Herrera-Silveira and Morales-Ojeda, 2009; Lange et al., 2010). Coastal areas support relatively greater plankton production and degradation and also play a key role in biogeochemical processes. However, their biodiversity and ecological function are threatened by global changes and anthropogenic pressures which cause the degradation of biotopes and biocenosis (Kemp and Boynton, 2012; Zhang, et al., 2021). Increased anthropogenic activities have accelerated the process of eutrophication, leading to dystrophic crises and/or irreversible deterioration—for example, a decrease in the mean size of dominant copepods from the late 1940s to 2012 was detected in the Central Basin of Long Island Sound, Japan (Rice et al., 2015).

Daya Bay is a semi-enclosed, shallow embayment with depths ranging from 5 to 20 m and an area of 650 km^2, which is located in the northern part of the South China Sea (Song et al., 2004). It contains complex habitats, tremendous biological resources, abundant biodiversity, and plentiful marine products, which make it one of the most important treasure houses for sub-tropical aquatic resources. In recent years, rapid social and economic developments have resulted in environmental degradation in Daya Bay. Studies have shown that degradation and habitat modification have significantly increased (Wu et al., 2009; Liu et al., 2018), while eutrophication has reduced the zooplankton species richness by about 50% (Li et al., 2014). Dominant species in the spring have changed because of the rapid increase in water temperature and abundant food supply in Daya Bay (Xiang et al., 2021; Zhao et al., 2022), and Li et al. (2021) reported that the zooplankton community was undergoing great changes, showing tendencies of miniaturization and gelatinization over the past 30 years. Several large-scale zooplankton blooms have occurred in Daya Bay, which were related to changes in water temperature, salinity, and food supply variation (Zeng et al., 2019; An et al., 2021; Zeng et al., 2021; Liu et al., 2022).

Zooplankton are sensitive to chemical, physical, and biological factors in marine systems (Sun et al., 2010; Shi et al., 2015). The composition and abundance of zooplankton are highly dependent on environmental conditions and respond quickly to environmental variations. Consequently, zooplankton are considered as bio-indicators of environmental quality and water mass (Dam, 2013; Carter et al., 2017; Wang et al., 2020; Wang et al., 2022). Zooplankton are not only a key link in energy transfer from primary production to higher trophic levels but also a key factor in controlling the harmful effects of eutrophication and proliferation of microalgae (Rissik et al., 2009)—for example, dinoflagellates and prasinophytes are the most preferred phytoplankton groups by the mesozooplankton in Daya Bay (Li et al., 2018).

Daya Bay Nuclear Power Station and Ling-Ao Nuclear Power Station were built in 1994 and 2002, respectively. They are located in the inner regions of west Daya Bay. The thermal discharge is affected by tidal currents, which depend on the topography of Daya Bay (Yuan et al., 2021). The residual current is relatively small within the bay in summer but is stronger with the stronger current fields in winter, and the self-purification capacity of this area is weak (Wu et al., 2007). In addition, other studies have demonstrated that the thermal discharge has a significant impact on the Daya Bay ecosystem, including levels of nutrients, and zooplankton and phytoplankton (Jiang and Wang, 2020). Therefore, it is vital to monitor the zooplankton composition and variation in Daya Bay.

The aims of this research were to (1) investigate whether there is significant variation in the zooplankton composition in the research area, (2) identify the indicator composition under different environmental conditions, (3) measure the correlation of indicator species with the environmental parameters in the research area, and (4) discuss whether the indicator species caused a potential threat to the safety of the nuclear power plant cooling systems in the research area.

Materials and methods

Field sampling

Twenty-four sampling stations were set up in Daya Bay during winter (January), spring (March), summer (August), and autumn (November) of 2020 (Figure 1). Zooplankton samples were collected at each station during every survey. In total, 96 zooplankton samples were obtained by vertical tow from 1 m above the bottom to the surface at a speed of 0.5 m/s using a plankton net (mesh size, 505 μm; mouth diameter, 50 cm; and net length, 145 cm). A Hydro-Bios flow meter (Hydro-Bios Apparatebau GmbH., Altenholz, Germany) was mounted at the mouth of the net to calculate the filtered water volume. Then, zooplankton samples were immediately preserved with 5% formalin seawater solution on board at each station. Environmental factors, such as temperature, pH, salinity, and dissolved oxygen (DO), were measured *in situ* using a multi-parameter sensor (YSI Professional Plus, Xylem Analytics, Beijing, China) at each station where the zooplankton samples were collected. In addition, 5,000 ml of seawater samples for nutrient analysis was collected from each station with a Niskin water sampler at a depth of 0.5 m and preserved immediately upon collection by placing them at -20°C in the dark. Simultaneously, approximately 500 ml of sampled seawater was filtered through GF/F filters. These filters were frozen and later extracted with 90% acetone at −20°C in the dark for 24 h to determine the concentration of chlorophyll-*a* (Chl-*a*) using a fluorometer (Tuner-10-AU).

