Plankton Biol. Ecol. 49 (1): 1–8, 2002

plankton
biology & ecology

Marine Planktology in Japan*

MAKOTO OMORI

Akajima Marine Science Laboratory, 179 Aka, Zamamison, Okinawa 901–3311, Japan

Received 29 June 2001; accepted 5 September 2001

Abstract: Planktology in Japan celebrates 100 years of history since the term "Plankton" had first been translated into Japanese "Fuyuseibutsu" by K. Okamura in 1900. It was initially taught at three fisheries-related governmental institutions. As the fisheries industry was of great importance to Japan, marine planktology gathered considerable interest from the beginning. The era of modernization of plankton research in Japan was in the 1960s. In the 1970s, environmental problems came to the fore and achievements were made concerning the red tides and relationship between plankton and shellfish poisoning. Although there was an unfortunate split between the field of planktology and fisheries science, Japan's plankton research attracts intense interest from scientists around the world, especially concerning fisheries-related subjects such as red tides, mass production of micro-organisms for aquaculture, and resource management with co-operation between fishermen and scientists. Marine planktologists once again have to redefine their role in the dissemination of knowledge and information for the benefit of the fisheries industry, environmental protection, and resource management. It is hoped to have many more planktologists with broad knowledge and interests to develop a holistic picture of biological processes and production in the ocean.

Key words: Japan, Plankton, Marine planktology, History, Biological Oceanography

History

Even without referring to the reports by the U.N. Food and Agriculture Organization, it is easy to notice that the fishery resources of the world oceans are diminishing due to overfishing, habitat degradation, and pollution. The world fisheries catch is approaching its upper limit. There is a big concern that the sea may not be able to continue to serve us as a source of food able to meet the demands of the current population increase.

During the late 19th century, when fishing technology improved significantly with the introduction of the otter trawl for fishing and natural ice for preservation, people in Europe caught as many fish as they could in the North Sea and the Baltic waters. As a result, overfishing became obvious and fisheries in European countries suffered. This serves as an example of how over-emphasis on industrial research to develop technology to harvest and catch living resources may, at times, have a negative impact on the industry.

It may still be possible to utilize fisheries, if we could determine ocean productivity and integrate ecosystem research and data into management. Therefore, we must evaluate the productivity of plankton, which is an important food source for fish, and the relationship of plankton to the environment. This was a strong argument of the German professor, Victor Hensen (1835–1924). He considered that fisheries resources are governed by the productivity of plankton, and emphasized the importance of plankton research. He then conducted the famous Plankton Expedition to the North Atlantic in 1889. Planktology became a field of study that cannot be separated from social needs such as the fishing industry.

The term "plankton" was translated into Japanese as "Fuyuseibutsu" by a phycologist, Kintaro Okamura (1867–1936), in 1900 (Fig. 1). It was 13 years after Hensen proposed the term. Toukichi Nishikawa (1874–1909), the founder of spherical pearl culture, wrote the first scientific report on marine plankton in Japan, "Report of investigations on Akasiwo (red tides)" in 1902 (Fig. 2). Thus, we consider that planktology in Japan is now celebrating 100

Corresponding author: Makoto Omori; e-mail, makomori@amsl.or.jp

* Revised from my previous publication, Omori, M. 1997. History of Marine Planktology in Japan. *Museu Bocage Publication Avulsas*, 2ªSer. (2), 271–279. (ed. L.Saldanha and P. Ré).

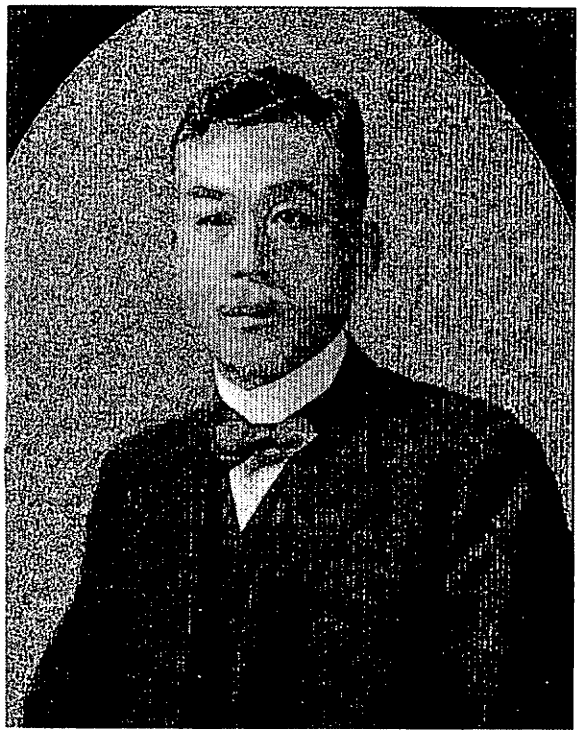

Fig. 1. Kintaro Okamura in 1914.

years of history.

