

## Notes on animal weight, cameral fluids, swimming speed, and color polymorphism of the cephalopod *Nautilus pompilius* in the Fiji Islands

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**Abstract.**—Forty-six specimens of *Nautilus pompilius* Linnaeus were captured in depths varying between 100 and 500 m outside of the fringing reef near Suva, Fiji Islands. Thirty-eight of the specimens were male. Air weight per individual varied between 347 and 630 g. Sexual dimorphism in size is indicated, since mature shell modifications (approximated septa, blackened aperture) were present in two females weighing about 350 g (soft parts plus shell) and one weighing slightly over 400 g; the smallest male showing mature shell modifications weighed 496 g. All newly captured specimens were heavier than seawater, with mean weight in seawater of 1.87 g determined for twenty-five specimens. Total volumes of cameral liquid ranged between 13.5 and 0 ml. Thirteen of twenty-five sampled specimens showed less than 1.0 ml of cameral liquid from all chambers. Average cameral liquid osmolarity was lower than that observed in sampled populations of *N. macromphalus* from New Caledonia and *N. pompilius* from the Philippine Islands. Maximum swimming rates were 0.25 m/sec. *N. pompilius* exhibits two common color polymorphs.

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### Introduction

To draw inference about form and function of fossil material, the paleontologist must ultimately make comparisons with currently living organisms. In the study of fossil shelled cephalopods, we have been most fortunate in this regard in having the extant species of *Nautilus* to turn to for guidance. Unfortunately, the deep and geographically isolated habitats of *Nautilus* have limited field studies on the living animal, and thus many questions about *Nautilus* which would be a great aid in better understanding its fossil analogues remain unanswered. For example, although the pioneering studies of Bidder (1962) and Denton and Gilpin-Brown (1966) have elucidated the method by which *Nautilus* produces and ultimately drains the camera, there is little information about the importance of buoyancy control in the daily activities of the animal. There is virtually no information about the embryology, ecology, and ethology of *Nautilus*. Even a detailed knowledge of the taphonomic history of shell and soft parts

following death, so necessary for understanding the potential of postmortem drift of extinct cephalopod shells, is missing. Only when we are armed with a better knowledge about *Nautilus* will we be able to make interpretations about the paleoecology of ammonoids and extinct nautiloids.

In this paper we present new information about one population of *Nautilus* which may be of use to the paleontologist. We have examined aspects of size, air and water weight, sex ratios, cameral liquid volumes and salinities, shell color patterns, and swimming speeds of a sample of *Nautilus pompilius* from outside of the Suva Harbor fringing reef, Viti Levu, Fiji Islands, and compare these data to similar information for other populations of *Nautilus* elsewhere in the Pacific.

The occurrence of living *Nautilus pompilius* Linnaeus in the Fiji Islands was first reported by Willey (1902) and later documented by Stenzel (1964) and Davis and Mohorter (1973). During the summer of 1975, several *N. pompilius* were captured in shrimp traps

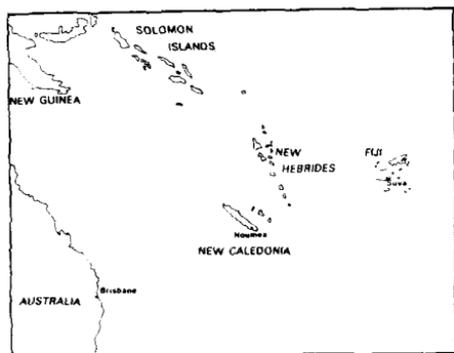


FIGURE 1. Location of Fiji Islands in Western Pacific Ocean.

set by the Fiji Department of Fisheries at 200–400 m near Suva, Viti Levu (Fig. 1). These findings were communicated to the senior author who then participated in the capture of two more specimens, including an immature animal (160 g) from deep water (400–500 m) (Ward and Martin 1976). Because of the deep and geographically peripheral habitat of this poorly known population (Stenzel 1964), it was decided to carry out extensive trapping during July and August, 1976.

### Field Area and Catch

All of our captures were made outside the fringing reefs of the Suva Harbor region (Figs. 1 and 2). Although close to Suva, the largest and most industrialized city of the Fiji Islands, the reefs showed little siltation, and the water in the region is highly transparent. The seaward edge of the reef here is somewhat scalloped; the convex parts have gentle slopes, whereas concave parts are characterized by nearly vertical scarps dropping to the gently sloping floor at 100–200 m. Bottom substrates near the reef are primarily reef talus and coral sand, while offshore of the 100 m contour, the substrate progressively changes into volcanoclastic muds.