Data analysis

In the laboratory, zooplankton samples were split into sub-samples with a Folsom plankton sample splitter until each subsample contained about 200 individuals. All individuals in the subsamples were quantified and identified to species level where possible under a stereomicroscope (Leica MZ95, Leica Microsystems Ltd, Wetzlar, Germany) according to the descriptions of Chen and Zhang (1965), Zheng et al. (1984), Chen (1992); Chihara and Murano (1997), and Lian et al. (2019). Abundance was calculated by the individuals' numbers to be divided by filtered water volume at each station. Total abundance was equal to the sum of all individuals' abundance in that station. Total average abundance means the summation of total abundance in each station to be divided by station numbers in each survey. Relative abundance represents the percentage of a certain species' average abundance in the total average abundance.

One-way analysis of variance with Tukey's *post-hoc* test was used to estimate the seasonal variation of environmental characteristics, and the correlation of different parameters was analyzed *via* Pearson correlation analysis using SPSS software (IBM SPSS statistics for Windows, Armonk, NY, USA). The dominance (Y) of each species was calculated using the formula $Y=(n_i/N)^*f_i$, where n_i represents the mean number of species i, and N represents the total mean number of zooplankton. The specificity and occupancy were calculated using the following formula with reference to Dufrene and Legendre (1997). The figure of specificity–occupancy was finished by ggplot 2 in R language.

$$\text{Specificity} = \frac{N_{\text{individuals}}i,j}{N_{\text{individuals}_i}};$$

$$\text{Occupancy} = \frac{N_{\text{sites}_{i,j}}}{N_{\text{sites}_j}}$$

Where $N_{\text{individuals}i,j}$ means the mean abundance of species i in survey j. $N_{\text{individuals}_i}$ means the sum of the mean abundance of species i in different surveys. Occupancy also means occurrence rate. $N_{\text{sites}_{i,j}}$ means the station numbers of species i occurrence in survey j and N_{sites_j} means all stations in survey j.

Results

Environmental parameters

The year-round mean surface water temperature was 24.59 ± 3.87°C, and the water temperature followed a clear seasonal pattern. The maximum was recorded in summer (30.48 ± 0.48°C), and the minimum was in winter (20.01 ± 0.93°C). The temperature was close to the year-round average surface water temperature in spring and autumn at 23.73 ± 1.00°C and 24.13 ± 0.85°C, respectively (Figure 2A). The values of salinity and pH peaked in spring but were relatively lower in summer (Figures 2B, C). Additionally, the values of DO ranged from 6.32 ± 0.45 mg/L in summer to 7.76 ± 0.67 mg/L in autumn, with a mean of 7.11 ± 0.70 mg/L (Figure 2D). The values of Chl-*a* varied consistently with DO—the maximum value was recorded in autumn, and the minimum value was recorded in summer. There were no obvious differences in Chl-*a* concentration between the spring, summer, and winter surveys (Figure 2E).

Zooplankton composition and seasonal variation

A total of 129 zooplankton species (16 groups of planktonic larvae and 20 indeterminate species) were identified in this study. All species were arranged into cladocera, copepoda, kollaplankton, large crustacean, meroplankton, other crustacean, and other plankton groups, based on the systematics and their function in the marine environment. Kollaplankton included tunicates, cnidaria, ctenophores, and chaetognatha. Mysidacea, euphausiacea, and decapoda were classified as large crustaceans. The other crustaceans included amphipoda and ostracoda. Annelida and petropoda were classified as other plankton in this study. The species composition of zooplankton showed obvious seasonal variation (Figure 3). In winter, 72 species were recorded at the species level. This was followed by autumn, summer, and spring,

