Mass strandings of the common paper nautilus *Argonauta argo* along the coast of Yoichi Bay, Hokkaido, Japan

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Abstract

Shells of the common paper nautilus, *Argonauta argo*, were washed up along the coast of Yoichi Bay, Hokkaido from October to November 2010. Shells were collected along the foreshore during ebb tide, where they were found together with driftwood and other flotsam that had been washed ashore by severe storms associated with the northwestern monsoon (autumn-winter) on the Japan Sea-side of Hokkaido. Measurements of shell length for 245 shells revealed that the range in shell length was 38-188 mm. The shell length of 241 shells was less than 150 mm and a bimodal peak was apparent at the size-frequency distributions of 80-90 mm and 110-120 mm. A strong correlation was observed between shell height and shell length ($R^2=0.99$). The mass strandings of *A. argo* along the Yoichi coast are considered to have occurred in response to an anomalous increase in sea surface temperatures in the northern Japan Sea in the autumn of 2010.

Key words: *Argonauta argo*, Japan Sea, mass stranding, Tsushima Warm Current, Hokkaido

Introduction

The epipelagic common paper nautilus, *Argonauta argo* Linnaeus 1758, is distributed throughout the tropical and subtropical oceans of the world (Kubodera 2000; Norman 2003), including the waters around Japan (Okutani 1987; Kubodera 2000). Although rarely recorded on the Pacific side of the Japanese archipelago (Kubota and Miyashita 1973; Kosuge 1982), *A. argo* is relatively common in the Japan Sea between Jeju Island in the south and Hokkaido in the north (e.g., Nishimura 1968; Okutani and Kawaguchi 1983; Ueno et al. 1996; Suzuki 2006; Shiga 2007). Of particular interest to malacologists and marine biologists are the mass strandings of *A. argo* that periodically occur on the Japan Sea of Japan (Nishimura 1968; Okutani and Kawaguchi 1983; Sakurai and Kawano 2010; Suzuki 2010).

In October to November 2010, mass strandings of *A. argo* occurred along the coast of Yoichi Bay. This study examined the phenomenon of mass strandings in *A. argo* and performed biometric analysis on the shells of this species. In addition, the relationship between mass strandings and environmental change in the marine environment were also clarified.

Materials and Methods

The study area was located along the coast of Yoichi Bay in central Hokkaido (Fig.1). The north-facing sandy beaches extend for 6 km and are composed of light-grayish, medium-grained sands. The area was divided into four sections, A to D, primarily according to coastal morphology (Fig.1). The sections are also dissected by rivers that originate in the hills around Yoichi Bay.

A. argo shells were collected along the beach at weekly intervals from September to November in 2010. In addition, I also collected flotsam that had washed up together with the *A. argo* shells, and identified any stranded marine animals. Undamaged *A. argo* shells were subjected to morphometric analysis according to Okutani and Kawaguchi (1983). Measurements were performed using a digital caliper (Mitutoyo CD67-S20PS).

Results

1. Modes of occurrence of stranded shells

In the study period, *A. argo* shells are thought to have started washing up on the beach of Yoichi Bay in October, 2010, with mass strandings occurring for ap-

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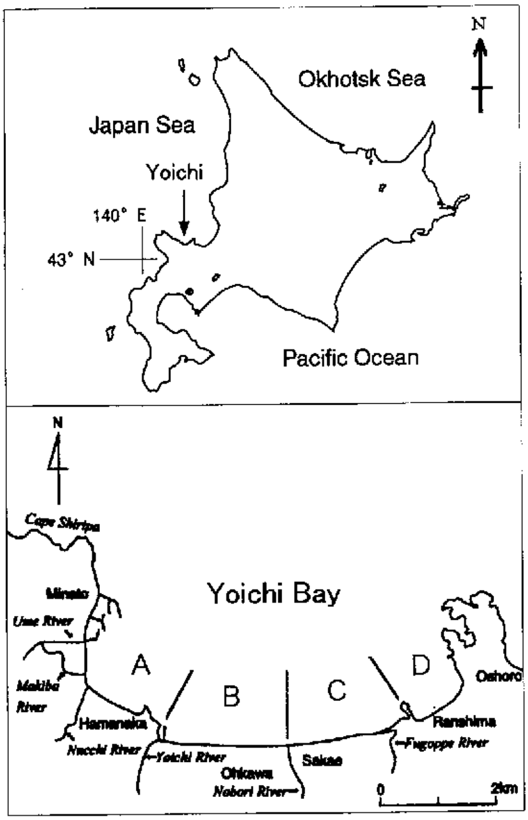

