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# Echinoderms in Sagami Bay: Past and Present Studies

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## ABSTRACT

Many taxonomically important echinoderms have been collected from Sagami Bay in the 130 years since German biologist Ludwig Döderlein discovered the extraordinarily diverse marine fauna of the bay. Four large and historically important echinoderm collections exist from previous taxonomical surveys of Sagami Bay. Recently, the National Museum of Nature and Science collected additional echinoderm material from Sagami Bay. For some taxa of echinoderms, compilation of lists of species occurring in Sagami Bay is almost complete based on the results of both historical and recent collections. However, despite this long research history, there are still taxonomical problems among echinoderms, and we need further study to elucidate the echinoderm fauna of Sagami Bay.

**Keywords:** Echinodermata, Collection, Research history, Taxonomy, Fauna

## INTRODUCTION

Sagami Bay is famous for its rich marine fauna including echinoderms [1]. Field surveys and studies of echinoderms in Sagami Bay initiated by the researchers from the West about 130 years ago, and followed by those in Japan have contributed to the accumulated knowledge on echinoderm fauna there. However, many undescribed species and newly recorded species are being reported from Sagami Bay even now, and taxonomical studies are kept on going actively. In this paper, the author briefly reviews 130-year-long research history of Sagami Bay echinoderms.

## RESEARCH HISTORY OF SAGAMI BAY ECHINODERMS

Since the beginning of the taxonomical studies of Sagami Bay echinoderms about 130 years ago, many scientists have carried out numerous surveys

of marine animals. I focus on 5 major taxonomical collections of Sagami Bay animals made by (i) expedition cruises of *Challenger* and *Albatross*, (ii) two German biologists, Ludwig Döderlein and Franz Doflein, (iii) the Misaki Marine Biological Station, (iv) the Biological Laboratory of the Imperial Household, and (v) the National Museum of Nature and Science, Tokyo. I will summarize echinoderm studies in Sagami Bay by each collection, with notes on prominent echinoderm biologists and some taxonomically important species.

### Collection by the vessels *Challenger* and *Albatross*

The expeditions by these two famous research vessels did not specially focus on Sagami Bay, but both of the H.M.S. *Challenger* and the U.S. Fish Commission steamer *Albatross* came to Japan. *Challenger* made dredge sampling at three sites in Sagami Bay in 1875. Later, in 1900 and 1906, *Albatross* made much more samplings in Sagami Bay and Japanese waters.

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Based on echinoderm specimens of these collections, for example, Walter Percy Sladen studied asteroids [2–3], Theodore Lyman and Hubert Lyman Clark studied ophiuroids [4–7], and Alexander Agassiz studied echinoids [8–9].

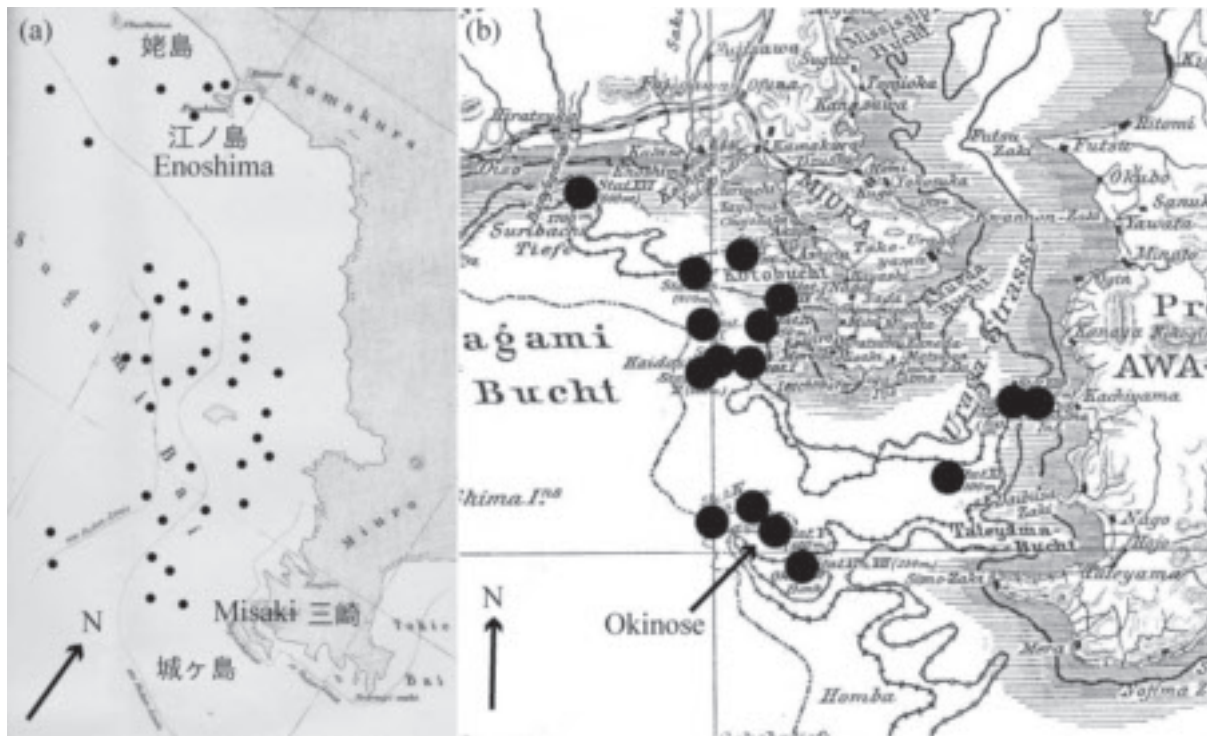
### Collection by German biologists, Ludwig H. P. Döderlein and Franz Doflein

