New Exhibitions of Beautiful Southeast Asian Jellyfish at Aquaria: Collection and Life Cycle

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ABSTRACT: Scyphozoans are very attractive as ornamental animals at public aquaria. Almost all European and American species are exhibited at world aquaria. However, few Southeast Asian scyphozoans are exhibited, although some of them are very beautiful species and deserve exhibition. We have been studying edible jellyfish biology in Southeast Asian countries. In the process of the sampling survey, we found some ornamental scyphozoans that are suitable for exhibition at public aquaria. Mature jellyfishes were collected from the fields to obtain the planulae. Collected planulae developed to polyps in the laboratory. Ephyrae liberated from strobilae developed into medusae. Medusae raised from polyps in the laboratory or collected in the field and imported into Japan were exhibited at Enoshima Aquarium and Kamo Aquarium as Japan's and the world's first exhibition. Our on-site husbandry and exportation methods are a breakthrough for jellyfish exhibitions in public aquaria and jellyfish sciences globally.

INTRODUCTION

Jellyfish exhibitions are very popular worldwide. Husbandry and display methods for jellyfishes have been progressing, and the number of species of exhibited jellyfish has also increased (Adachi, 2016; Knowles, 2016; Lange et al, 2016; Murakami, 2016). Scyphozoans, especially, are very attractive as ornamental animals at public aquaria. Almost all European and American species are exhibited at aquaria worldwide. However, few Southeast Asian scyphozoans are exhibited, although some of them are very beautiful species and deserve exhibitions. The biggest reasons for this are that no aquariums have full-scale jellyfish exhibitions in Southeast Asia, and Southeast Asia is too far from Europe and the United States to export exotic jellyfish in good condition, and that there are no professional jellyfish aquarists or biological scientists.

We have been studying edible jellyfish biology for sustainable jellyfish fisheries in Southeast Asian countries (Malaysia, Republic of the Philippines, and Thailand) for a decade under the Japan Society for the Promotion of Science (JSPS) cooperative research programs between those countries and Japan. A public aquarium, Bangsaen Aquarium, is attached to the Institute of Marine Science, Burapha University, Thailand. In the process of the JSPS cooperative research, the Institute of Marine Science, Burapha University concluded academic exchange contracts with Enoshima Aquarium and School of Marine Biosciences, Kitasato University, Japan. Bangsaen aquarium built a full-scale jellyfish display space and a jellyfish research laboratory for the first time in Southeast Asia under the academic exchange contracts (Fig.1). These efforts have made great progress in Southeast Asian jellyfish study and exhibition.

Fig. 1. Full-scale jellyfish exhibition in Bangsaen Aquarium, Burapha University, Thailand

In the process of a sampling survey of Southeast Asian countries, we found some ornamental scyphozoans which are well suited for aquarium exhibition. Japanese aquarists and scientists needed to export these jellyfish to Japan to study the lifecycle and potential for aquarium

exhibition.

This paper shows that our trials to export live ornamental jellyfishes to Japan and to obtain scyphopolyps for life cycle study and regular exhibition.

MATERIALS AND METHIODS

Sampling

Sampling surveys were conducted at Bagan Datoh, Perak, Malaysia for *Acromitus hardenbergi*, Palawan Island, the Philippines for *Acromitus maculosus*, and Gulf of Thailand for *Acromitus flagellatus*, *Catostylus townsendi*, *Lobonemoides robustus*, and *Rhopilema hispidum* (Fig 2). Sampling was conducted with permission from the Palawan Council for Sustainable Development (PCSD), Republic of the Philippines; Department of Marine and Coastal Resources (DMCR), Thailand; and under JSPS cooperative projects and academic exchange contracts.

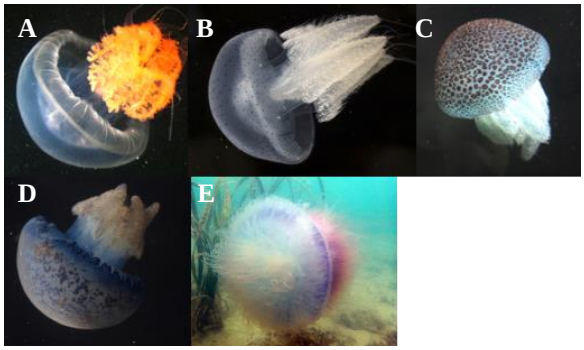

Fig. 2. Scyphozoan species in Southeast Asia.
A: *Acromitus hardenbergi*, B: *Acromitus flagellatus*, C: *Acromitus maculosus*, D: *Catostylus townsendi*, E: *Lobonemoides robustus*

Jellyfishes were collected using a ladle or fine-meshed dip net from a boat or off the beach, and using light-traps at fishing ports or mangrove swamps. After sampling, jellyfishes were packed into plastic bags without air when our hotel or university was near the sampling point, and with oxygen tablets or oxygen gas (oxygen can or oxygen tank) when our hotel or university was far from sampling point (Fig. 3).

