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Plankton diversity and distribution in marine ecosystem in Japan

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Abstract
Marine area comprises largest ecosystem on earth and plankton is the most significant element of marine ecosystem. Information on plankton diversity and distribution is essential to evaluate the health of marine ecosystems. Kuroshio Current and Tsushima Warm Current, a branch of Kuroshio Current, are the major factors for diversity and distribution of plankton communities surrounding the Japanese Archipelago. This paper summarizes the diversity, richness and distribution of plankton communities based on literatures in Japan. Copepods, cladoceran and chaetognath showed major features of zooplankton whereas diatom showed major features of phytoplankton in marina ecosystem of Japan. Life history studies of plankton in the Sea of Japan and the Pacific Ocean might be useful for better understanding the biodiversity and sustainability of plankton communities in Japan as a temperate region.

Keywords: Plankton, diversity, distribution, marine ecosystem, Japan

1. Introduction
Marine planktons are the base of food webs, and essential to other aquatic living organisms as well as sustaining fisheries [4]. Phytoplankton plays a fundamental role for the productivity of entire marine ecosystem [8] and a crucial role in the ocean's biological pump having great impacts on global biogeochemical cycles [32]. Marine zooplankton also plays an important ecological role by connecting primary producers with organisms of higher-trophic levels [23]. Due to their inability to move against ocean currents, planktons are directly affected by changes in ocean currents and the environment caused by climate change [19, 30].
Since marine environment is largely different in each region, plankton communities are unique throughout the world ocean. Plankton has been well-studied in polar, tropical, and sub-tropical regions [5.6], but studies are relatively limited in the temperate regions. Among the temperate regions, we focus on marine waterbody around Japan as it has various environments (20°-45°N, 122°-153°E). It is located in the Pacific Ocean off the northeast coast of the Asian, and is bordered on the west by the Sea of Japan (Fig.1).
The hydrographic properties in the upper layer of the Sea of Japan are principally influenced by the northward flowing Tsushima Warm Current (TWC) [21, 33]. The TWC is a surface oceanic layer that branches off the Kuroshio Current (KC) and transports warm water into the Sea of Japan [18]. These two warm currents are the major factors for the diversity and distribution of plankton communities, as well as general climate surrounding the Japanese Archipelago.

2. Materials and Methods
2.1 Review of Literature
Literatures has been collected from scientific publications which were focused on plankton diversity in marine ecosystems in Japan and were published from 1984 to 2023. A literature review of peer-reviewed journals in indexed databases such as Scopus, Web of Science, and Google Scholar was conducted.

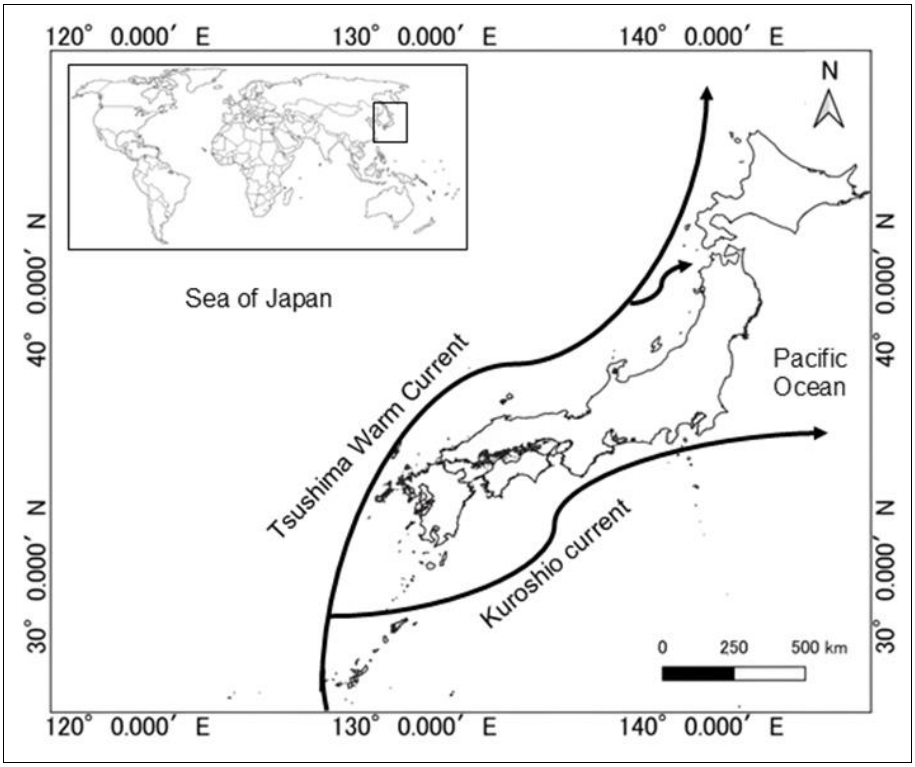

Fig 1: Location of Japan with the Sea of Japan and the Pacific Ocean and major currents

The purpose of this paper is to review current knowledge of the diversity and distribution of plankton in Japan as a temperate marine ecosystem. This review will contribute to understanding the general trend of plankton communities in the temperate region.