Challenger visited Sagami Bay earlier; however, studies on marine fauna of Sagami Bay were practically started by a German biologist, Ludwig Heinrich Philipp Döderlein. Döderlein stayed in Japan from 1879 to 1881, as a professor of the Imperial University of Tokyo. He found many rare marine creatures sold in gift shops at Enoshima, a coastal town of Sagami Bay, and recognized very diverse animals living in Sagami Bay. After all, he collected such rare animals by himself using a local small fishing boat between Enoshima and Misaki (Fig. 1a) [10]. During his surveys, a rare stalked crinoid was collected from a depth of 130 m. Based on this Döderlein's specimen, *Metacrinus rotundus* was described by Phillip Herbert Carpenter (Fig. 2a) [11]. Stalked crinoids were a dominant taxon in the Paleozoic, but, they are living only in deep waters after the Cretaceous and rarely collected at present.

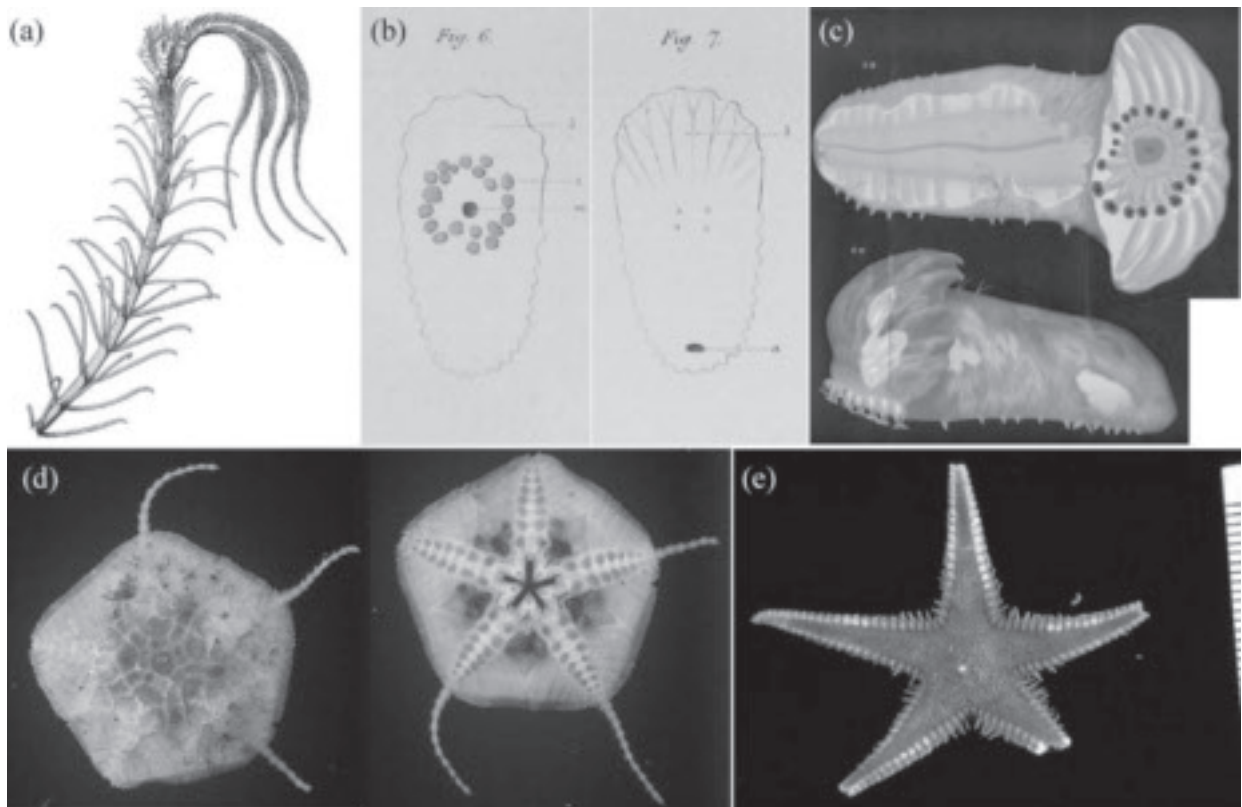
Compared to any other extant stalked crinoids, *Metacrinus rotundus* was distributed in shallower waters. Following Döderlein's finding of this species, many specimens of *Metacrinus* were collected, and these findings led a greater understanding of crinoid and echinoderm evolution.