As the sea surrounds Japan and as the fishing industry was of great importance to this country, the field of marine planktology gathered considerable interest right from this early period. The views of Hensen were well accepted right from the beginning. This views were a strong underlying theme in the first Japanese textbook on the plankton, "Fuyuseibutsugaku" by Seiji Kokubo in 1923, which was written based on Steuer's (1910) "Planktonkunde". Tsugunobu Fujita (1869–1945), a pioneer of Fisheries Science in Japan, dedicated this book with the words "Discussion of fishery resources without determination of productivity of plankton is something like a blind person describing an elephant by passing his hand over the body."

At the initial stage, planktology was mainly taught and studied at three fisheries-related governmental institutions. The first was the Imperial Fisheries Institute (presently Tokyo University of Fisheries) where Okamura had a chair. The second was the Agriculture School of the Tokyo Imperial University (presently the University of Tokyo). The third was the Agriculture School of the Tohoku Imperial University (later the Hokkaido Imperial University and presently Hokkaido University) where another phycologist, Kichisaburo Yendo (1873–1921), and his assistant, Kozo

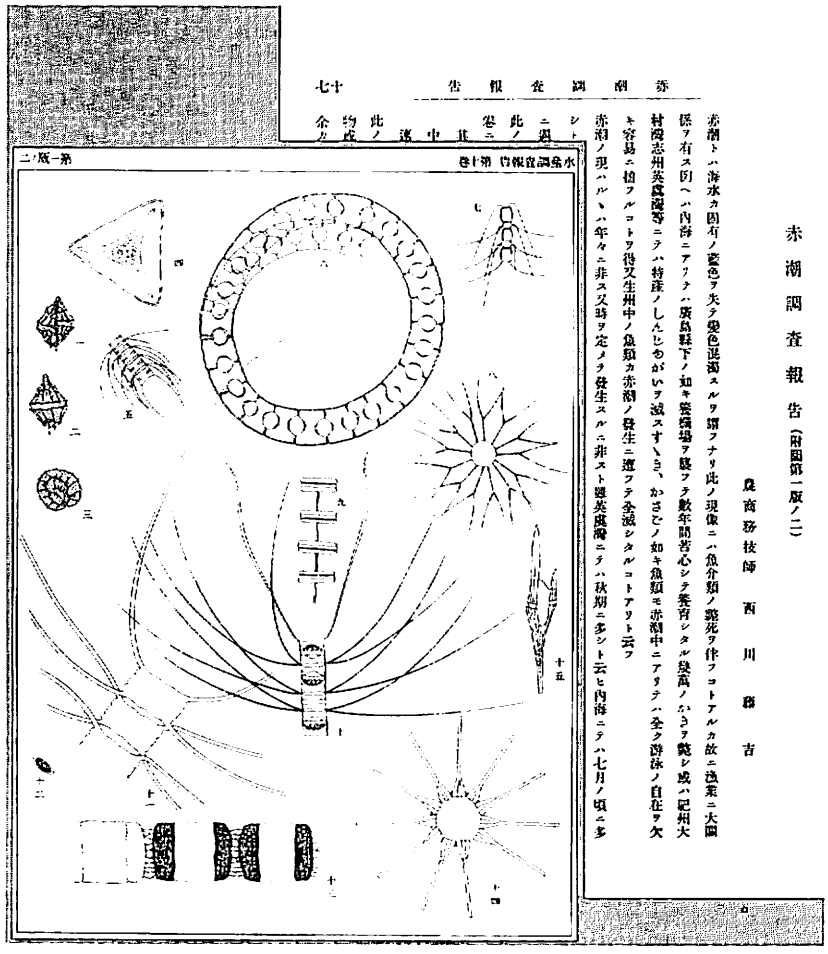

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Fig. 2. First report on a red tide in Japan by T. Nishikawa in 1902 (*Journal of Fisheries Bureau*, 10(1)).