Fig. 3. Oxygen sources for packing jellyfish.
Oxygen tablet (left), Oxygen can (center), packing jellyfishes using oxygen tank.

Keeping and collecting fertilized eggs on site.

Jellyfishes transported from the sampling points were released into tanks (baby pools, containers, or FRP tanks) with simple filters (sponge filter or under-gravel filter), which was set up in the hotel room or garden and facility of the university as soon as possible. Transporting time was 10 min to 6 h. Each jellyfish species was kept in a same pool or tank to encourage the fertilization of eggs. Next morning, the rearing water was filtered using a plankton net (50 µm mesh) to collect fertilized eggs or planulae (Fig. 4).

Artificial fertilization

Large jellyfishes, such as *R. hispidum*, whose umbrella size was over 50cm, were difficult to bring back to the hotel or university site. Moreover, they are difficult to export to Japan. To export those large jellyfish to Japan, the easiest way is to bring planulae back to Japan. We tried artificial fertilization to obtain the planulae, according to the method of Ohtsu et al. (2007).

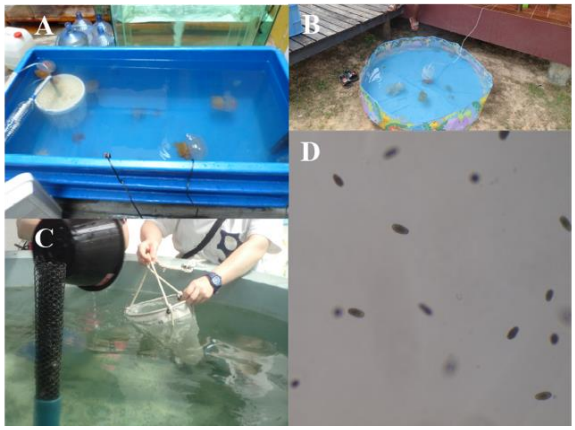

Fig. 4. Keeping jellies and collecting eggs or planulae.
A, B: Keeping jellyfish on-site. C: Collecting fertilized eggs or planulae. D: Collected planulae.

Exportation

Before exporting the jellyfishes, we received government permission to export jellyfish for scientific purposes and obtained an export invoice from the cargo company. An official document to export jellyfish under the JSPS cooperative research and a memorandum of understanding (MOU) on academic exchange contracts were prepared.

Jellyfishes kept in a tank were packed in plastic bags with oxygen tablets without air or with oxygen gas on the last day of the sampling trip. Planulae were packed in plastic bottles (500 or 1000 mL) or 50 mL plastic tubes. Packed animals were placed in foam cooler boxes. Then, the jellyfishes were exported as baggage or unaccompanied goods by air cargo.

Maintaining polyps and making ephyrae

Imported planulae were transferred into plastic vessels (58 mm in diameter, 34.6 mm high) and leave to stand them at 28–30 °C for a week. Planulae settled on the bottom of the plastic vessels and developed into polyps. Polyps were kept at 28–30 °C and 15–30 ppt salinity and fed *Artemia* sp. nauplii every 2 days. The rearing temperature was increased up to 30–32 °C to make polyps develop into strobila. 5-Methoxy-2-methylindole (10 µM) or indomethacin (10 µM) was used to induce strobilation (Kuniyoshi et al., 2012; Yamamori et al., 2017).

RESULTS AND DISCUSSION

Transport methods

Four types of packing for jellyfish transport methods were tested (packed without air, with oxygen tablet, with oxygen gas using oxygen can, and with oxygen gas using oxygen tank). Small jellyfishes < 10 cm diameter arrived alive at Japan in all packing methods. However, some of larger sized jellyfishes died in the plastic bags without air and with oxygen tablets. Jellyfishes packed with oxygen were alive and well. To prevent air bubbles entering under the umbrella or in the body of jellyfish, we used to pack jellyfish in a plastic bag without air in domestic transport. Almost all domestic transportation is successful. In our jellyfish transport trials from Southeast Asia to Japan, packing without air was not as successful; these tropical species need high temperatures to survive, which decreases the dissolved oxygen level. Moreover, large tropical species are more active and demanded more oxygen than warm- and cold-water species. The artificial addition of oxygen gas was highly successful for transporting jellyfishes in good condition to Japan.

