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[OVERVIEW]

JAMBIO and Its Coastal Organism Joint Surveys: Network of Marine Stations Explores Japanese Coastal Biota

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Marine stations have continued to contribute significantly to understanding the physiology, taxonomy, development, ecology, and evolution of animals. There are more than 50 marine stations of national universities in Japan, and historically their establishments were closely related to the initial stage of zoology in the country. More than 10 years ago, Japanese Association for Marine Biology (JAMBIO) was established to facilitate the collaboration among marine stations in the activities of research, education and administration. One of the successful activities of JAMBIO that contribute to zoology is the JAMBIO Coastal Organism Joint Surveys, in which scientists and students at multiple marine stations, as well as those from research institutes or museums, stay at a marine station for a few days, and collect and make a record of marine organisms. As of 2021, 22 surveys have been performed and new species have been reported from taxa such as Cnidaria, Nematoda, Platyhelminthes, Annelida, Mollusca, Arthropoda, and Echinodermata.

Key words: animal diversity, evolution, marine station, fauna and flora, marine benthos

INTRODUCTION

Japan is an archipelago nation comprising thousands of islands with latitude ranging from 24.34°N to 45.41°N, which gives this country several climate regimes. The coastline of Japan is approximately 35,000 km, including several habitats for marine animals, such as rocky shores, rock pools, sandy beaches, mud flats, estuaries, and mangroves. Japan is intersected by multiple tectonic plates, i.e., the Eurasian plate, the North American plate, the Pacific plate and the Philippine plate, resulting in significant variations in the seabed. In fact, Japan has a wide variety of topographic situations, such as submarine volcanoes, multiple trenches, and troughs, in the vicinity of coastal areas (Fujikura et al., 2010; Inaba and Hall-Spencer, 2020).

Japan is surrounded by the North Pacific Ocean, Japan Sea, Sea of Okhotsk, and East China Sea. The Pacific coast of Japan is largely affected by two currents: the warm Kuroshio or Japan Current that flows to the north, and the plankton-rich cold Oyashio that flows from north to south. In the Japan Sea, the Tsushima Current runs from south to north and two other warm currents flow east in the northern regions, the Tsugaru Current and the Soya Current. All of these environments make the coastal area of Japan enormously rich in fauna and flora (Fujikura et al., 2010; Inaba and Hall-Spencer, 2020). The diversity of marine organisms in Japanese water is very high with 33,629 species reported, but there are still an estimated approximately 120,000 undescribed species, bringing the total to more than 150,000 marine species (Fujikura et al., 2010; Asakura et al., 2020; Nakano, 2020).

Modern zoology and marine stations

One of the important events for the growth and development of zoology in Japan was the visits of European scientists in the late 19th century. A German zoologist, Ludwig Döderlein, came to Japan as a professor of Natural History at the Medical Department of the University of Tokyo. Along with two pioneer American zoologists, Edward Morse and Charles Otis Whitman, Döderlein was impressed by the richness in fauna of Japanese coasts (Isono, 1988; Scholz et al., 2012). He published many papers on new marine animal species that he found during his stay in Japan. His finding of the richness of marine animals at Sagami Bay was conducive to the establishment of the Misaki Marine Biological Station by the University of Tokyo in 1886. Anton Dohrn, the founder of Statione Zoologica at Naples, gave advice concerning the architectural design to Kakichi Mitsukuri, the first director of the station (Isono, 1988).

Appreciating the importance of marine stations for zoology and basic biology, especially in the areas of taxonomy, physiology, and developmental biology of marine invertebrates, many other faculties of science in other national universities set up their own marine stations. The significance of these stations for education and research was recognized by departments of fishery science in national universities, also bringing them to establish their own marine stations.

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The oldest marine station affiliated with a Department of Fishery Science in Japan is Oshoro Marine Station of Hokkaido University, which was originally established within Tohoku University in 1908.

Researchers visit and stay at marine stations for several days or months in some cases, in order to carry out research on the specific fauna and flora in the coastal areas surrounding the station. Marine stations not only serve scientists, but also have had a close relationship to local citizens. A facility for displaying marine organisms to the public was opened in 1909 at Misaki Marine Biological Station, which was the first "aquarium" in Japan. Other marine biological stations followed by establishing aquaria for the public. However, these aquaria have declined due to the increase in prefecture-, city-, or private-public- aquaria (Inaba, 2015).