Fig. 1 Map showing the study area along the coastline of Yoichi Bay, which was divided into four sections (A-D).

proximately one month from October 15. The *A. argo* shells were typically associated with marine litter and natural flotsam, such as drift wood, walnuts, mollusks, sea urchins (Fig.2-1, 2-2). On rare occasions, whole *A. argo* specimens also washed ashore (i.e. the body was still attached to the shell) (Fig.2-3, 2-4). In addition, large shells were occasionally found at the low-tide line during late October.

Although *A. argo* shells were collected on all of the sections of beach in Yoichi Bay (Fig.1), most were found in Section A (Hamanaka Beach), followed by sections C (Sakae Beach), B (Ohkawa Beach) and D (Rankoshi Beach). The number of *A. argo* shells in the flotsam was related to the morphology of the coast and the presence of a rocky cape (Fig.3). Detailed frequency characteristics of shells on Hamanaka Beach are shown in Fig.4. Mass stranding of shells started in mid-October 2010 and continued until mid-November, peaking in late October. This peak also corresponded to a period of mass *A. argo* strandings along the coast of Ishikari Bay in the same year.

2. Morphometry of shells

The shell length in the 245 *A. argo* specimens collected in the study area ranged between 38 to 188 mm

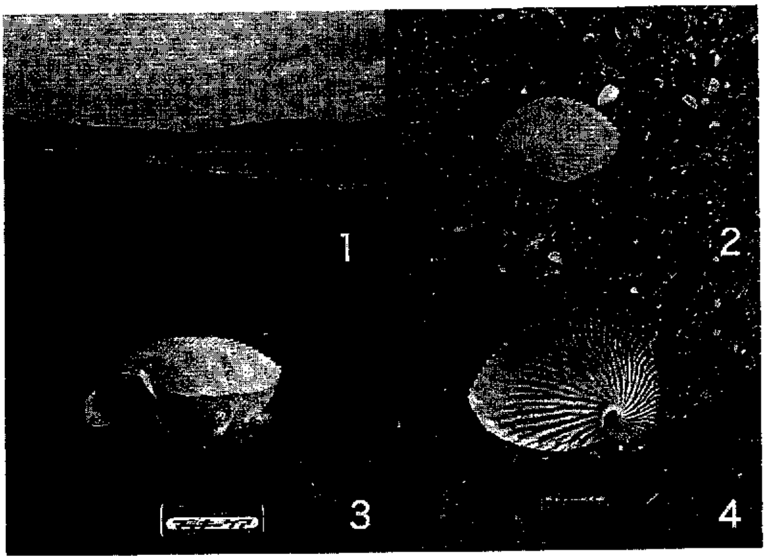

Fig. 2 Shells of *Argonauta argo* that had washed up on the sea shore.
1. View of Hamanaka Beach (section A) in late October 2010.
2. Complete shell washed up along the low-tide line on Hamanaka Beach.
3. *A. argo* washed up on Hamanaka Beach (black marker: 14 cm).
4. Large *A. argo* shell on the beach (black marker: 14 cm).

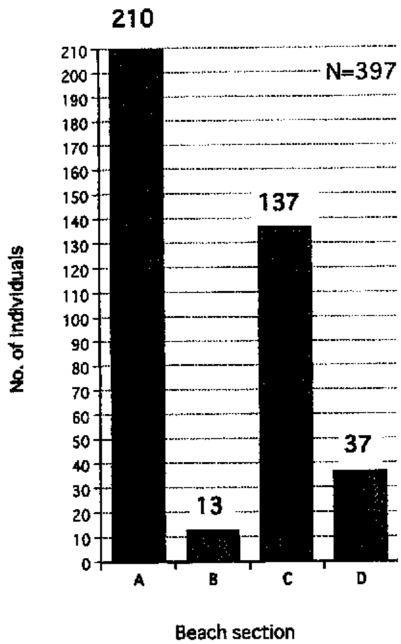

Fig. 3 Number of *A. argo* shells found in sections A-D of the study area.

