

4. Notes on Shell Breakage in *Nautilus pompilius* from Fiji

by

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Introduction

During our field studies in 1983 and 1986 in Fiji, many specimens of *Nautilus pompilius* were captured from the waters off Suva, Pacific Harbour and Ovalau Island. These live-caught animals preserve remarkable injuries in their soft tissue (mantle and hood) and shells. Similar injuries have been described in specimens from other regions and discussed in relation to the possible predators upon *Nautilus*: for *N. pompilius* from the Philippines and Papua New Guinea (WILLEY, 1902; TUCKER and MAPES, 1978; HAVEN, 1972; ARNOLD, 1985; SAUNDERS *et al.*, 1987), *N. macromphalus* from New Caledonia (TUCKER and MAPES, 1978; WARD, 1987), and *N. scrobiculatus* from Papua New Guinea (SAUNDERS *et al.*, 1987). In this paper we describe the morphological features of the shell breaks and boring in the samples from Pacific Harbour and Ovalau areas with an aid of the scanning electron microscope (SEM), and infer their probable origin on the basis of the results obtained.

Results and Discussion

We examined 73 specimens (N=41 from off Ovalau and N=32 from off Pacific Harbour, Viti Levu; see TANABE, 1985 for details of locations and trapping records in Pacific Harbour). Every specimen has several injuries on the shell surface. Based on the morphology and magnitude, they are classified into the following four types:

- Type A. Small subcircular drill hole, with scalloped edges (Plate 14, figs. 1a-b).
- Type B. V-shaped bite marks, generally with serrate cutting edges (Plate 15).
- Type C. Circular bite marks, with shallow and incomplete depression like a meteorite crater (Plate 16).

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Type D. Larger, irregular breaks, with cracks or fractures (Plate 14, figs. 2-4)

Occurrences of these types in the samples examined are summarized in Table 1. Of these, type A boring is observed in the single specimen (OL 3-1-3 from off Ovalau Island), and is apparently compared with those previously interpreted as *Octopus* borings (TUCKER and MAPES, 1978; ARNOLD, 1985; SAUNDERS *et al.*, 1987), because of the characteristic features with etched surface and the position near the retractor muscle. The inner surface of the body chamber in the posterior portion is repaired by a thick organic membranes.

Bite marks of Type B are frequently observed at the apertural ventral shell margin. They correspond to "bites" of ARNOLD (1985) and type 2 of WARD (1987), and have been reported in many specimens from various regions. Most previous authors (HAVEN, 1972; ARNOLD, 1985; WARD, 1987; SAUNDERS *et al.*, 1987) attributed the marks to a product of attacks by other *Nautilus*. The sharp, serrate cutting edges fit well with the anterior calcified portion of the *Nautilus* jaws (serrate edges are present in the lower jaw), and this supports the previous interpretation. Indeed, chewed pieces of *Nautilus* tentacles are occasionally found in esophagus-stomach contents of *Nautilus pompilius* from off Pacific Harbour (SAISHO and TANABE, 1985, pl. 24, fig. 4). Circular bite marks of Type C are compared with the "nips" of Arnold (1985) in the general outline. They occur less commonly on the ventral shell margin near the aperture. Under the SEM, the mark is round in outline, approximately 1 mm in diameter. Outer periostracum and the middle prismatic shell layer were completely perforated by biting, retaining a sharp and conical cutting edge. The underlying nacreous layer remains undamaged, and therefore, the bottom of the mark is almost flat (Pl. 15, fig. 3). The bite marks of this type were interpreted as indicating attacks by other *Nautilus* (ARNOLD, 1985) and/or by teleost (SAUNDERS, 1987, figure 5). The circular and conical perforations do not match well with the serrate calcified denticles of *Nautilus* jaws. This fact suggests that they were produced by teleost rather than other *Nautilus*.

The irregular breaks of Type D are frequently observed at various portions of most specimens. Some of them were probably made by fighting with other *Nautilus* or by impact against foreign object (e.g. reef walls). However, the major

Table 1. Abundance of injuries on the shells of live-caught *Nautilus pompilius* from Fiji.