In the early stage, marine stations mostly focused on the study of animal taxonomy and biodiversity. This important task in zoology is still actively carried out in the marine stations (e.g., Kajihara, 2007; Atsumi and Saito, 2011; Okanishi and Fujita, 2011; Miyamoto et al., 2020). Taking advantage of the simple and unique body structures of marine invertebrates, many important findings were achieved at marine stations in physiology and cell/developmental biology. These include the developmental processes of marine invertebrates such as nemerteans and ctenophores (Yatsu, 1909; Komai, 1942), discovery of the acrosome reaction (Hoshi et al., 1994; Suzuki, 1995), discovery of tubulins from sperm flagella (Mohri and Hosoya, 1988), mechanical properties of the mitotic apparatus (Dan, 1984; Nakano and Hiramoto, 1988; Yoneda, 1988), cell fate and differentiation in ascidian embryos (Nishida and Stach, 2014), and hormonal regulation of oocyte maturation (Chiba, 2000). Many of the scientific findings at early stages of marine stations were published in Zoological Magazine, the previous incarnation of Zoological Science from the Zoological Society of Japan.

JAMBIO, an association of Japanese marine stations for collaborations

Approximately 50 university-based marine stations are now distributed from north to south in Japan, including biological and fisheries stations (Inaba, 2015). In 2009, with an initiative of Shimoda Marine Research Center, University of Tsukuba, and the Center for Marine Biology, the University of Tokyo, an association of marine biological stations, termed Japanese Association for Marine Biology (JAMBIO), was established to facilitate collaboration in research and education and information sharing among the research community. JAMBIO was then reorganized to be an assembly of marine stations, not only for biological stations but also for fisheries stations and other types of marine stations that aim to contribute to the progress of marine biology and related sciences. As of April 2021, the members of JAMBIO amount to 23 marine stations (Fig. 1A).

Defining "marine stations" as field stations where scientific research and observation of marine organisms, ecosystems, and environments are performed (Isensee et al., 2017b), approximately 800 marine stations are distributed in the world (Isensee et al., 2017a). Similarly to the case in JAMBIO, marine stations abroad are also regionally organized and make up associations such as The European Network of Marine Research Institutes and Stations (MARS), National Association of Marine Laboratories (NAML) in the USA, and Tropical Marine Network (TMN) in Australia (Fig. 1B). These regional organizations, as well as JAMBIO, became linked to each other under a global network, WAMS (World Association of Marine Stations), which was established in April 2010 at UNESCO-Intergovernmental Oceanographic Commission (IOC). WAMS is a worldwide network that shares information about the activity of research and education in each marine station, as well as contributes now to the sustainable development goals (SDGs) and the programs of the United Nations Decade of Ocean Science.

JAMBIO provides several opportunities for collaboration and information sharing not only to the members but also to all scientists who are more or less involved in marine biology. These activities include issuing a News Letter, holding Forums and International Symposiums, and providing a database of coastal organisms.

JAMBIO Coastal Organisms Joint Surveys

Since 2014, JAMBIO has organized JAMBIO Coastal Organisms Joint Surveys as one of its central strategic projects (Nakano et al., 2015). The original aim of the Survey was to uncover the benthic marine fauna (especially animals that are about several centimeters long) of the coastal areas in and around the Sagami Sea. The Surveys were originally held at Shimoda Marine Research Center, University of Tsukuba, situated near the southern tip of the Izu Peninsula, and Misaki Marine Biological Station, the University of Tokyo, located on the Miura Peninsula. Since the main focus was on benthic animals, collections using dredges, bottom mud samplers, or epibenthic sleds were performed. By assembling researchers who specialize in various taxonomic groups for each survey, JAMBIO also aimed to collect and study as many different species as possible, as well as to promote interactions and research collaborations in the field of marine biology.