### Field Methods

All our *Nautilus* were captured in baited traps on the seaward side of the Suva reef system. Two types of traps were employed:

(1) a standard double-entry "shrimp pot," modified by enlargement of the entrances, and (2) a double-bottomed crab pot in which animals had to pass through two entrances to gain access to the bait. The second trap was far more successful. The traps were placed singly or two to a line and attached to surface floats with 12 mm polypropylene floating line. Fresh fish served as bait; different kinds of fish appeared to be similarly effective. Catch records are listed in Table 1.

Trap locations were determined by triangulation on navigational markers outside Suva Harbor. The depths were ascertained by echo-soundings on the shallow reef and by line sounding on the deeper muddy bottoms. The listed capture-depths are probably subject to error of plus or minus 10%. Early trapping was concentrated on the reef talus and slope areas at less than 100 m because these environments had yielded the greatest number of *Nautilus macromphalus* in New Caledonia (Ward and Martin 1976). Since no *Nautilus* were captured at these depths in Fiji (less than 75 m), trapping was transferred to deeper mud bottoms, where the highest *Nautilus* concentration occurred over 1 km from the reef at depths of 200–500 fathoms (Fig. 3). The deepest capture to date was made by one of us (Stone in October, 1976) at a depth of between 300–350 fathoms (550–650 m).

In addition to the *Nautilus*, commonly captured animals included penaeid shrimp, hermit crabs, decapod crabs, and occasional fish, including small sharks. Shrimp were most common, with tens to hundreds of individuals common in each trap.

### Laboratory Procedures

Each *Nautilus* was numbered upon removal from the trap and transported to the laboratory in seawater. In the laboratory the animals were dried with a towel, and weighed on a top loading electronic balance.

The buoyancy of an animal can be defined as its weight in seawater; an animal with a positive weight is denser than seawater and hence negatively buoyant, and vice versa. To measure the buoyancy of freshly captured *Nautilus pompilius*, we (1) placed the animals for fifteen minutes in a solution of 2% urethane, an effective cephalopod anesthetic

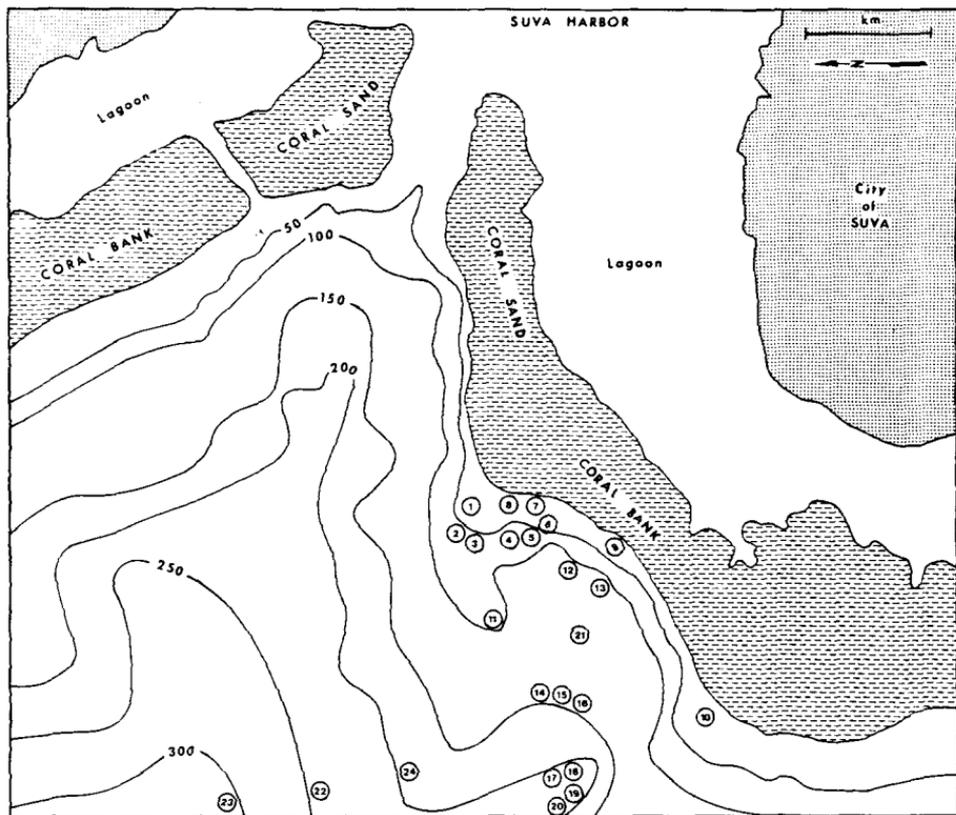


FIGURE 2. Bathymetry and capture locations of Suva Harbor region, Fiji. Depths were taken from nautical charts and are in fathoms (1 fathom = 6 ft). Circled numbers refer to capture localities of Table 1.