Franz Doflein, another German biologist, learned from Döderlein that Sagami Bay is a rich repository of marine animals. In 1904, Doflein visited the Misaki Marine Biological Station to collect Sagami Bay animals. He hired a bigger steam boat, and achieved more modern field surveys. His survey area was at more offshore than Döderlein's area (Fig. 1b) [12]. Doflein did not limit just to collecting animals, but measured water temperature in deep waters, and discussed oceanological characteristics of Sagami Bay.

The echinoderm specimens collected by Döderlein and Doflein are deposited mainly in Zoologische Staatssammlung München, Musée Zoologique Strasbourg and the other European museums [1]. Based on their collections, Döderlein himself studied echinoids [13–14], asteroids [15], ophiuroids (only Euryalina) [16–18], and Ernst Augustin studied holothuroids [19].



**Fig. 1** Maps showing sampling locations (solid circles) by Döderlein (a) and Doflein (b) in Sagami Bay. Modified from Döderlein (1883) [10] and Doflein (1906) [12].



**Fig. 2** (a) *Metacrinus rotundus*. From Carpenter (1884) [11]. (b) *Eynpniastes eximia*. From Théel (1882) [24]. (c) *Eynpniastes eximia*. From Mitsukuri (1912) [23]. (d) *Astrophiuira kawamura* collected in the project study by the National Museum of Nature and Science. (e) *Astropecten sagaminus*. Holotype deposited in Zoologische Staatssammlung München.

### Collection of the Misaki Marine Biological Station

After Döderlein's discovery of rich marine fauna of Sagami Bay, according to his advice, the Misaki Marine Biological Station was established at Misaki by the Imperial University of Tokyo (currently the University of Tokyo) in 1886. By the time, Sagami Bay and its diverse marine animals had already been known for Western zoologists through Döderlein's papers. An article about the Misaki Marine Biological Station appeared in the journal *Nature* [20]. After establishment of the Misaki Marine Biological Station, using the specimens mainly collected from Sagami Bay, Japanese scientists started their taxonomic works on Japanese marine animals. Part of the echinoderm collection by the Misaki Marine Biological Station is deposited in the University Museum of the University of Tokyo [21].

Many zoologically important animals were collected at the station, noteworthily by a skilled fisherman Kumakichi Aoki often called by his nickname 'Kuma'. Kuma collected many animals using a vertical bottom long line, called "Dabo-nawa" (Fig. 3). One of his most famous sampling location was Oki-

nose. Okinose is a bank, at a depth of about 140 m, surrounded by much deeper bottom between about 500 and 1000 m (see Fig. 1b). At the Misaki Marine Biological Station, supported by the excellent specimens collected by Kuma, echinoderm taxonomy was studied by the following three founding and prominent Japanese echinoderm taxonomists: Kakichi Mitsukuri, Seitaro Goto and Hikoshichiro Matsumoto.