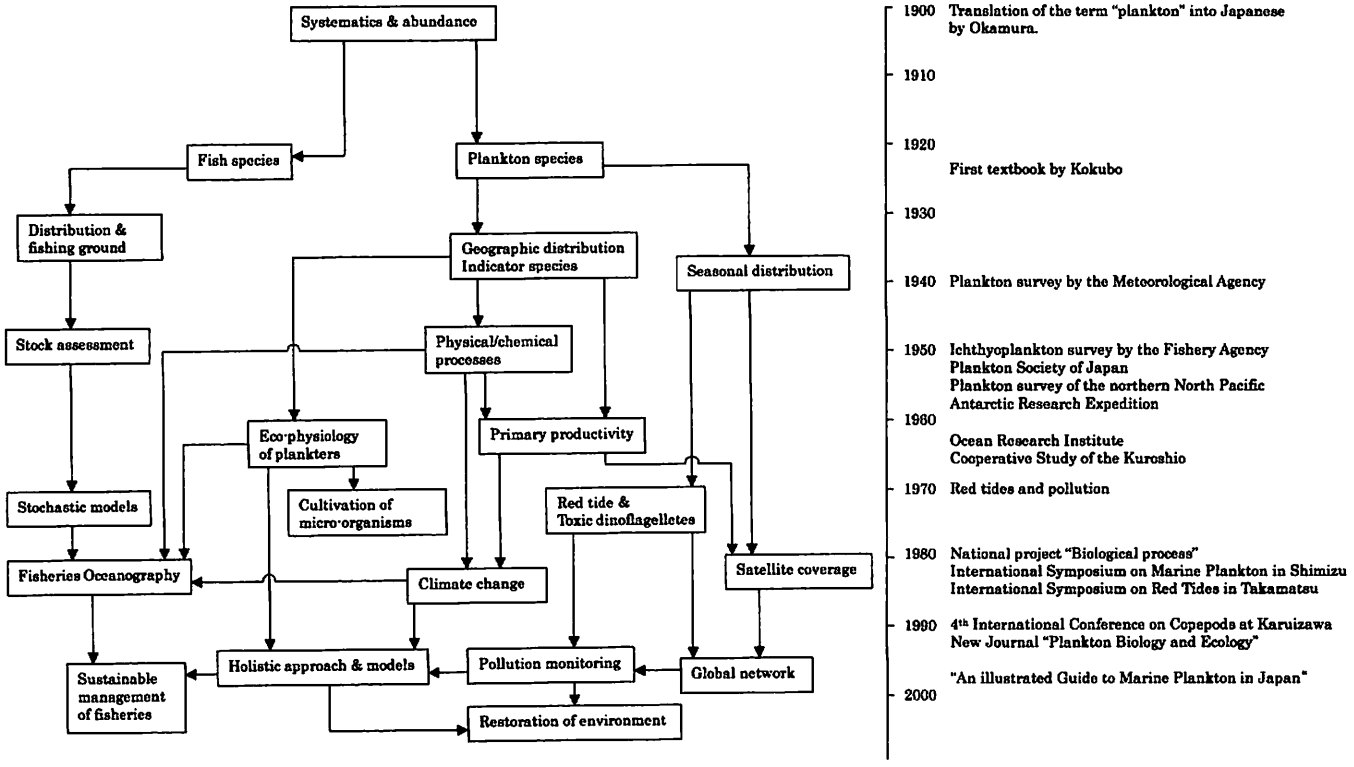

Fig. 3. A schematic history of marine planktology and related fields of science in Japan.