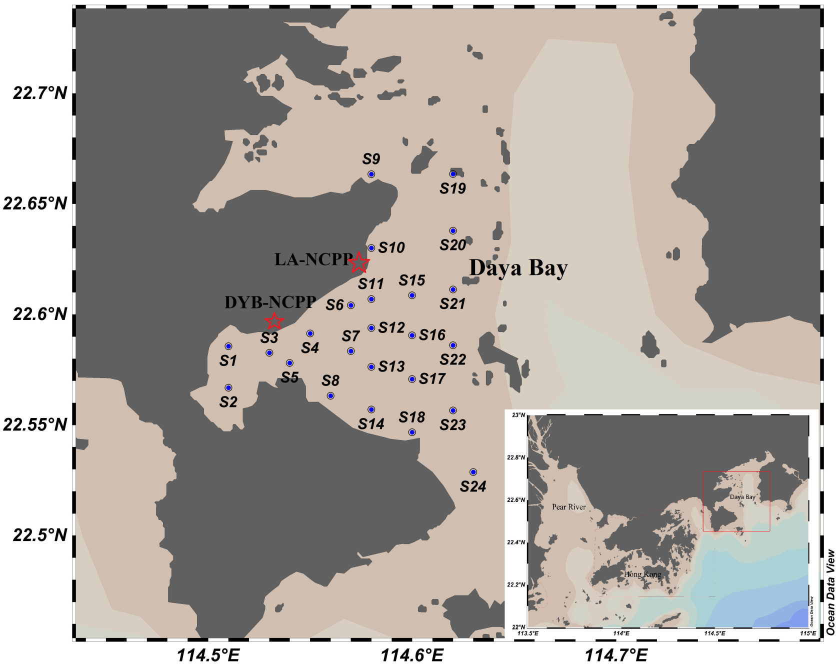

FIGURE 1
Study area and stations located at western Daya Bay. DYB-NCPP, Daya Bay Nuclear Power Plant; LA-NCPP, Ling'ao Nuclear Power Plant.

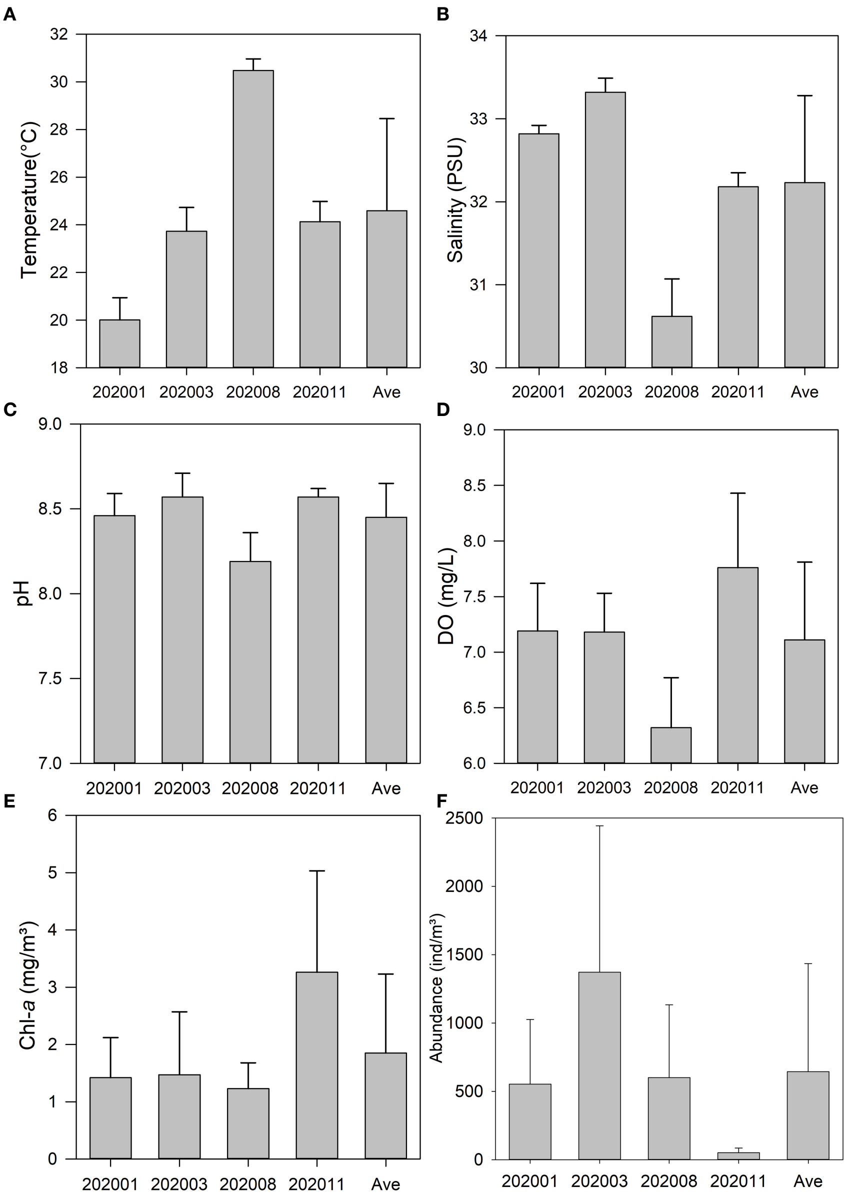

FIGURE 2
Bar plot of the temperature **(A)**, salinity **(B)**, pH **(C)**, dissolved oxygen **(D)**, chlorophyll-a **(E)**, and total average abundance **(F)** in the research area.