As described above, JAMBIO has been reorganized in recent years, and concurrently, the aims of the JAMBIO Coastal Organisms Joint Surveys have also been revised. Although its focus on wide collaborations between researchers remains unchanged, the present scientific aim is to uncover the marine fauna of the coastal areas around Japan. To address this broader aim, several changes have been made to the Surveys over the years. The surveys are not only limited to the two marine stations mentioned above but are now being held at marine stations across Japan (Fig. 2). For example, Seto Marine Biological Laboratory, Kyoto University, situated at the Kii Peninsula, Ushimado Marine Institute, Okayama University, facing the Seto Inland Sea, and Oki Marine Biological Station, Shimane University, situated at the Oki Islands in the Japan Sea, have hosted the Surveys. Since the focus is not restricted to benthic animals about several centimeters long, a broad range of collection methods are now being employed. Plankton-net, free-diving, scuba-diving, snorkeling, and rocky-shore collections have been performed so far. Techniques for collecting meiobenthos, animals that can pass through a 1-mm mesh, have also been used in some surveys.

Twenty-two surveys have been performed so far, with 408 participants from 37 institutes taking part (Table 1). The participants include not only researchers, staff, and students

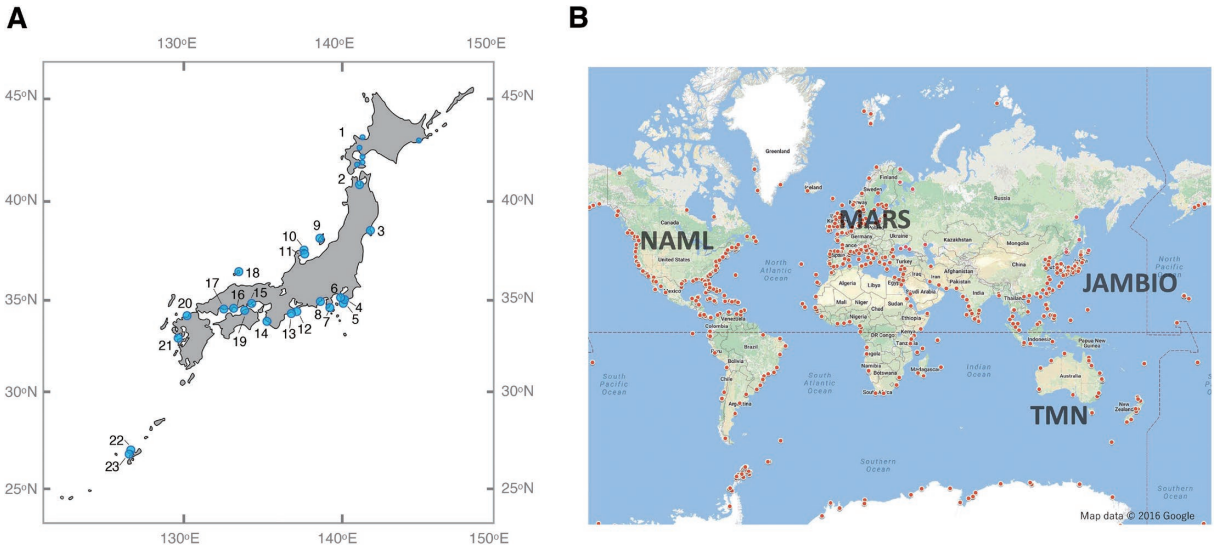

Fig. 1. Marine stations in Japan and the world. **(A)** Locations of 23 marine station members of JAMBIO as of April 2021. Smaller blue dots represent a member station of JAMBIO from Hokkaido University as an assembly of field stations (1). Other marine stations labeled with a larger blue dot are Asamushi Research Center for Marine Biology, Graduate School of Life Sciences, Tohoku University (2), Onagawa Field Center, Graduate School of Agricultural Science, Tohoku University (3), Marine and Coastal Research Center, Ochanomizu University (4), Field Science Center, Tokyo University of Marine Science and Technology (5), Misaki Marine Biological Station, School of Science, the University of Tokyo (6), Shimoda Marine Research Center, University of Tsukuba (7), Center for Education and Research in Field Sciences Hydrosphere Ecosystem Division, Shizuoka University (8), Sado Marine Biological Station, Niigata University (9), Noto Marine Laboratory, Institute of Nature and Environmental Technology, Kanazawa University (10), Noto Center for Fisheries Science and Technology, Kanazawa University (11), Sugashima Marine Biological Laboratory, Graduate School of Science, Nagoya University (12), Fisheries Research Laboratory, Mie University (13), Seto Marine Biological Laboratory, Field Science Education and Research Center, Kyoto University (14), Ushimado Marine Institute, Faculty of Science, Okayama University (15), Marine Biological Laboratory, Graduate School of Integrated Sciences for Life, Hiroshima University (16), Takehara Station, Setouchi Field Science Center, Graduate School of Integrated Sciences for Life, Hiroshima University (17), Oki Marine Biological Station, Shimane University (18), Aji Marine Station, Seto Inland Sea Regional Research Center, Kagawa University (19), Fishery Research Laboratory of Kyushu University (20), Amakusa Marine Biological Laboratory, Kyushu University (21), Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus (22), and OIST Marine Science Station (23). **(B)** A map of marine stations in the world. Red dots show the locations of marine stations. JAMBIO, MARS, NAML and TMN represent the associations of marine stations in Japan, Europe, USA and Australia, respectively. Modified from Isensee et al. (2017a).