(Denton and Gilpin-Brown 1966). The animals were (2) then placed in a mesh bag attached to the arm of Model LG torsion balance, and weighed in seawater. Great care was taken to ensure that no air bubbles were lodged in the mantle cavity, since this markedly affected the measurements by reducing the overall density. The soft body was (3) removed from the shell by prying the adductor muscles from the shell, weighed in seawater (as above) and then in air. Finally, (4) the crop contents were removed, and the soft body again weighed in seawater and in air.

Cameral liquid was removed from the shell by drilling a 1–2 mm hole into each chamber, inserting a thin plastic tube in the hole, and blowing gently into the tube. The liquid was

forced into a beaker around the sides of the tube, its volume determined in a hypodermic syringe, and 0.1 ml samples were analyzed for chloride on a Beuchler-Cotlove chloridometer.

## Results

*Weight and sex determinations.*—The weights in air, number of septa, and sexes of trapped *Nautilus* are listed in Table 2. The majority of our specimens are in the 400–600 g range, and most over 500 g are adults. This is evident from the approximation of the final two or three septa, the thickening of the ultimate septum and apertural shell region, and secretion of a black band of proteinaceous material on the inside of the aperture.

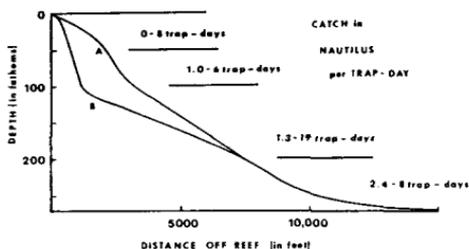


FIGURE 3. Reef profiles from Suva Harbor region. Profile A is from the region of trap localities 1-2-22 (Fig. 2), and profile B from the region of localities 9-13-21-14. "Trap-day" refers to a single trap being left submerged for one day.

In the Suva Harbor region many more males than females were captured. Of the 46 specimens captured, only 8, or one-sixth were females. The results of buoyancy determinations are listed in Table 3. With one exception (no. 12), all of these *Nautilus* had slight negative buoyancy several hours after capture. In the traps with ready access to the bait, the *Nautilus* gorged themselves. A maximum of 76 g (air weight) of fish was recovered from within the crop of a single specimen. Depending on the amount, the

bait material accumulated in the crop added up to several grams to the negative buoyancy.

**Cameral fluid.**—Cameral liquid volumes and osmolarities are listed in Table 4. The greatest total volume (for all chambers) extracted from any of our specimens was 16 ml. Thirteen of twenty-five sampled specimens showed less than one milliliter. In general, volumes of cameral liquid decreased in successively older chambers, although several animals showed greater volumes in the third chamber than in the second (chambers are designated by position, where chamber 1 refers to the most recently formed chamber).

The osmolarities for the cameral fluid have been estimated by measuring the chloride content, since it has been shown that the percentage of chloride is an accurate indicator of osmolarity (Denton and Gilpin-Brown 1966). In most specimens, osmolarity of the cameral fluid remains similar or increases slightly in successively older chambers. Many of the Fiji specimens yielded liquid with osmolarities of one fifth the value of normal seawater, the lowest ever observed in *Nautilus* (cf. Denton and Gilpin-Brown 1966; Ward and Martin, unpublished) and are roughly equivalent to the cameral liquid osmolarities

TABLE 1. Catch record, July-August, 1976.

Trap Location	Date	Days on Bottom	Number of Traps	Total number of <i>Nautilus</i>	Depth (m)	Bottom type
1	July 22	1	2	0	50	coral
2	July 22	1	2	1	100	mud
3	July 28	1	1	3	100	mud
4	July 28	1	1	1	140	mud
5	July 29	1	1	0	140	mud
6	July 29	1	1	1	100	mud
7	July 30	1	2	0	50	coral
8	July 30	1	2	0	50	coral
9	July 31	1	2	0	50	coral
10	July 31	1	2	0	50	coral
11	Aug. 2	2	2	4	180	mud
12	Aug. 3	1	2	3	180	mud
13	Aug. 4	1	2	3	180	mud
14	Aug. 6	2	2	9	280	mud
15	Aug. 9	3	1	2	280	mud
16	Aug. 10	1	1	0	280	mud
17	Aug. 11	1	1	4	350	mud
18	Aug. 12	1	1	2	350	mud
19	Aug. 13	1	1	3	350	mud
20	Aug. 14	1	1	1	350	mud
21	Aug. 16	2	1	2	200	mud
22	Aug. 17	1	1	2	450	mud
23	Aug. 18	1	1	3	550	mud
24	Aug. 19	1	1	2	350	mud

TABLE 2. Weight measurements on *Nautilus pompilius* from the Fiji Islands. All weights are in grams. "A" following septal number refers to strong approximation of the final two septa.