Kakichi Mitsukuri (Fig. 4a) was the first director of the Misaki Marine Biological Station. He studied holothuroids. His monographic paper 'Studies on actinopodes Holothuroidea' was published in 1912 after his death, based on the posthumous manuscript, by another great holothuroid biologist, Hiroshi Ohshima [23]. This paper described 69 Japanese holothuroids including 20 new species. In this monograph, an elasipod holothuroid named after Kuma, *Preiamma kumai*, was described. Another elasipod holothuroid, *Eynpniastes eximia*, is one of the most beautiful holothuroids. Before Kuma collected a complete specimen, only fragments had been collected. Shown by the original description by

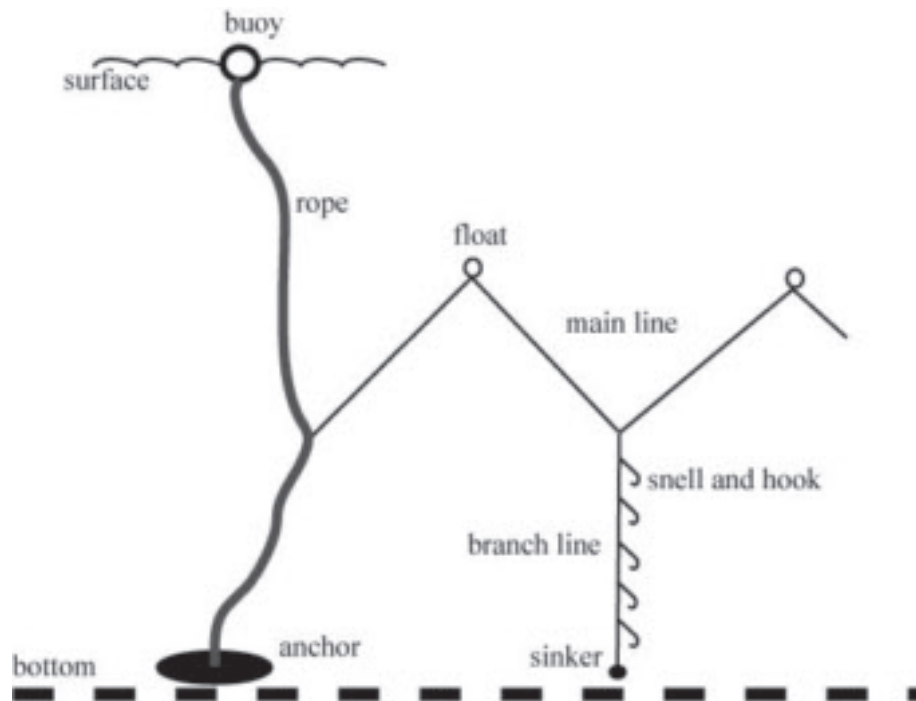


Fig. 3 Schematic diagram of 'Dabo-nawa'. Modified from Mitani (2000) [22].



Fig. 4 Japanese echinoderm biologists. (a) Kakichi Mitsukuri. (b) Seitaro Goto. (c) Hikoshichiro Matsumoto.

Théel (Fig. 2b), morphology of this species had been poorly known. Based on the good conditioned specimen collected by Kuma, Mitsukuri gave a full description and colored drawing of a whole body (Fig. 2c).

Seitaro Goto (Fig. 4b) studied asteroids. He published a very big volume 'A descriptive monograph

of Japanese Asteroidea' [25]. In this monograph, he described several new species using Sagami Bay specimens, and named some of them after locality names of Sagami Bay, e.g., *Pentagonaster misakiensis*.

Hikoshichiro Matsumoto (Fig. 4c) studied ophiuroids. His most important work was 'A monograph

of Japanese Ophiuroidea, arranged according to a new classification' [26]. He proposed a new systematics of ophiuroids. Traditionally, branching of arms and other external morphology were important for ophiuroid systematics, but Matsumoto used internal ossicle morphology too. First, his new classification had been rejected by the Western echinoderm biologists of those days, including Döderlein; but, later in 1950s, it was accepted at last. Current ophiuroid classification is still principally based on Matsumoto's view. His new insight was born stimulated by a discovery of a new strange-shaped ophiuroid, *Astrophium kawamurai* (Fig. 2d). Kuma collected the specimen from Okinose, and Matsumoto described it. He classified this strange ophiuroid as closely related to a Paleozoic fossil ophiuroid.