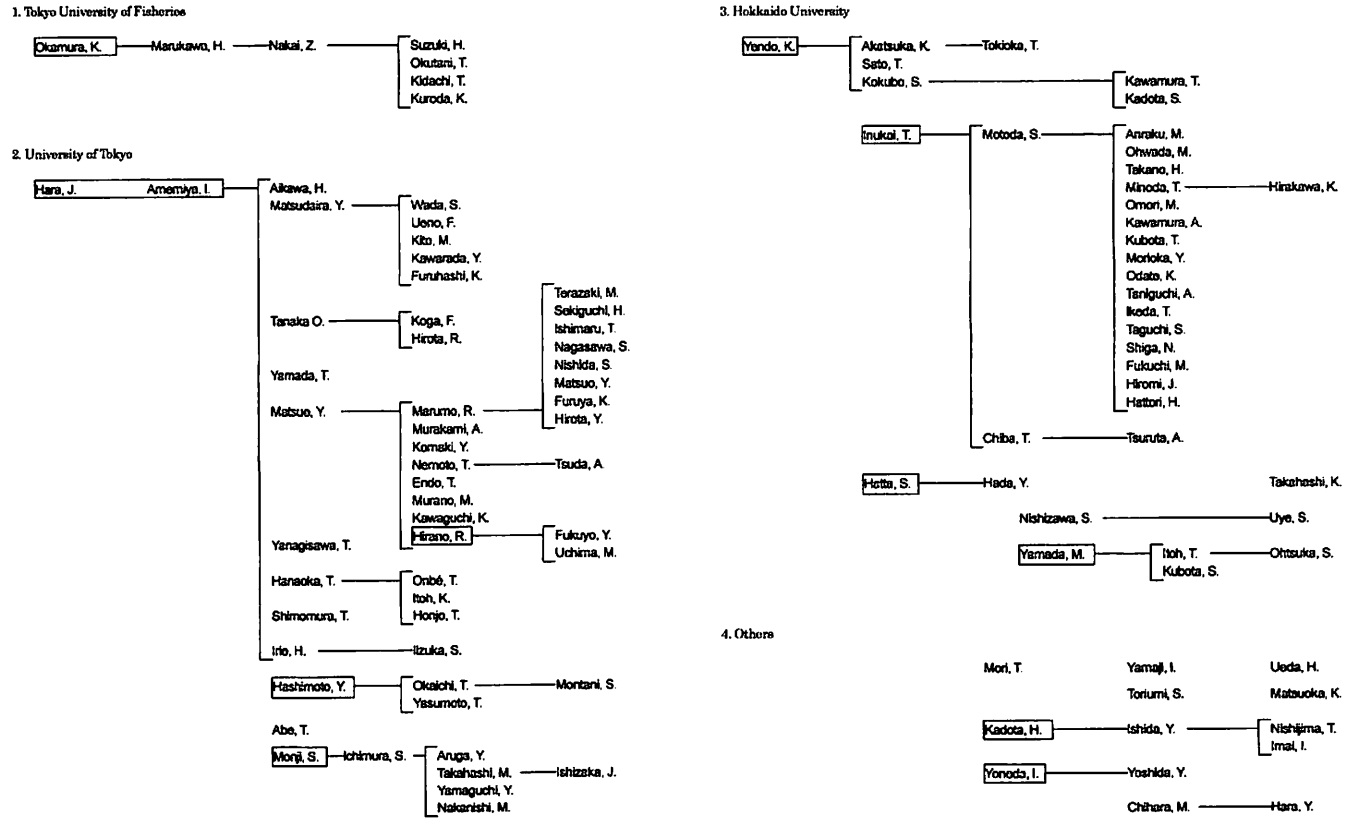

Fig. 4. Marine planktologists in Japan before the 1980s and their academic roots.
1. Tokyo University of Fisheries, 2. University of Tokyo, 3. Hokkaido University, 4. Others.

Akatsuka (1884–1957), studied marine diatoms and gave lectures.

In order to help the readers' understanding, the present author has compiled a schematic history of research activities in marine planktology and the related fields of science in Japan (Fig. 3) and the academic roots of planktologists before the 1980s (Fig. 4). Figure 3 is self-explanatory. The selection and arrangement of scientist's name in Fig. 4 are based on his assessment and not on the value of their scientific contributions. For scientists after the 1980s it is difficult to indicate relationship between master and pupil as they often had a number of supervisors during their career.

Okamura's student, Hisatoshi Marukawa (1882–1958), and Yendo's students Tadao Sato (1887–1984) and Seiji Kokubo (1889–1971) (Fig. 5) made considerable contributions to the early study of the taxonomy of diatoms and copepods around Japan. From the University of Tokyo, Hiroaki Aikawa (1903–1963), Yasuo Matsudaira (1903–1996), Otohiko Tanaka (1902–1990), Yoshiyuki Matsue (1905–1989), Tasuku Hanaoka (1910–1996) and others who studied fisheries science became planktologists.