Polyps, ephyrae, and medusae

The planulae of all target species (*A. hardenbergi*, *A. maculosus*, *A. flagellatus*, *C. townsendi*, *L. robustus*, and *R. hispidum*) attached to the bottom of plastic vessels and metamorphosed to polyps in the laboratory (Fig. 5). Polyps were in good condition in low salinity (around 20 ppt) and at 28–30 °C. Asexual reproduction was budding, except for that of *R. hispidum*, whose asexual method of reproduction was podocysts. Strobilation occurred when the temperature increased with food limitation. However, the key stimulus for strobilation was not detected yet. One month later, ephyrae had developed through metephyrae into medusae (Fig. 5).

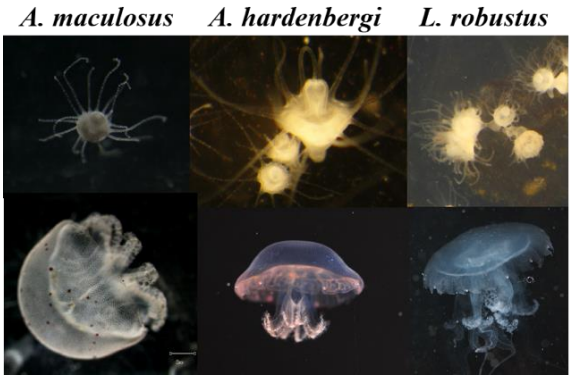

Fig. 5 Polyp and medusa reared in laboratory

Exhibition

Medusae imported into Japan were exhibited at Enoshima Aquarium and Kamo Aquarium as Japan's and the world's first exhibition (Fig. 6). Especially we succeeded in the import of large-sized *L. robustus*. At the beginning of our project, we thought that exporting large jellyfish (about 30 cm diameter) was impossible. However, a decade of cooperative efforts with local scientists and staff has progressed knowledge of how to collect and keep jellyfish on-site and export them step by step. Our jellyfish husbandry and exportation methods are a breakthrough for jellyfish exhibitions in public aquaria and jellyfish sciences worldwide.

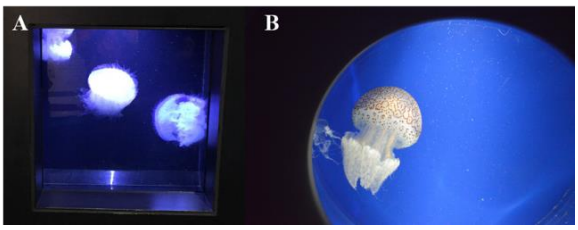

Fig.6. Exhibited jellyfish in public aquarium
A: *Lobonemoides robustus* in Kamo Aquarium
B: *Acromitus maculosus* in Enoshima Aquarium

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REFERENCES

ADACHI, A. 2016, Exhibition and Breeding of Jellyfish in Enoshima Aquarium, *Der Zoologische Garten* **85**: 8-13.

KNOWLES, T. 2016, The History of Jelly Husbandry at the Monterey Bay Aquarium, *Der Zoologische Garten* **85**: 42-51.

KUNIYOSHI, H., OKUMURA, I., KURODA, R., TSUJITA, N., ARAKAWA, K., SHOJI, J., SAITO, T., OSADA, H. 2012, Indomethacin Induction of Metamorphosis from the Asexual Stage to Sexual Stage in the Moon Jellyfish, *Aurelia aurita*, *Bioscience Biotechnology and Biochemistry* **76**: 1397-1400.

LANGE, J., TAI, M., KAISER, R. 2016, Husbandry of jellyfish, from the beginning until today, *Der Zoologische Garten* **85**: 52-63.

MURAKAMI, T. 2016, History and Introduction of the Kamo Aquarium, *Der Zoologische Garten* **85**: 64-73.

OHTSU, K., KAWAHARA, M., IKEDA, H. UYE, S. 2007, Experimental induction of gonadal maturation and spawning in the giant jellyfish *Nemopilema nomurai* (Scyphozoa: Rhizostomeae), *Marine Biology* **152**: 667-676.

YAMAMORI, L., OKUIZUMI, K., SATO, C, IKEDA, S., TOYOHARA, H. 2017, Comparison of the Inducing Effect of Indole Compounds on Medusa Formation in Different Classes of Medusozoa. *Zoological Science* **34**: 173-178.