3. Results and Discussion

In general, copepods, cladoceran and chaetognath showed major features of zooplankton whereas diatoms showed major features of phytoplankton in marina ecosystem of Japan (Table 1).

3.1 Diversity and distribution of planktons in the Sea of Japan

Various group of plankton were distributed and major one was copepods in the Sea of Japan. Copepods and chaetognath and were abundant in Tsushima straits region, western Sea of Japan [12]. Copepods are main food source of chaetognaths [29], and it might be related their cooccurrence. Copepods (*Mesocalanus tenuicornis*, *Pseudocalanus minutus*, and *Metridia pacifica*), euphausiid (*Euphausia pacifica*) and amphipod (*Themisto japonica*) were most important group in Toyama Bay, central Sea of Japan [11]. Copepods (*Calanus* spp., *Oithona* spp., *Euterpina acutifrons* and *Oncaea*) were abundantly distributed in Toyama Bay, and were the major food of larval anchovy (*Ergraulis japonicus*) [14]. Cladoceran was abundantly distributed in Sea of Japan [20]. The steep thermocline in the surface layer creates environments in the Sea of Japan that support the cladoceran, a unique zooplankton ecosystem in the Sea of Japan [16]. Abe *et al*., (1984) conducted survey of plankton taxa at Sado Island, eastern Sea of Japan, by monthly daytime vertical plankton collections and listed out 150 species of zooplankton and 211 species of phytoplankton with a major group as diatom. Various radiolarians and foraminifera were also found on that Island. High species diversity of radiolarians was related to the strength of the TWC around Sado Island, Sea of Japan [23, 24]. Copepods, Appendicularia and bivalve snail were largely distributed in Ishikari Bay, northern Sea of Japan [3]. For the phytoplankton, due to high growth rates and wide tolerance of temperature, diatom (*Skeletonema* and *Chaetoceros*) was abundant round the year at Tajima Bay, southwestern Sea of Japan [28].

Table 1: Diversity and distribution of planktons in marine waterbodies of Japan

Plankton	Study area and period	Abundant Species/group	References
Zooplankton	Tsushima straits, Sea of Japan. January-December 1992	Copepods (*Calanus sinicus*, *Pseudocalanus aculeatus*, *Oithona plumifera*), Hydrozoa (Siphonophora), Tunicate (Thaliacea) and Chaetognath (*Sagitta bedoti*)	Hirakawa *et al.*, (1995) [12]
Zooplankton	Yamaguchi, Sea of Japan. January-December 1992	Copepods (Calanidae, Eucalanidae, Corycaeidae, Centropagidae, and Sapphirinidae)	Hirakawa *et al.*, (1996) [13]
Phytoplankton	Tajima Bay, Sea of Japan. September 2009-March 2016	Diatom (Skeletonema, *Chaetoceros*, *Rhizosolenia*, *Eucampia zodiacus* and *Thalassiosira*)	Nishikawa *et al.*, (2022) [28]
Zooplankton	Wakasa Bay, Sea of Japan. May 1995-April 1996	Copepods (*Calanus sinicus*, Corycaeus affinis, *Acartia omori*, *Oithono similis* and *Microstella novergica*)	Iguchi *et al.*, (1999) [15]
Zooplankton	Toyama Bay, Sea of Japan. February 1990-January 1991	Copepods (*Mesocalanus tenuicornis*, *Pseudocalanus minutus*, *Metridia pacifica*), Euphausiid (*Euphausia pacifica*) and Amphipod (*Themisto japonica*)	Hirakawa *et al.*, (1992) [11]
Zooplankton	Toyama Bay, Sea of Japan.	Copepods (*Calanus spp.*, *Oithona* spp., *Euterpina acutifrons* and *Oncaea*)	Hirakawa *et al.*,