And furthermore, Sagami Bay specimens were also studied by the Western scientists. One of them was the famous Danish echinoderm biologist, Theodor Mortensen. He visited the Misaki Marine Biological Station in 1914. He published a lot of great works on echinoderm taxonomy, morphology and embryology. One of his excellent works was 'A monograph of the Echinoidea', comprising 9 big volumes published between 1928 and 1951 [27–35]. From 1904 to 1950, he reported Japanese echinoids including 14 new species.

#### Collection by the Biological Laboratory of the Imperial Household

The Biological Laboratory of the Imperial Household, a private institute of His Majesty the Showa Emperor, Hirohito, was founded in 1928. The laboratory collected marine invertebrate specimens from Sagami Bay until 1988. The enormous number of specimens in the collection were donated to the National Museum of Science, Tokyo, in 1994. A total of about 1360 lots of echinoderm specimens are now deposited there. Based on this Showa Emperor's collection, three volumes of taxonomic monographs on echinoderms were published. Asteroids were studied by Ryoji Hayashi [36], ophiuroids by Seiichi Irimura [37] and echinoids by Michio Shigei [38]. This collection includes one rare species of echinoids of family Brissidae. The heart urchin belongs to the genus *Brissopatagus*. *Brissopatagus* was originally a fossil genus only known from the Eocene, and Mortensen thought this genus was closely related to *Eupatagus*, another genus of Brissidae. Shigei studied detailed morphology using the extant specimens, and revealed that *Brissopatagus* is not related to *Eupatagus*.

#### Project study conducted by the National Museum of Nature and Science

Following these preceding studies, the National Museum of Nature and Science (formerly National Science Museum), Tokyo, conducted a biological research project on Sagami Bay from 2001, principally to describe the fauna of Sagami Bay [1]. The target area included Sagami Bay and its adjacent waters, the Sagami Sea and Tokyo Bay. In this research project, both past records and new materials are investigated and current knowledge of echinoderm fauna in Sagami Bay has been so far summarized for some taxa in echinoderms as follows.

With regard to the crinoids and echinoids, species occurring in Sagami Bay were compiled almost completely in this study. In the case of crinoids, 4 species were newly recorded from Sagami Bay, and a total of 64 species including them have become known in Sagami Bay [39–40]. Concerning echinoids, the total number of species recorded from Sagami Bay has now reached 84 [41].

For asteroids, Paxillosida and Valvatida were studied, and 41 species are listed from Sagami Bay [42]. Ref. 42 includes an indeterminate species of *Ctenopleura* that has been confused with *Astropecten sagaminus*. *Astropecten sagaminus* was described by Döderlein (1917) [18], based only on the small holotype collected by Doflein (Fig. 2e). Later in 1973, Hayashi [36] identified two specimens of the Showa Emperor's collection with this species, and moved this species to *Ctenopleura*. In this project, two more specimens identical to Hayashi's specimens were collected. Saba and Fujita [42] examined Hayashi's two specimens again, and clarified that these 4 specimens really belong to *Ctenopleura*, but they are not conspecific with Döderlein's *Astropecten sagaminus*. Probably these *Ctenopleura* specimens are undescribed species. Hayashi did not examine this holotype, and we need to re-examine this holotype to make clear the status of Döderlein's *Astropecten sagaminus*. In spite of long research history of Sagami Bay, there are still many unsolved questions in echinoderm taxonomy.

In the case of ophiuroids, only one deep-water family, Ophiacanthidae has been studied [43]. Including newly recorded species, 29 species have been recorded from Sagami Bay. But, there are still many taxonomical problems, and further studies are required. The collection by this project contains *Astrophium kawamurai*. Kuma collected this species from Okinose in 1912. Since then, no specimens were reported until 2003, when at last this new finding of ophiuroid near Okinose was made by the new

project.

Many taxonomically important echinoderms have been collected from Sagami Bay, through a long research history since the first study by Döderlein. In Sagami Bay, however, there is still confusion on the taxonomy of echinoderms, and undescribed echinoderm species are being discovered even now. Some more time is needed to complete the inventory of echinoderms of Sagami Bay. These facts/observations point to the difficulties in faunal study probably resulting also from the really rich nature of the marine fauna in Sagami Bay.

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