Number	Sex	Total Wt. (g)	Maximum shell diameter (mm)	# Septa	Dry Wt. Shell (g)	Tissue Weight (g)	Crop contents (g)	Cameral Fluid (ml)
1	-	413	134	28	103	-	9	9.2
2	F	430	140	28	120	267	-	-
3	F	481	-	-	-	309	-	-
4	M	505	-	-	127	341	14	2.5
5	M	585	147	30	121	443	-	2.1
6	F	347	134	28	106	207	-	-
7	M	527	142	29	119	369	38	0.7
8	M	638	150	30	131	485	31	0
9	M	542	145	28	116	-	-	0.2
10	F	411	137	30A	111	258	19	0.5
11	-	560	148	30	123	407	44	0.5
12	-	508	140	29A	-	355	67	0.7
13	-	485	143	28	116	343	65	0.1
15	F	381	-	29A	120	245	-	-
16	M	540	143	30A	122	-	49	-
19	M	592	148	32A	131	429	34	4.0
20	M	599	146	29	123	446	15	0.4
21	M	551	141	30	122	397	33	0
22	M	534	-	-	-	347	0	5.0
23	F	353	131	30A	108	206	-	-
24	M	531	147	31A	130	361	23	-
25	M	569	150	28	130	416	15	0.2
26	M	309	120	26	75	198	25	13.5
27	M	496	138	29A	118	-	30	9.3
28	M	477	139	29	111	-	39	-
31	M	595	152	-	144	420	0	3.3
32	M	542	-	-	124	407	6	0.1
36	M	550	-	-	126	389	74	0.3
37	M	485	-	28	107	351	76	9.2
38	M	630	-	32	153	453	51	0.2
39	M	439	-	-	109	311	10	0.9
40	M	502	-	-	131	319	7	3.9
41	M	357	-	-	-	-	-	-
42	M	427	-	-	-	-	-	-
43	M	392	-	-	-	-	-	-
44	M	469	-	-	-	-	-	-
45	M	347	-	-	-	-	-	-
46	M	548	-	-	-	-	-	-
47	M	475	-	-	-	-	-	-
48	M	489	-	-	-	-	-	-

observed in *Spirula* (Denton and Gilpin-Brown 1971).

*Swimming velocity.*—Because of recent interest in the hydrodynamic properties of cephalopod shells (Chamberlain 1976; Chamberlain and Westermann 1976) and the lack of knowledge about many aspects of swimming in *Nautilus*, we conducted twenty tests of the swimming speed of the Fiji *Nautilus*. The freshly captured *Nautilus* were carried by a SCUBA diver to depths below the effect of wave surge; velocity was measured over a one meter distance (Table 5). Maximum rates of 0.25 m/sec were observed. As these rates were measured with animals under

stress, they may reflect near-maximal swimming speeds.

*Shell coloration.*—Patterns of shell coloration of the *Nautilus pompilius* from our study area are variable, but two groups can be distinguished (Fig. 4). Slightly more than half of our specimens (Variant A, Fig. 4A-F) show a pattern of brown stripes that extends from the venter to the umbilicus. Such coloration is common in *N. pompilius* elsewhere in the Pacific. The remainder of our specimens (Variant B, Fig. 4G-L) show coloration that is characteristic of *N. repertus* Iredale (1944). This pattern consists of a brownish patch on the umbilicus and brown stripes that extend

TABLE 3. Weight in seawater (buoyancy) of freshly captured *Nautilus pompilius* from the Fiji Islands.

Animal Number	Total air weight (g)	Shell & Animal Buoyancy (g)	Animal only (g)	Animal, Crop Contents removed (g)
4	505	-1.3	-	-
5	585	-1.4	-	-
7	527	-0.6	-	-
8	638	-2.5	-	-
9	542	-4.4	-	-
10	411	-3.2	-	-
11	560	-1.8	-	-
12	508	0	-	-
13	485	-1.8	-	-
19	592	-2.5	-11.7	-11.0
20	599	-1.2	-14.0	-13.2
21	551	-1.9	-11.8	-
22	534	-4.4	-14.0	-14.0
23	353	-2.0	-	-
24	531	-2.4	-	-
25	569	-1.2	-15.0	-
26	309	-2.6	-7.5	-6.0
27	496	-4.3	-12.1	-
28	477	-2.8	-11.8	-8.0
31	595	-0.8	-15.7	-
32	542	-1.5	-14.6	-12.0
36	550	-1.2	-12.7	-11.0
37	485	-0.3	-9.3	-8.4
38	630	-0.3	-14.4	-12.4
40	502	-0.2	-10.4	-10.1