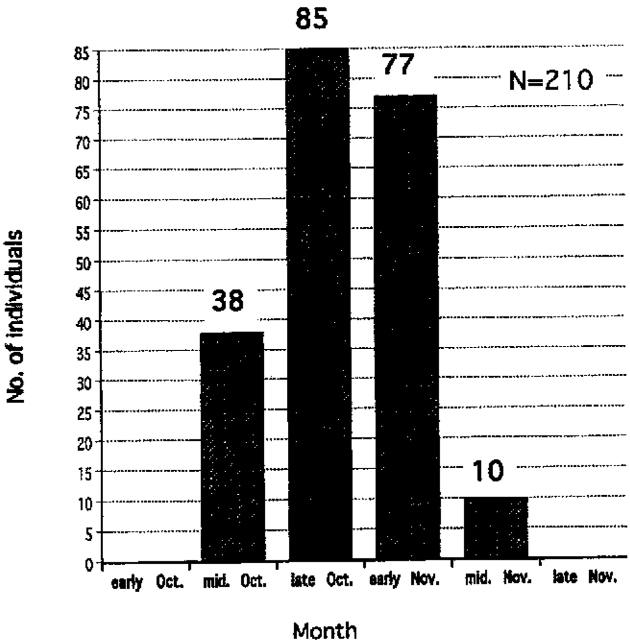

Fig. 4 Number of *A. argo* shells washed up on Hamanaka Beach (section A) from October to November in 2010.

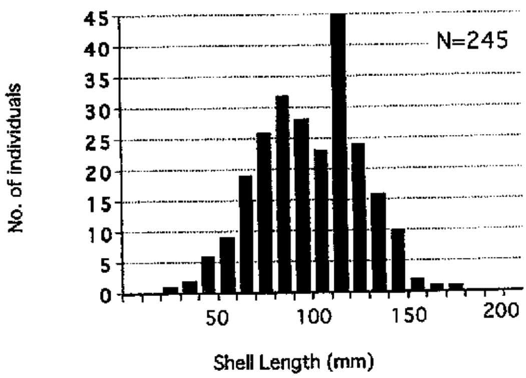

Fig. 5 Size-frequency distribution of shell length of *A. argo*. Each unit of the X-axis is equivalent to 10 mm.

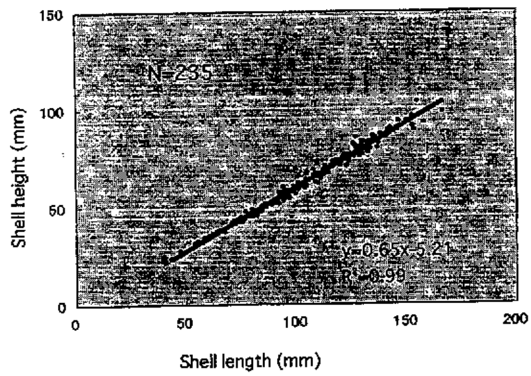

Fig. 6 Relationship between *A. argo* shell height and length.

(Fig.5). The shell length of 241 specimens (ca. 98%) measured less than 150 mm, and exhibited a bimodal size-frequency distribution with peaks at 80-90 mm and 110-120 mm. Only one shell had a length that exceeded 180 mm. The bimodal distribution was likely due to the existence of two separate cohorts in the population that were collected on different dates.

A strong linear relationship, described by the equation $y=0.65x-5.21$, was observed between shell length and shell height (Fig.6). Similarly, shell length was also proportional to shell width and could be described by the equation $y=0.23x+13.41$ (Fig.7).

Discussion

Figure 8 shows the oceanographic conditions in the autumn of 2010 in western Japan Sea (Hakodate Marine Station, Japan Metrological Agency 2010). The sea surface temperature (SST) of the Tsushima Warm Current north of 42°N ranged within normal limits (15-

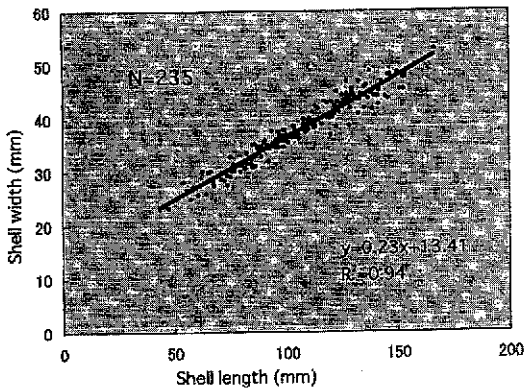

Fig. 7 Relationship between *A. argo* shell width and length.