with 54 species, 44 species, and 42 species, respectively. Copepods accounted for the highest number of species, and the percentage ranged from 43.18% to 62.96%.

The total average zooplankton abundance showed a significant seasonal variation. The greatest average abundance was in spring, and the lowest in autumn (Figure 2F). In spring, the average abundance of zooplankton was 1,372.01 individuals/m^3, while the zooplankton assemblage was largely dominated by kollaplankton (46.36% of total average abundance), meroplankton (27.04% of total average abundance), and copepods (19.95% of total average abundance). In summer, the average abundance of zooplankton was significantly reduced to 601.10 individuals/m^3, with the average abundance of cladocera (58.21% of total average abundance) being the highest, followed by copepods (28.20% of total average abundance) and meroplankton (10.97% of total average abundance). In autumn, zooplankton average abundance was only 50.93 individuals/m^3, with copepods and meroplankton dominating, accounting for 57.22% and 21.93% of total average abundance, respectively (Figure 3). However, the zooplankton average abundance increased in winter, reaching 553.06 individuals/m^3. The dominant species were cladocera and copepods, with abundance values of 233.14 individuals/m^3 (42.15% of total average abundance) and 225.86 individuals/m^3 (40.84% of total average abundance), respectively.

The Pearson correlation analysis results showed that the total abundance of zooplankton was significantly positively correlated with surface water salinity and markedly negatively correlated with Chl-*a* (p< 0.01) (Table 1). In addition, the abundance of cladocera and copepods was significantly negatively correlated with Chl-*a* (p< 0.01). Similarly, there was a significant negative correlation between

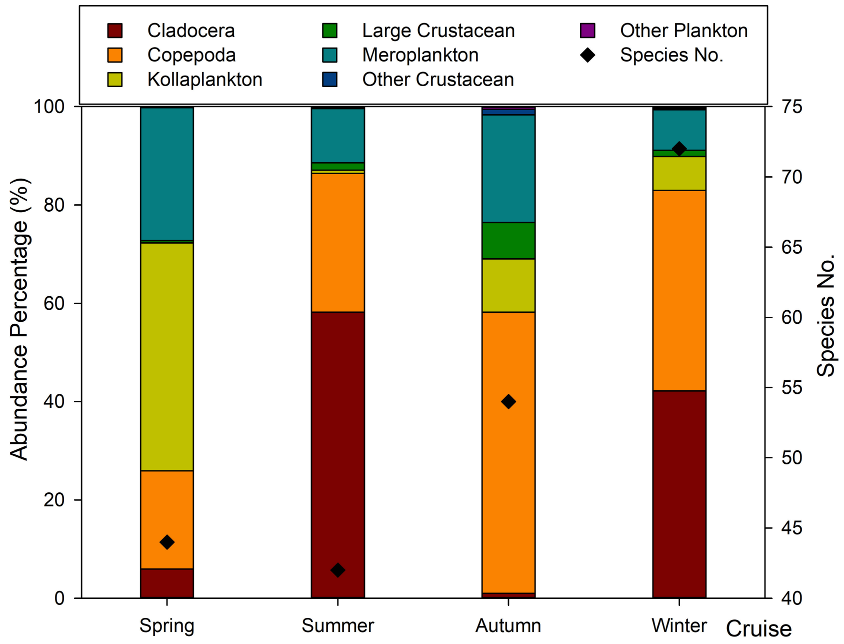

FIGURE 3
Species number and abundance percentage in Daya Bay.

the abundance of kollaplankton, large crustaceans, meroplankton, and Chl-*a* ($p < 0.05$). However, cladocera abundance showed a significantly positive correlation with surface water temperature and a notable negative correlation with DO. The abundance of cladocera showed a notable negative correlation with pH, while kollaplankton abundance was positively correlated with pH ($p < 0.01$). The salinity showed a significantly negative correlation with the abundance of cladocera and a notably positive correlation with abundance of kollaplankton and meroplankton ($p < 0.01$). Both the abundance of other crustaceans and that of other plankton showed

TABLE 1 Correlation analysis of environmental parameters with different functional groups in the research area.