Some of these scholars became professors at various universities and institutions. For example, Marukawa, after studying in Germany and Norway, succeeded chair of Oceanography at the Imperial Fisheries Institute and developed various sampling gears including plankton net for hydrographic survey. Akatsuka inspired a distinguished taxonomist of tunicates and chaetognaths Takasi Tokioka (1913–2001) at the Seto Marine Biological Laboratory, Kyoto University. Kokubo lectured at the Asamushi Marine Biological Station, Tohoku University, and wrote textbooks of planktology. Aikawa, Tanaka, and Hanaoka taught planktology at Kyushu University. Matsudaira, later professor of Hiroshima University, trained a number of planktologists at the Kobe Marine Observatory and surveyed the oceanographic conditions around Japan by examining the distribution of indicator species. This type of plankton research was conducted routinely by the Meteorological Agency over a long period with the understanding and support of the renowned meteorologist Takematsu Okada (1874–1956)

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Fig. 5. Hisatoshi Marukawa (1), Kozo Akatsuka (2), Tadao Sato (3) & Seiji Kokubo (4).

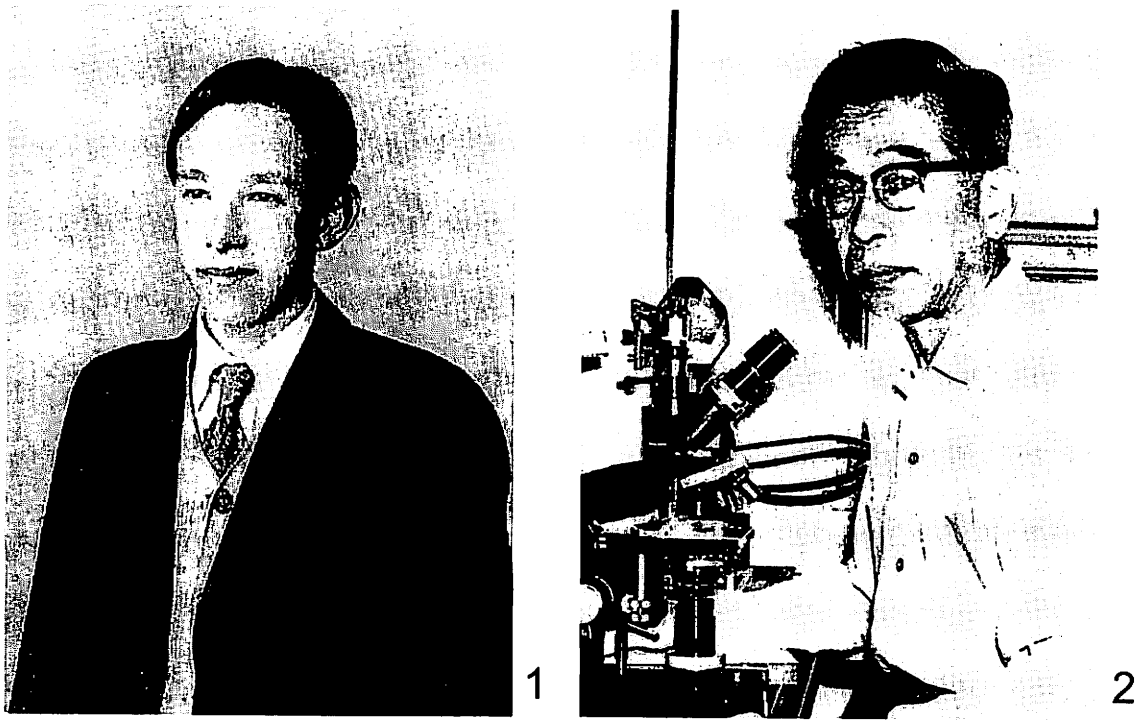

Fig. 6. Takamochi Mori (1) and Otohiko Tanaka (2).

who was the director of the Central Observatory. The most intensive research was carried out from the 1930s to the 1950s. Matsue and his colleagues at the University of Tokyo educated Ryuzo Marumo (1921–2001), Tomotoshi Okaichi (1929–) and Takahisa Nemoto (1930–1990), who themselves became scientific leaders in the field.

Takamochi Mori (1902–1945) seems to have walked his path alone (Fig. 6). His lifetime's research on marine copepods from waters neighboring Japan was carried out whilst he taught mathematics at Hiroshima City Commercial School. Unfortunately, his research efforts were untimely shortened when he perished during the atomic bombing of Hiroshima. Tadasane Yanagisawa (1909–1945), at the Kobe Marine Observatory, also lost his life during the bombing of Kobe in the Second World War.