Locality	No. of specimens	<u>Octopus</u> boring	V-shaped bite marks	Circular bite marks	Irregular fractures major	Irregular fractures minor
Pacific Harbour	32	0 (0%)	5 (15.6%)	2 (6.3%)	28 (87.5%)	32 (100%)
Ovalau	41	1 (2.4%)	31 (75.6%)	5 (12.2%)	24 (58.5%)	32 (100%)

breaks are too large to infer predatory attacks by other *Nautilus* or non-predatory impact (Plate 14, fig. 3). During the field experiments in 1983 and 1985, large teleost (snapper : *Lutjanus malabaricus* and *Etelis carbunculus* ; grouper : *Epinephelus magniscuttis*) and deep sea shark were trapped together with *Nautilus* (SHINOMIYA *et al.*, 1985). Furthermore, a mandible of *Nautilus* was newly found in the stomach of the cat chark, *Cephaloscyllium isabella* (see TANABE in this volume). Judging from these lines of indirect evidence, major breaks were probably made by predatory attacks of large fish including shark.

To sum up, *Nautilus* in Fiji water is certainly subjected to predation by various kinds of animals such as *Octopus*, other *Nautilus* and large fish, as in the populations of other regions. The abundance of minor and major injuries in live-caught animals, however, shows that they can survive tenaciously in most cases.

Concluding Remarks

The ecology of *Nautilus* in its natural habitats has become made clear as a results of recent investigation from various viewpoints. Nevertheless, little is known about the exact predators of *Nautilus*. To clarify this problem, further research other than the observations on shell breaks is needed. Quantitative analysis of stomach contents in the associated large animals and direct observation using long-term underwater photo sequences may be useful for this research.

Acknowledgments

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Plates 14-16

Explanation of Plate 14

Shell breaks and boring in *Nautilus pompilius*, captured alive from the Fiji water.

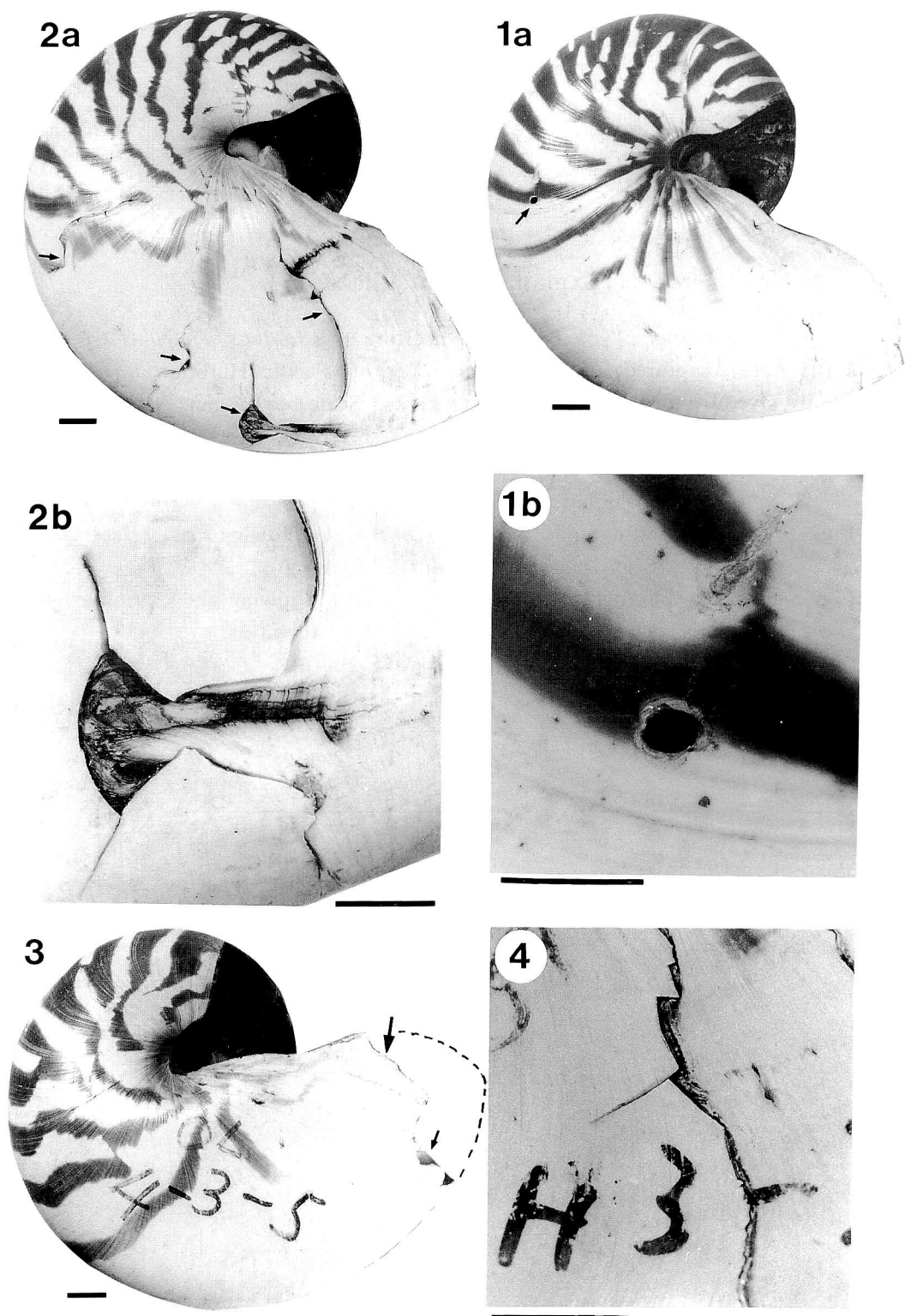
Fig. 1a-b. Small, subcircular drill hole (arrow : Type A) attributed to *Octopus* boring in the specimen OL 3-1-3 from the water off Ovalau Island.