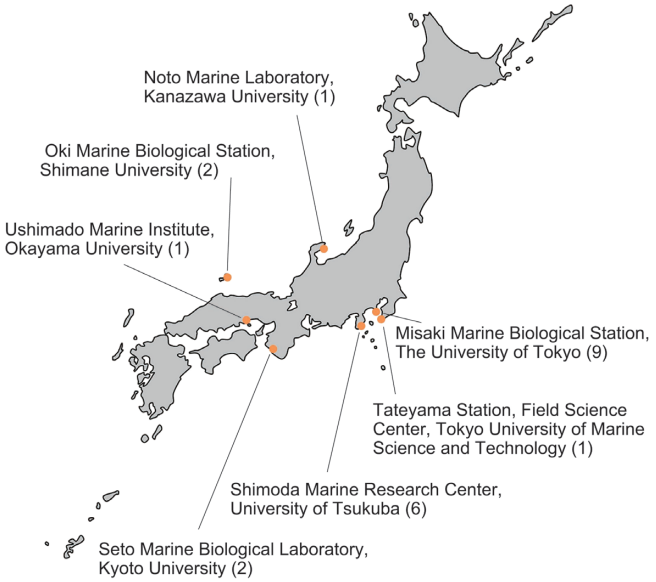

Fig. 2. Locations of marine stations where JAMBIO Coastal Organism Joint Surveys have been held. As of April 2021, 22 surveys have been carried out. Numbers in parentheses indicate the number of times that the station hosted the survey. Detailed information on each survey is presented in Table 1.

affiliated with universities, but also those belonging to museums, aquaria, and research institutions. A great deal of data and information has been accumulated through these surveys, and it is summarized in the JAMBIO webpage (https://jambio.jp). The Surveys have and will continue to contribute to many scientific projects, and a list of scientific publications that describe the samples collected during the surveys can be found in the webpage. Many of the publications describe new species or report the discovery of species that had not been reported in Japan (Kakui and Kohtsuka, 2015; Shimada and Kakui, 2015, 2019; Jimi and Fujiwara, 2016; Izumi et al., 2017; Jimi et al., 2017, 2018; Jimi and Kajihara, 2018; Oya and Kajihara, 2019, 2021; Tanaka et al., 2019; Saito, 2020; Tsuyuki et al., 2021), while others are in the field of molecular phylogeny (Kushida and Reimer, 2019), embryology (Wakabayashi, 2017), behavior (Yoshikawa et al., 2018), evolution (Kakui and Hiruta, 2017), methods development (Maeno et al., 2019), and paleobiology (Mitsui et al., 2021). Information on animals obtained by the surveys are publicly available, from the webpage described above and through RINKAI (Regionally Integrated Marine Database; https://www.shimoda.tsukuba.ac.jp/~marinelife-db/), a database including organisms collected in these surveys. To reach a larger potential user group, it is planned to share data in RINKAI with other databases, such as BISMaL,

Table 1. Description of JAMBIO coastal organisms joint surveys.