Since Hensen, emphasis within the field of planktology has gradually shifted from natural history to biological oceanography studies. Various investigations were carried out in Europe and in the United States from the 1940s to the 1960s to clarify the relationship between the physico-chemical environment and the distribution of plankton. Eco-physiology and the role of plankton in the marine ecosystem also became the subjects of research. In Japan, however, there was not much progress, other than in taxonomy and geographic distribution, until the 1950s. This was partly due to the rapid progress in fisheries science in Japan that aimed ultimately to increase fish landings. Fisheries scientists emphasized stock assessment of target species based on catch data and did not pay much attention to physico-chemical conditions in the environment and interactions within food webs. On the other hand, planktologists did not provide the answers that fisheries administration and fishermen were looking for. These circumstances caused an unfortunate split between planktology and fisheries science.

There were a few scientists, such as Zinjiro Nakai (1901–1984) and Michitaka Uda (1905–1982), however, who evaluated the significant role that planktology and physical oceanography play in fisheries science (Fig. 7). From the fisheries resource assessment point of view, Japan's Fisheries Agency and prefectural fisheries experimental stations conducted monthly oceanographic observations and plankton sampling in the 1950s. Surveys were expanded to include all the waters around Japan from 1969. As scientific leader of the surveys, Nakai promoted the quantitative study of macro-zooplankton and ichthyoplankton in relation to the sardine fishery. The study could be compared with the early stages of the California Cooperative Oceanic Fisheries Investigation of the United States, although it did not gather the world's attention. Uda was interested in dynamic relationships between marine organisms and the physical environment and made a significant contribution to the development of fisheries oceanography as it is defined today.

The study of planktology at Hokkaido University was greatly encouraged by Sigeru Motoda (1908–1995) who was Professor of Planktology at the Faculty of Fisheries since 1950 (Fig. 8). He conducted plankton research mainly in the northern North Pacific, and made significant efforts in initiating the Plankton Society of Japan, which was finally realized with 89 members in 1952. During his 16

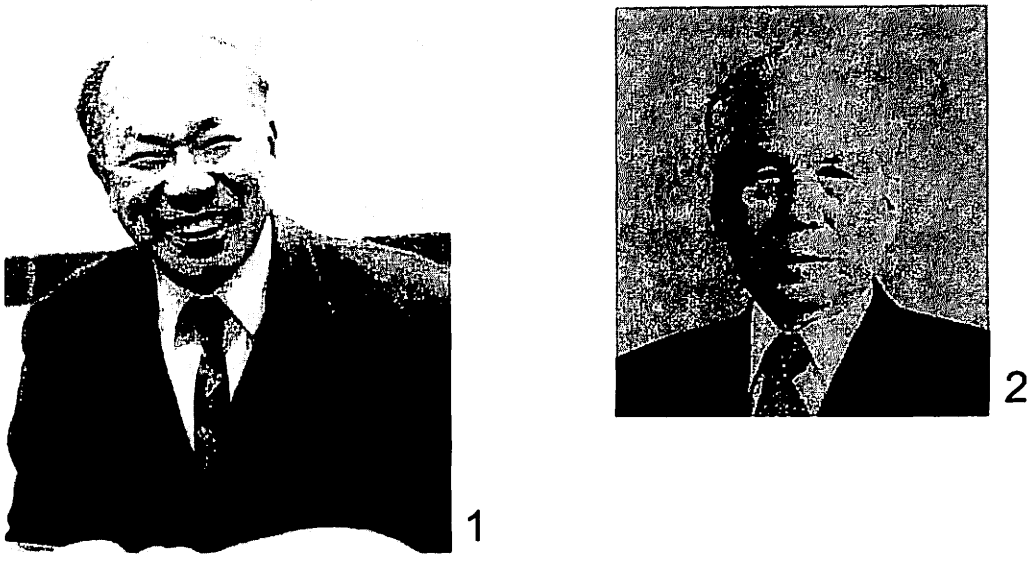

Fig. 7. Michitaka Uda (1) and Zinjiro Nakai (2).