Fig. 2a-b. Larger, irregular shell breaks (arrows : Type D) in the specimen OL 1-2-2 from the water off Ovalau Island.

Fig. 3. Major shell break (arrow : Type D) attributed to the attack by unknown large fish in the specimen OL 4-3-5 from the water off Ovalau Island.

Fig. 4. Larger, irregular shell break (Type D) in the specimen PH 3-2 from the water off Pacific Harbour, Viti Levu.

Scale bars indicate 1 cm.



Explanation of Plate 15

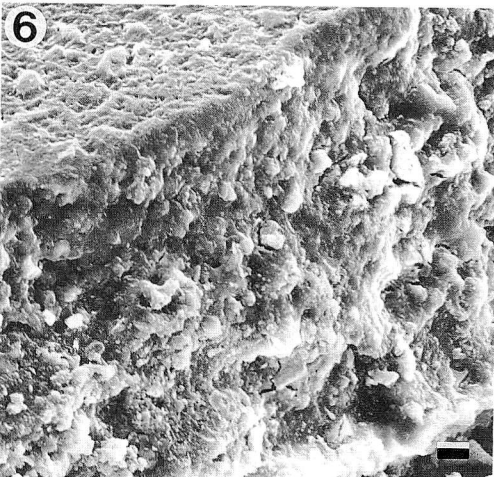
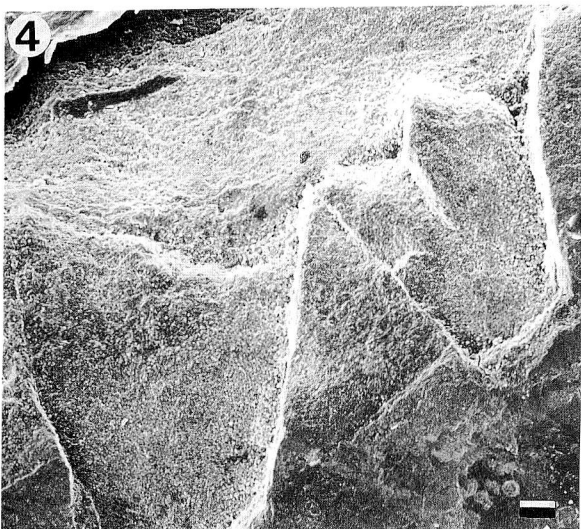
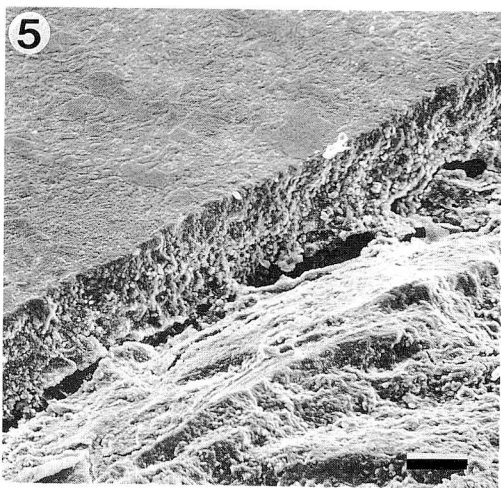
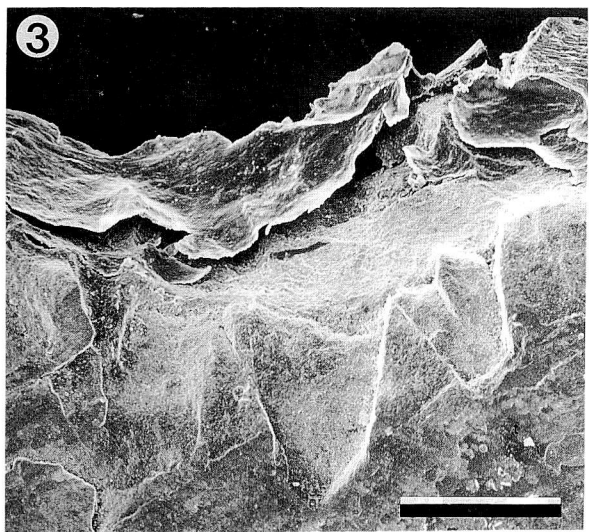
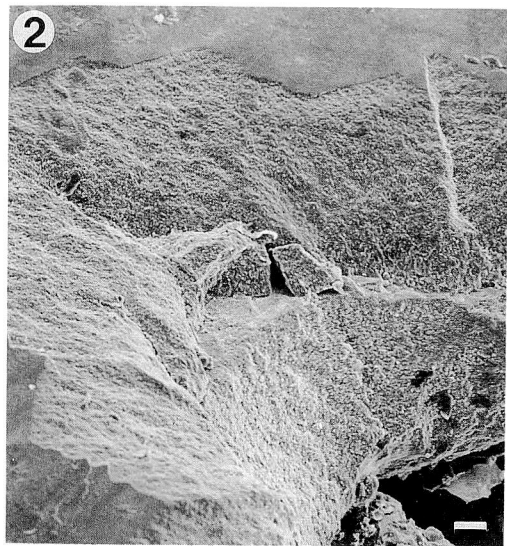
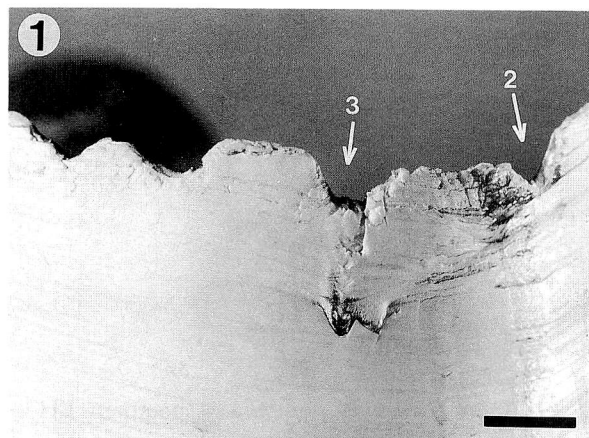
V-shaped bite marks (Type B) at the aperture of *Nautilus pompilius* (specimen PH 6-15), captured alive from the water off Pacific Harbour.

Fig. 1. Overall morphology of the bite marks. Scale bar: 5 mm. Arrows indicate the portions of Fig. 2 and Fig. 3, respectively.

Fig. 2. SEM photograph of a part of Fig. 1, showing the V-shaped cutting edge.
Scale bar: 50 μm .

Figs. 3-4. SEM photographs of a part of Fig. 1, showing the serrate cutting edges. Scale bars: 500 μm (3) & 50 μm (4).

Figs. 5-6. SEM photographs of a part of Fig. 4, showing the cutting edge of the outer periostracum and middle prismatic layer.
Scale bars: 50 μm (5) & 5 μm (6).



Explanation of Plate 16

Circular bite marks (Type C) at the aperture of *Nautilus pompilius* (specimen PH 1-1), captured alive from the water off Pacific Harbour.

Fig. 1. Overall morphology of the bite marks. Scale bar : 5 mm. Arrow indicates a portion shown in Fig. 2-3.

Figs. 2-3. SEM photographs of a part of Fig. 1, showing the shallow, crater - like perforation. Scale bars : 500 μm (2) & 50 μm (3).

Fig. 4. SEM photograph of a part of Fig. 3, showing the almost flat surface of unpenetrated inner nacreous layer. Scale bar : 5 μm .

Fig. 5. SEM photograph of a part of Fig. 3. showing the cutting surface of the middle prismatic layer. Scale bar : 5 μm .