		Temperature	Salinity	pH	DO	Chl-a concentration
Cladocera	Pearson correlation	0.23*	-0.33**	-0.33**	-0.32**	-0.34**
	Significance (two-tailed)	0.03	0.001	0.001	0.002	0.001
Copepoda	Pearson correlation	-0.07	0.16	0.02	-0.11	-0.35**
	Significance (two-tailed)	0.48	0.13	0.83	0.27	0
Kollaplankton	Pearson correlation	-0.08	0.44**	0.27**	0.05	-0.24*
	Significance (two-tailed)	0.50	0	0.008	0.62	0.02
Large crustacean	Pearson correlation	0.13	-0.11	-0.10	-0.17	-0.22*
	Significance (two-tailed)	0.22	0.30	0.33	0.11	0.04
Meroplankton	Pearson correlation	-0.01	0.34**	0.18	-0.007	-0.21*
	Significance (two-tailed)	0.93	0.001	0.09	0.94	0.04
Other crustacean	Pearson correlation	-0.04	0.14	0.14	-0.06	-0.16
	Significance (two-tailed)	0.69	0.18	0.18	0.55	0.13
Other plankton	Pearson correlation	-0.02	-0.07	-0.04	-0.08	-0.18
	Significance (two-tailed)	0.82	0.53	0.67	0.43	0.08
Total abundance	Pearson correlation	0.02	0.25*	0.08	-0.11	-0.40**
	Significance (two-tailed)	0.88	0.01	0.43	0.27	0

*Correlation is significant at the 0.01 level (two-tailed).
**Correlation is significant at the 0.05 level (two-tailed).

no obvious correlation with the environmental parameters in the research area.

Dominance was calculated when the individual was identified to the species level. A total of 13 species were considered as dominant species, with dominance values higher than 0.02 (Table 2). In spring, *Dolioletta gegenbauri* was the most dominant species. Its mean abundance and relative abundance (RA) were 435.10 individuals/m^3 and 44.15%, respectively. It was followed by *Doliolum denticulatum* and *Centropages tenuiremis*, with mean abundance of 177.25 individuals/m^3 and 130.23 individuals/m^3, respectively. In summer, there were three new dominant species—*Peniliaavirostris*, *Evadne tergestina*, and *Acartia clausi*—with *P. avirostris* being the most dominant species in summer. Its abundance was 257.14 individuals/m^3, and its RA was 49.21%. Eight species were defined as dominant species in autumn, and the most dominant species was *A.clausi*, with an average abundance of 8.38 individuals/m^3 and RA of 22.88%. In winter, the dominant species were *E.tergestina* and *Temora turbinata*. Their abundance and RA were 231.48 individuals/m^3 and 46.76%, and 90.84 individuals/m^3 and 18.35%, respectively. In addition, the most dominant species showed an obvious seasonal variation in the research area and was abundant with a relatively high occurrence rate only in one or two surveys. In contrast, both the occurrence rate and the relative abundance of *T. turbinata* showed relatively higher values during the 1-year survey.

Specificity and occupancy of the zooplankton

The specificity and occupancy were calculated and projected onto a plot (Figure 4). In the plot, the x-axis indicates occupancy, which means how the species was distributed across all stations in that survey. As indicated by the spread across the x-axis, zooplankton displayed a highly varied occupancy in all surveys. Fewer species were present in all stations. The y-axis represents the specificity, which means whether that species was found in other surveys. The highest number of habitat-specialist species (20 species) was found in the winter survey, while there were eight, six, and two specialist species in autumn, spring, and summer, respectively.

Species which were specific to a habitat and common in their habitat at most sites were selected as indicator species of each survey when specificity and occupancy were greater or equal to 0.7 (dotted boxes in Figure 4). The number of indicator species differed significantly between different surveys (Table 3). *Dolioletta gegenbauri*, *D. denticulatum*, *Diphyes chamissonis*, *Sagitta bedoti*, and *C. tenuiremis* were selected as indicator species in spring. In summer, the indicator species were *A. clausi* and *P. avirostris*. *Aglaura hemistoma* was the only indicator species in winter. There was no species suitable as an indicator species in autumn.