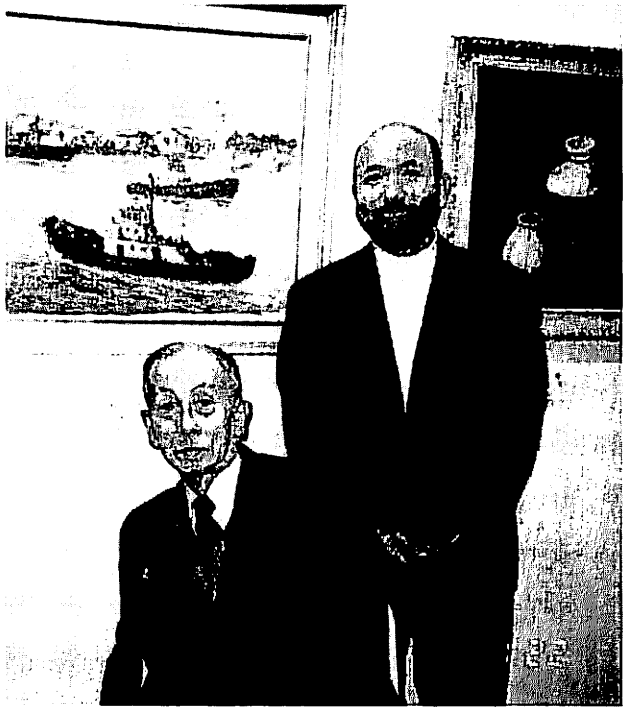

Fig. 8. Sigeru Motoda, with the present author in 1991.

years of tenure at Hokkaido University, he educated many students including the present author, who are now themselves active as planktologists and biological oceanographers.

The Japanese Antarctic Research Expedition started in 1956 in connection with the International Geophysical Year, and plankton surveys in Antarctic waters have been carried out since 1959. This expedition may be remembered as signifying that Japan had resumed activity in the international scientific community.

The worldview of oceans as a source of energy and the potential for the exploitation of resources produced a large investment in marine research and development in the 1960s. Rapid expansion of the economy in Japan helped to gain significant progress in marine science in general. As a result, the Ocean Research Institute was founded at the University of Tokyo in 1962, and it established the Plankton Laboratory in 1963. In this laboratory, special emphasis was initially given to reveal the distribution and behavior of epi- and mesopelagic micronekton around Japan. Several large research vessels including the *Ryofu Maru* of the Meteorological Agency, *Hakuho Maru* of the Ocean Research Institute, and *Kaiyo Maru* of the Fisheries Agency were launched in 1966 and 1967.

Thus, one may say that the era of modernization of plankton research in Japan was in the 1960s. Development and improvement of various sampling techniques and laboratory methodology were achieved during this period. The return of several researchers, including Satoshi Nishizawa (1925–) and Masateru Anraku (1926–1998), from abroad also became a source of new inspiration to the progress of research. Some scientists' interests were focused on the measurement of primary productivity of the ocean when the International Biological Program started in 1965. Shun-ei Ichimura (1923–1998) trained specialists in primary productivity and played a significant role in the development of this subject. Furthermore, opportunities increased to investigate the geographical distribution, vertical migration and eco-physiology of zooplankton during the period of the International Cooperative Study of the Kuroshio, since 1965, in which Japan took the major role. Prior to the evidence was shown in physical oceanography, southwestward transport of Oyashio-influenced water below the Kuroshio along Honshu, Japan, was revealed by the occurrence of some boreal plankton species.

With the industrialization of the country, however, environmental problems came to the fore in coastal areas in the 1970s. Red tides occurred frequently in shallow waters and caused serious damage to fisheries and aquaculture. The government emphasized the monitoring of pollution in local waters and the identification of causative organisms. The mechanisms involved in the occurrence of red tides were investigated on a large scale. Among numerous studies, one of the most remarkable achievements was the isolation and structural determination of gonyautoxin and ciguatoxin, which cause serious poisoning in people who have eaten fish and bivalves made toxic by dinoflagellates, by Takeshi Yasumoto (1935–). The International Symposium on Red Tides was successfully held in Takamatsu in 1987.

In 1980, the government approved a big national project, "Basic Research on Marine Biological Processes and Exploitation." The project, led by R. Marumo, progressed for three years with the participation of more than 100 marine biologists. Among many aspects, planktologists have made special efforts to reveal the life history and productivity of individual planktonic species so that they could get more precise information on the ecological roles of different species and different size groups in the ocean. Planktonic ciliates and photosynthetic picoplankton drew attention and were studied carefully.

By 1980, the geographic area of plankton research carried out by Japan expanded to cover the whole of the Pacific Ocean, from the Bering Sea to the Antarctic waters, and vertically from the surface to the bathypelagic zone. The availability of the deep submersible *Shinkai 2000* of the Japan Marine Science and Technology Center in 1981 made it possible to observe and collect organisms at great depths. In 1984, the Western Society of Naturalists honored Prof. Motoda by organizing the "International Symposium on Marine Plankton" in Shimizu. And in 1990, members of the Plankton Society of Japan hosted the Fourth International Conference on Copepods at Karuizawa. These two meetings provided an excellent opportunity for young Japanese scientists to talk to and be inspired by a number of world-renowned planktologists. Subsequently, planktology in Japan has further diversified and deepened.