16° C: Japan Metrological Agency 2010) until mid-October, where after it increased abruptly by 1 to 2°C above the mean for the period 1950-2000 until early November. It seems likely that the observed increase in SSTs was responsible for the mass stranding of warm-water species such as *A. argo*.

From a faunistic point of view, the marine biota along the Yoichi coast is typical of the cool-template realm and is represented by both cold- and warm-water species. Recently, however, records of subtropical and tropical species are becoming increasingly frequent along the coast. It is thus possible that the mass strandings of *A. argo* and the associated species that were washed up along the Yoichi coast could be explained by an increase in the temperature of the Tsushima Warm Current that flows northwards.

This tendency of warm-water species to migrate northward in the Pacific Ocean has also been reported in the Atlantic Ocean, where increased SSTs are considered to be responsible for the appearance of *A. argo* (Guerra et al. 2002). Stranding records for *A. argo* extend to approximately 44°N in the northeastern Atlantic Ocean. A similar anomalous increase in SSTs in the Atlantic Ocean was considered to be responsible for the unusual mass stranding of the congeneric octopus, *A. nodosa*, along the Uruguayan coast in Uruguay (Demicheli et al. 2006). The stranding of *A. nodosa* was the first reported mass stranding record in an argonautid in the southwestern Atlantic Ocean.

It is proposed that the mass strandings of the common paper nautilus, *A. argo*, which occurred along the coast of Yoichi Bay in the autumn of 2010, were attributed to the combination of an anomalous increase in SSTs and the northwestern monsoon in autumn. In addition, such increases in SSTs in the northern Japan Sea are considered to be accelerating the northward migration of warm-water mollusks in cold regions.

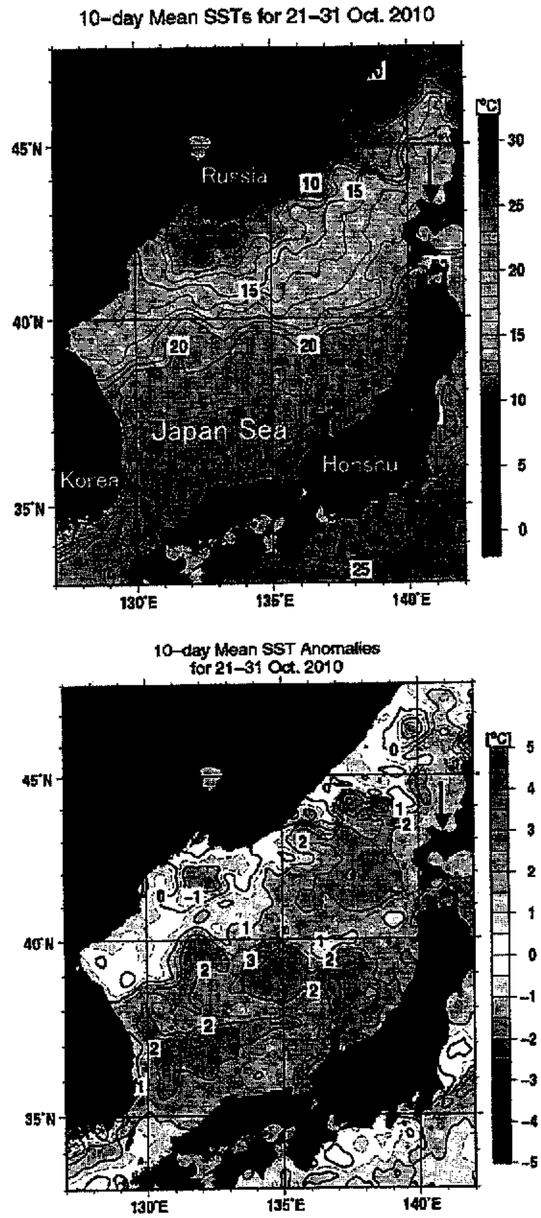

Fig. 8 Mean sea surface temperatures (SST) and anomalies in the Japan Sea in late October 2010. Arrows indicate the study area. (from Japan Metrological Agency 2010)

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