	May 1994		(1997)
Zooplankton	Toyama Bay, Sea of Japan. April 1995-March 1996	Copepods (*Calanus sinicus*, *Oithona atlantica*, *Metridia pacifica*, and *Corycaeus* spp.)	Iguchi and Tsujimoto, (1997) [14]
Zooplankton	Toyama to Wakasa Bay, Sea of Japan. May 2010-May 2011	Copepods (*Corycaeus affinis*, *Oithono atlantica* and *Calanus sinicus*), Appendicularia (*Oikopleura longicauda*), Cladoceran (*Evadne nordmanni*), Euphausiids (*Euphasia pacifica*)	Kodama *et al.*, (2018)
Zooplankton	Yamato Tai, Sea of Japan. February-October 1999	Copepods (*Calanus pacificus*, *Oithona atlantica*, *Neocalanus plumchrus* and *Microsetella rosea*)	Dolganova *et al.*, (1999)
Phytoplankton	Sado Island, Sea of Japan. January 1982-January 1983	*Diatom* (*Coscinodiscus*, *Chaetoceros* and *Rhizosolenia*)	Abe *et al.*, (1984)
Zooplankton		Copepods (Calanidae, Paracalanidae, Oithonidae, Ectinosomidae) and Larvacean (Oikoplueridae)	
Radiolarian		*Acanthometron pellucidum* and *Aulosphaera trigonopa*	
Foraminifera		*Globigerina bulloides*	
Radiolarian	Sado Island, Sea of Japan. 6-7 September 2000	Spumellaria (*Dictyocoryne profunda* and *Spongaster tetras*) and Nassellaria (*Acanthodesmina vinculata* and *Lipmanella dictyoceras*)	Matsuoka *et al.*, (2001)
Radiolarian	Sado Island, Sea of Japan. 25 June 2001	Spumellaria (*Cyrtidosphaera reticulata* and *Larcopyle butschlii*) and Nassellaria (*Plectocantha* sp. and *Lithomellisa setosa*)	Matsuoka *et al.*, (2002)
Radiolarian	Yamagata, Sea of Japan. 26 August 2014	Spumellaria (*Tetrapyle octacantha* and *Spongaster streptacantha*) and Nassellaria (*Pseudocubus obeliscus*)	Ishida, 2019
Zooplankton	Ishikari Bay, Sea of Japan. March 2001-May 2002	Copepods (*Paracalanus parvus*, *Oncaea* and *Oithona similis*), Appendicularia and bivalve snail	Arima *et al.*, (2014)
Zooplankton	Sea of Japan April 1997-September 2018	Cladocerans (*Evadne spinifera*, *Pseudoevadne tergestina* and *Pleopis schmackeri*)	Kodama *et al.*, (2021) [20]
Zooplankton	Kagoshima Bay, Pacific Ocean. March-November 2008	Copepods (Acartiidae, Calanidae, Oithonidae, and Oncaeidae), Appendicularia, Tunicate (Thaliacea) and Mollusca	Minowa *et al.*, (2011) [25]
Zooplankton	Sagami Bay, Pacific Ocean. January-May 2006	Chaetognath (*Zonosagitta nagae* and *Flaccisagitta enflata*)	Miyamoto *et al.*, (2012)
Zooplankton	Tokyo Bay, Pacific Ocean. August 2009	Copepods (*Paracalanus parvus*, *Oithona davisae*, *Labidocera rotunda* and *Acartia sinijiensis*)	Itoh *et al.*, (2011) [17]
Phytoplankton	Tokyo Bay, Pacific Ocean. April 1998-March 2019	Diatom (*Skeletonema*, *Chaetoceros* and *Thalassiosira*) and Microflagellate (Cryptomonadaceae)	Nakada *et al.*, (2019) [27]
Zooplankton	Funka Bay, Hokkaido, Pacific Ocean, Japan. September 2009-March 2016	Copepods (*Eucalanus bungii* and *Neocalanus*), Amphipoda, Appendicularia, Polychaeta, Benthos larvae and *Noctiluca*	Teraoka *et al.*, (2022) [31]
Zooplankton	Hokkaido, Okhotsk Sea. January-December 2011	Meroplankton (Euphausiid eggs and nauplii), Copepods (*Pseudocalanus newmani* and *Eurytemora herdmani*), Cladoceran (*Evadne nordmanni*), Decapods (Brachyura) and Barnacles (Balanomorpha)	Hikichi *et al.*, (2018) [9]
Zooplankton	Sea of Japan and Pacific Ocean, Japan. June-August 2011, June 2014	Copepods (Calanoida and Cyclopoida), Calyptopis, Crustacean nauplii, Ostracoda, Phaeodaria and Foraminifera	Yamamae *et al.*, (2023) [34]

3.2 Diversity and distribution of planktons in the Pacific Ocean

Various groups of plankton were also found in the different regions of the Pacific Ocean coast (Table 1). In the southern area, copepods, especially cyclopoid, Appendicularia, Tunicate (Thaliacea) and Mollusca were distributed in Kagoshima Bay, Pacific Ocean coast in Japan [25]. Copepod (*Paracalanus parvus*) was more abundant in Tokyo Bay due to estuary environment [17]. In the central area, for the phytoplankton, diatom (Skeletonema, *Chaetoceros* and *Thalassiosira*) and Microflagellate (Cryptomonadaceae) were commonly found the Tokyo Bay [27]. In the northern area, copepods (*Eucalanus bungii* and *Neocalanus*), Amphipoda, Appendicularia, Polychaeta, benthos larvae were abundant in Funka Bay, and these were food source of flatfish larvae in the area [31]. Dinoflagellate (*Noctiluca scintillans*) was abundant in the area in relation to Tsugaru warm current into the Funka Bay [31]. Copepods (Calanoida and Cyclopoida), Calyptopis, crustacean nauplii, Ostracoda, Phaeodaria and Foraminifera were distributed in the sub-artic Pacific Ocean in Japan [34].

4. Conclusion

High diversity of marine plankton in Japan where have variety of environments was outlined in this review. Composition of plankton depends on ecological conditions including water temperature, transparency, food availability, and nutrient supplies [2]. Knowledge on distribution of plankton is indispensable for the predicting environmental fluctuation in the sea. Comparative life history studies of plankton in the temperate regions where have slightly different environments among close areas might be useful for better understanding the biodiversity and sustainability of plankton communities under current situation in relation to global warming.

5. Conflicts of interest. None.

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