The Plankton Society of Japan now has about 700 members and contributes to the promotion of science by issuing two journals biannually, i.e. *Plankton Biology and Ecology* and the *Bulletin of the Plankton Society of Japan*, and by holding symposia twice a year. Nearly 100 years of study on taxonomy and distribution of Japanese plankton produced a 1574 page, monumental publication, "An Illustrated Guide to Marine Plankton in Japan" in 1997, edited by Mitsuo Chihara (1927–) and Masaaki Murano (1932–).

As shown in Fig. 3, the rise of marine planktology in Japan was not very different from that elsewhere in the world. The difference between research in Japan and other industrialized countries became less and less with increasing opportunities for cooperative study and the exchange of information. If the author was to try and locate a difference, Japan's research may be said to attract intense interest world wide in fisheries-related subjects such as red tides and mass production of micro-organisms as food for larval stages in aquaculture. Research on the long-term exploitation of planktonic organisms for human food has been another interesting subject. Although they would not rank as exceptionally outstanding based on the conventional system of international science, many years of devoted efforts of a few researchers such as Sato, Okaichi and the present author have promoted co-operation between fishermen and marine planktologists and have become outstanding examples of endeavors to maintain resources and productivity on as sustainable a basis as possible.

Future

What's next? Marine ecosystems are rapidly altered by human disturbances, such as overfishing, degradation of water quality, mechanical habitat destruction, and anthropogenic climate change. Plankton data may help to demonstrate achievable goals for restoration and management of them. Global networks and monitoring should be further encouraged in studies. Annual and decadal fluctuation of biomass and species composition should be studied in detail so that we can distinguish anthropogenic impact from natural cyclic variation. In order to do so, long-term routine surveys of plankton and oceanographic conditions at selected stations/lines are needed. However, individual scientist who are busy endeavoring to write original and striking papers are not always interested in these sober efforts, and such surveys can only be continued by the firm resolve and financial support by governmental bodies. Accumulation and quality control of biological data at the Japan Oceanographic Data Center for wider utilization by third parties should be emphasized.

In spite of the bitter lessons learnt by the North Sea fisheries in the late 19th century, the worldwide capitalist economy with its highly advanced fishing technology and marketing systems has caused a depression in fisheries resources worldwide. Several major fisheries in the Atlantic Ocean have experienced a population decline so rapid that fishing is no longer commercially viable. Fisheries science is being called on to reflect on its past conduct. Protection of fisheries can be more readily achieved by an understanding of the total ecosystem rather than the traditional study of population dynamics based on catch data.

Probably, the major objective of marine planktology should be to synthesize the various aspects of biological oceanography to understand the dynamic relationships between the organisms and their physical, chemical, and biological environments, and to disseminate knowledge and information for the benefit of fisheries and resource management at large. This idea is not new, and the efforts of several scientists such as Timothy Parsons (1932–) and Michael Mullin (1937–2000) have been producing a new school of holistic ocean scientists and managers who stand

to put into practice realistic approaches for the management of living resources and conservation of the marine environment.

Under the present social regime, education in marine science is producing many specialists who are not interested in fields outside their own disciplines. However, such specialists are seldom able to develop a holistic picture of oceanic processes and production. It is the teacher's responsibility not be caught in this tendency to produce more and more specialists with only narrow and specialized knowledge. The present author eagerly hopes to have many more planktologists with broad knowledge and interests who feel responsible for the entirety of marine biology and fisheries.

In his message as the President of the Plankton Society of Japan, the anthor emphasized in 1998 the need for more study of the role of plankton in the marine ecosystem in relation to predicting fluctuations in fisheries resources and preserving biological diversity. Marine scientists are also expected to provide good interpretation of scientific facts to society. With respect to the development of technologies, such as the oceanic disposal of carbon dioxide and utilization of nutrient-rich seawater drawn from deep layers, there are a number of questions outstanding about their environmental impact. Providing opinions and warnings, based on precise observations and detailed study, to the general public and decision makers is a challenging task. Through these activities, he is convinced that we will be able to create a vibrant school of planktology with vital originality.

Acknowledgement

I would like to express sincere appreciation to my friends the late M. M. Mullin, D. M. Checkley, Jr., and D. M. Damkaer for their reading and suggestions.

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