The Pearson correlation analysis results revealed that zooplankton abundance was negatively associated with Chl-*a* (p< 0.01) and positively associated with salinity (p< 0.05). Nevertheless, the variations of indicator species were mainly affected by salinity and pH—for example, *D. gegenbauri*, *D. chamissonis*, *S. bedoti*, and *C. tenuiremis* had a significantly positive correlation with salinity (p< 0.01), whereas *A. clausi* and *P. avirostris* showed a significantly negative correlation with salinity (p< 0.01). Simultaneously, other significantly positive correlations included those between *D. denticulatum* and salinity and between *D. chamissonis*, *S. bedoti*, *C. tenuiremis*, and *D. gegenbauri* and pH. However, *A. clausi* and *P. avirostris* showed negative correlations with pH. In addition, the water temperature was significantly negatively correlated with *A.*

TABLE 2 The average abundance (AA), relative abundance (RA), and occurrence rate (OR) of dominant species in the research area.

Species	Spring			Summer			Autumn			Winter		
	AA	RA	OR	AA	RA	OR	AA	RA	OR	AA	RA	OR
Acartia clausi	7.20	0.01	0.54	**81.39**	**0.16**	**0.96**	**8.38**	**0.23**	**1.00**	12.34	0.02	0.54
Acartia danae	3.58	0.00	0.33	1.16	0.00	0.21	**3.13**	**0.09**	**0.88**	13.49	0.027	0.67
Canthocalanus pauper	19.60	0.02	0.75	0.95	0.00	0.25	**2.84**	**0.08**	**0.75**	9.22	0.02	0.58
Centropages tenuiremis	**130.23**	**0.13**	**1.00**	4.31	0.01	0.58	0.69	0.02	0.58	**20.00**	**0.04**	**0.88**
Doliolum denticulatum	**177.25**	**0.18**	**1.00**	0.04	0.00	0.04	0.00	0.00	0.00	1.27	0.00	0.46
Dolioletta gegenbauri	**435.10**	**0.44**	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	10.37	0.02	0.88
Evadne tergestina	12.01	0.01	0.83	**92.75**	**0.18**	**1.00**	0.18	0.00	0.25	**231.48**	**0.47**	**1.00**
Lucifer intermedius	0.87	0.00	0.38	6.24	0.01	0.88	2.33	0.06	0.96	1.60	0.00	0.46
Penilia avirostris	**69.11**	**0.07**	**0.92**	**257.14**	**0.49**	**1.00**	0.32	0.01	0.29	1.66	0.00	0.25
Sagitta enflata	4.01	0.00	0.83	0.67	0.00	0.42	**2.84**	**0.08**	**0.88**	4.32	0.01	0.92
Subeucalanus subcrassus	12.03	0.01	0.71	10.39	0.02	0.83	**1.22**	**0.03**	**0.63**	**13.10**	**0.03**	**0.88**
Temora turbinata	26.92	0.03	0.88	36.50	0.07	0.92	**3.60**	**0.10**	**0.96**	**90.84**	**0.18**	**1.00**
Tortanus gracilis	0.39	0.00	0.08	7.58	0.01	0.79	**1.76**	**0.05**	**0.92**	5.03	0.01	0.75

Bold values is that species was the dominant species on that survey.

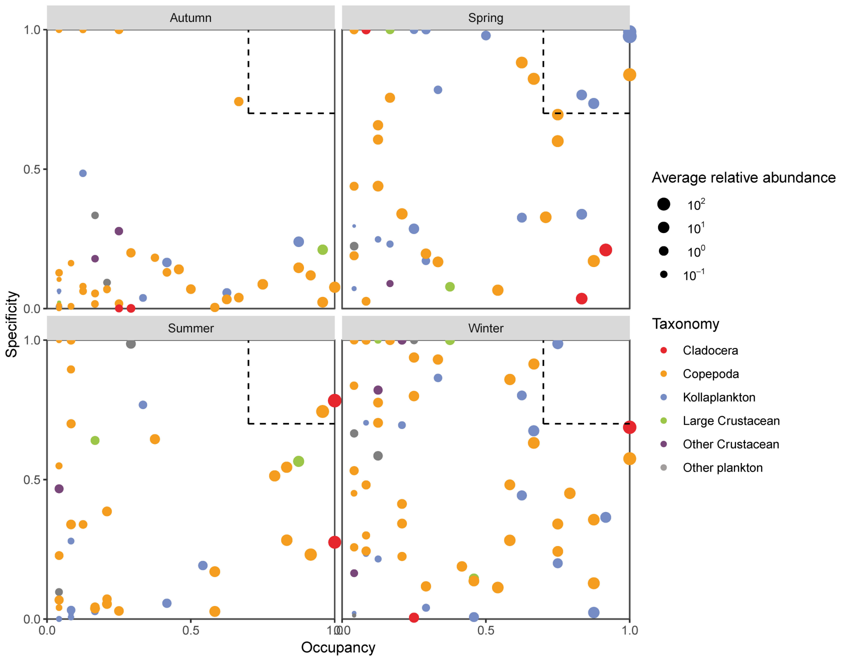

FIGURE 4
SPEC-OCCU plots of zooplankton.