	Dates (dd/mm/yyyy)	Host	# of dredged sites	Approx. depths of dredged sites (m)	Sampling methods other than dredging	Participants
1	23–24/01/2014	MMBS	15	5–250	Smith-McIntyre grab sampler/Niskin sampler	14
2	19–20/02/2014	MMBS	11	10–750	Smith-McIntyre grab sampler	17
3	01/05/2014	SMRC	2	100		20
4	26–27/11/2014	SMRC	6	2–45	Ekman-Berge bottom sampler	15
5	19–20/01/2015	MMBS	8	2–700		23
6	12–13/02/2015	MMBS	4	3–270		20
7	23–25/06/2015	MMBS	5	101–741		16
8	11–13/11/2015	SMRC	5	30–360	plankton net/larval net	22
9	16–18/02/2016	MMBS	3	294–600	rocky shore collection/larval net	15
10	16–18/05/2016	SMBL	3	4–240	rocky shore collection	25
11	11–14/10/2016	OMBS	5	36–67	rocky shore collection/plankton net/scuba diving	20
12	14–16/02/2017	MMBS	7	95–541		27
13	24–26/10/2017	SMRC	4	17–400		16
14	20–22/11/2017	TS	3	30–70	rocky shore collection	11
15	12–14/12/2017	UMI	15	5–38	rocky shore collection	11
16	21–23/02/2018	MMBS	6	76–511	larval net	26
17	1–3/10/2018	OMBS	2	50.8–58	free-diving/scuba diving	8
18	11–13/12/2018	SMRC	6	21.8–450	rocky shore collection/free-diving	24
19	20–22/02/2019	MMBS	6	93–627		30
20	8–10/05/2019	SMRC	3	67–115	rocky shore collection/free-diving/scuba diving	20
21	7–9/10/2019	SMBL	3	32.6–64.3	rocky shore collection	13
22	18–21/11/2019	NML	6	21.8–91.1	free-diving/rocky and sandy shore collection	15

MMBS: Misaki Marine Biological Station, The University of Tokyo; SMRC: Shimoda Marine Research Center, University of Tsukuba; SMBL: Seto Marine Biological Laboratory, Kyoto University; OMBS: Oki Marine Biological Station, Shimane University; TS: Tateyama Station, Field Science Center, Tokyo University of Marine Science and Technology; UMI: Ushimado Marine Institute, Okayama University; NML: Noto Marine Laboratory, Kanazawa University

OBIS, and GBIF. There have also been two special exhibitions, one at the National Museum of Nature and Science, Tokyo in 2017 and the other at Kannonzaki Nature Museum, Kanagawa in 2021, describing JAMBIO and JAMBIO Coastal Organisms Joint Surveys, with animals collected during the surveys put on display. Similar exhibitions are being planned for the future.

The JAMBIO Coastal Organisms Joint Survey has been put on hold since November 2019 due to the COVID-19 pandemic. When resumed, in order to achieve the purpose of uncovering the marine fauna of the coastal areas around Japan, surveys are being planned in areas that have not been venues previously, such as Kyushu and the Ryukyu Islands in the south and Tohoku region and Hokkaido in the north. Furthermore, expansion of the Survey is being discussed, by adding plants and protists to its aim and by utilizing other collection methods. Our hope is that many new participants will take part in the Survey in the future.

This special issue of Zoological Science (Vol. 39 No. 1), titled 'Diversity of Coastal Organisms Around Japan' covers various topics of marine organisms, including those from JAMBIO Coastal Organisms Joint Surveys. There are two reviews, one on the current state of taxonomic studies on marine invertebrates in Japan (Nakano et al., 2022), and the other reporting a taxonomic list of sea spiders from the country (Miyazaki, 2022). Many of the original research articles report interesting studies on specific coastal organisms: azooxanthellate scleractinian corals (Sentoku and Tokuda, 2022), lineid heteronemerteans (Kajihara et al., 2022), a palaeonemertean genus, *Tubulanus* (Hookabe and Kajihara, 2022), deep sea ctenostome bryozoans (Hirose, 2022), amphinomid polychaetes (Jimi et al., 2022), free-living marine nematodes (Shimada and Kakui, 2022), parasitic copepods (Uyeno et al., 2022), gnathiid isopod crustaceans (Ota et al., 2022), typhlotanaid tanaids (Kakui and Hiruta, 2022), and an acoel (Asai et al., 2022). This issue also contains two other articles; one reviews the effects of ocean acidification on the diversity of marine invertebrates clarified from a series of studies of a CO_2 seep at Shikine Island (Hall-Spencer et al., 2022), and the other describes environmental DNA analysis, a new approach to explore marine organisms along Japanese marine coasts (Kawashima et al., 2022). We hope that this special issue will encourage further research into the biology of diverse marine organisms and will facilitate collaboration by researchers in various fields of science.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

HN, YI, and KI conceived the review, prepared the figures and the table, and wrote the manuscript.

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