hemistoma but positively correlated with *A. clausi* and *P. avirostris*. The DO showed a significantly negative correlation with *A. clausi* and *P. avirostris*. The Chl-*a* concentration was significantly negatively correlated with *D. gegenbauri*, *D. chamissonis*, *S. bedoti*, C. *tenuiremis*, and *P. avirostris*.

Discussion

Daya Bay, which is located in a subtropical zone, is a semi-closed bay. Due to the influence of the monsoon, there is plenty of rainfall from May to October and less from November to April (Wu and Wang, 2007). In the dry season (winter), the northeast monsoon prevails, with low temperatures and precipitation. In contrast, in the wet season (summer), the southwest monsoon predominates, with relatively high levels of precipitation and temperature. Spring and autumn are the monsoon transition seasons in the research area (Xu, 1989; Wu et al., 2009; Wu et al., 2010, Wu et al., 2011, Wu et al., 2012; Wu et al., 2016). The highest surface water temperature was observed during summer in this study. Owing to the precipitation and runoff, the surface water was diluted, resulting in relatively low salinity, pH, DO, and Chl-*a* concentration in summer. The correlation analysis showed that there was a significantly positive correlation between salinity, DO, and pH. Nevertheless, a significantly negative correlation was observed between DO and Chl-*a* in summer (Supplementary), which was consistent with the results reported for the northern region of the South China Sea during autumn (Long et al., 2006). Shen et al. (2017) reported that a significantly negative correlation was also observed between salinity and Chl-*a* in Daya Bay. In contrast, we found a notably positive correlation between Chl-*a* and salinity in autumn and a negative correlation in spring. However, no

TABLE 3 Mean abundance (MA), specificity, and occupancy of indicator species.

Species	Specificity (%)	Occupancy (%)	MA (individuals/m^3)	Cruise
Dolioletta gegenbauri	97.67	100.00	435.10	Spring
Doliolum denticulatum	99.27	100.00	177.25	Spring
Diphyes chamissonis	76.62	83.33	3.48	Spring
Sagitta bedoti	73.59	87.50	5.47	Spring
Centropages tenuiremis	83.90	100.00	130.23	Spring
Acartia clausi	74.45	95.83	81.39	Summer
Penilia avirostris	78.34	100.00	257.15	Summer
Aglaura hemistoma	98.78	75.00	4.41	Winter

obvious correlation was detected between Chl-*a* and salinity in summer or winter in this study. During the dry and monsoon transition seasons, the values of surface water salinity, pH, and DO remained fairly constant without the effects of rainfall dilution in the research area.

Zooplankton species composition and abundance are known to change seasonally in the marine environment (Sammacro and Crenshaw, 1984). Zooplankton diversity and abundance are also greatly affected by environmental parameters (Wang et al., 2018; Aguilera, 2020; Wang et al., 2020; Wang et al., 2022). In this study, there was a significantly negative correlation between the total zooplankton abundance and Chl-*a* concentration. This finding was in accordance with the result of Jiang and Wang (2020). They found that the seasonal change of zooplankton had its own characteristic pattern, which did not coincide with the phytoplankton but lagged behind by nearly 1 month (Jiang and Wang, 2020). Similarly, in our research, there was a significant seasonal variation in zooplankton composition, and the highest species number was observed in winter. Interestingly, many warm temperature species appeared in winter. This warm temperature species intrusion could be carried by the China Coastal Current—for instance, *Salpa fusiformis* has been defined as a warm temperature indicator species in California and displays a massive occurrence in the Southern Yellow Sea during summer (Silver, 1975; Liu et al., 2012). *Calanus sinicus* is the indicator species of the China Coastal Current in the Taiwan Strait and was collected only during winter in the research area (Hwang and Wong, 2005; Wang et al., 2020). In addition, the zooplankton abundance was highest in spring. *Dolioletta gegenbauri* is a warm-water species which was the most dominant species in spring. It commonly appears in productive subtropical neritic regions worldwide. The abundance of *D. gegenbauri* is usually at bloom concentrations, which could consume a large fraction of daily primary production (Paffenhöfer and Köster, 2011; Walters et al., 2019).

Temora turbinata is regarded as the predominant species in mesozooplankton communities in various environments around the world. It is able to adapt to various habitats, such as eutrophic lagoons, polluted and eutrophicated waters, outfall areas, and nuclear power plant discharge areas (Hsu et al., 2008; Tseng et al., 2011; Wang et al., 2021). In particular, *T. turbinate* and *Karenia brevis* can co-occur in the Gulf of Mexico. *Karenia brevis* is a toxic dinoflagellate, which often causes blooms (Lester et al., 2008). Copepodites and adults of *T. turbinata* are often found in upwelled water masses which are usually preferred by *D. gegenbauri* (Paffenhöfer and Köster, 2011). Li et al. (2018) reported that *T. turbinanta* ranges in abundance from 1 individual/m^3 to 1,185 individuals/m^3 in Daya Bay, and the highest abundance was recorded during a winter survey in 2017. Consistent with previous results, *T. turbinata* was the only dominant species present throughout the year. *Temora turbinanta* was recorded during our 1-year survey, and the average abundance ranged from 3.60 individuals/m^3 (autumn) to 90.84 individuals/m^3 (winter) in this study. *T. turbinanta* abundance changed significantly with season, but it was the dominant species throughout the year. Thus, we suggest that *T. turbinanta* could be considered as a potential indicator species to monitor its aquatic habitat. Notably, *T. turbinanta* abundance was obviously lower in the research area than in the northeast coastal area of Taiwan (Tseng et al., 2011; Wang et al., 2021). The seasonal variation characteristics of *T. turbinanta* abundance were also different. Undoubtedly, these differences could be due to differences in sampling method, local conditions, or the thermal discharge from the nuclear power plant in Daya Bay. Additionally, the other indicator species, *P. avirostris*, is not only a quality live food supply for marine pelagic fish but also an important component of the zooplankton community of many tropical, subtropical, and temperate waters and occurs seasonally with especially high abundance in summertime (Calbet et al., 2001; Fernández de Puelles et al., 2003; Marazzo and Valentin, 2003; Rose et al., 2004). The body length of female *P. avirostris* ranges from 0.70 to 1.09 mm (Zhou et al., 2022). Thus, *P. avirostris* blooms could block the cooling system of a nuclear power plant by attracting huge numbers of larva and adult pelagic fish (such as herring, mackerel, sardine, horse mackerel, *etc*.). *Centropages tenuiremis* is an important common copepod in the neritic mesozooplankton assemblage. It is an obviously omnivorous feeding species and can expand its food spectrum under stressful conditions (Xu et al., 2020). *Dolioletta gegenbauri* and *D. denticulatum* have been reported to form dense blooms in shallow waters of the continental shelf (Paffenhöfer et al., 1995; Nakamura, 1998; Tew and Lo, 2005). Our results are consistent with previous reports (Lian et al., 2011; Li et al., 2011; Li et al., 2021). These species mentioned above have also become the dominant species in Daya Bay. Additionally, our research revealed that *P. avirostris* blooms and *C. tenuiremis* blooms might also threaten the cooling system by acting as the food supply for pelagic fish in spring. It is noteworthy that most of the above-mentioned indicator species in spring belong to kollaplankton. Thus, we suggest that kollaplankton could cause potential disaster to the nuclear power plant cooling system due to their relatively large body size and potential to form huge blooms in spring. Moreover, *C. tenuiremis* blooms in spring and *P. avirostris* blooms in summer could also threaten the cooling system security by attracting larva or adult pelagic fish assemblages into Daya Bay. Therefore, these species should be considered as key species in future ecological studies.

Conclusion

In summary, the zooplankton communities showed a significant seasonal variation in terms of species composition, abundance, and dominant species in Daya Bay. Seasonal variations in the dominant species were observably related to environmental variations, such as thermal discharge, pH, salinity, and Chl-*a*. Thus, zooplankton could be considered as a favorable indicator of the marine environment. In addition, some kollaplankton, cladocera, and copepod species might directly or indirectly affect nuclear power plant cooling systems.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding authors.

Author contributions

F-XW: conceptualization, data curation, writing—original draft, and writing—review and editing. H-HH: Writing—review and editing and funding acquisition. Y-GW: Writing—review and editing, validation, and visualization. Y-GG: investigation and supervision. Q-XL, S-FZ, Y-YR, H-XL, and MD: investigation and formal analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1110160/full#supplementary-material

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