from the venter to mid-flank leaving a circular white patch on the dorsolateral flank surrounding the umbilical region. The Fiji shells, however, obviously do not possess the large size generally cited as characteristic of *N. repertus*. In addition to the large size and color pattern, specimens considered to represent *N. repertus* from the W. Caroline Islands show reticulate shell sculpture and lower jaws with a chevron pattern on the calcareous elements (Dr. W. B. Saunders, pers. comm.). We have received several of these specimens from the Caroline Islands, courtesy of Mr. D. Faulkner. The reticulate pattern on these shells is only slightly more pronounced than that on the Fijian specimens. The differences in jaw structure may be related to prey differences between these forms and the examples of *N. pompilius* in Fiji and the Philippine Islands. In summary, we feel that the diagnostic characters of that *N. repertus* Iredale are insufficient to warrant specific differentiation.

Only two or three Fiji Island specimens have transitional patterns between variants A and B. The two color variants show no evidence of correlation with sex or depth; they appear to be otherwise identical and to

share the same habitat. The coloration on the hood (Fig. 5) resembles that in *N. pompilius* and *N. macromphalus* as figured by Stenzel (1964).

## Discussion

Weight distribution of our *N. pompilius* is shown in Fig. 6 and compared in Fig. 7 with that of *N. macromphalus* captured in New Caledonia (compiled by Ward and Martin, unpublished) and *N. pompilius* trapped in the Philippine Islands (1975 *Alpha Helix* expedition). The Suva population has a smaller mean weight than the other two populations. Like the collections of Willey 1902; Haven 1972; Ward and Martin, in press, our collections contain few juveniles. Adults with approximated septa vary in weight between 353 and 592 g. The total number of septa in individuals (with approximation) ranges between 28 and 32. Adults from the Philippines usually weigh over 800 g (minimum 700 g) and have 35-37 septa. Adult *N. macromphalus* from New Caledonia weigh about 650-800 g and have 29-32 septa. It is evident that the Suva adults are the smallest yet known, although they lie at the eastern margin of the species range. Most mollusk species exhibit

TABLE 4. Cameral liquid volumes and salinities. For each chamber, top figure refers to volume of liquid (measured in ml), and lower figure (in brackets) refers to salinity, where seawater = 100. TR means trace.

Animal	Total Volume in ml	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7
1	9.2	7.1 (06)	TR	0.7 (27)	0	0.6 (26)	0.3 (25)	0.3 (25)
4	2.5	2.0	0.5	TR	TR			
5	2.1	1.2 (13)	0.4 (25)	0.3 (21)	0.2 (23)	TR		
7	0.7	0.3 (20)	0.3 (32)	0.1	TR			
9	0.2	0.2 (20)						
10	0.5	0.4 (23)	0.1	TR				
11	0.5	0.5 (21)	TR					
12	0.7	0.7 (31)	TR					
13	0.1	0.1	TR					
16	0.5	0.5 (21)	-					
19	3.9	0.6 (35)	0.4 (30)	1.4 (23)	0.7 (24)	0.6 (22)	0.2 (25)	TR
20	0.4	0.4 (21)	TR					
23	4.8	2.3 (20)	0.8 (27)	0.6 (30)	0.5 (32)	0.3	0.2 (22)	0.1
24	3.9	1.2 (27)	0.4 (40)	0.5 (38)	0.4 (57)	TR	0.3	0.1
25	0.2	0.1	0.1					
26	13.5	9.8 (100)	2.0	-	0.7 (37)	0.9 (30)	0.6 (24)	0.3 (33)
27	9.3	8.6 (15)	0.6 (63)	TR	0.1			
28	16.1	13.1 (68)	0.4 (48)	1.9 (24)	0.5 (25)	TR	0.2 (28)	TR
31	3.4	2.2 (15)	0.9 (24)	0.2	0.1	TR		
32	0.1	0.1	TR					
36	0.3	0.2 (23)	0.1	TR				
37	9.2	5.8 (09)	0.5 (24)	1.0 (27)	0.6 (28)	1.0 (25)	0.3 (24)	TR
38	0.2	0.1	0.1	TR				
39	0.9	0.9 (24)	TR					
40	3.9	2.0 (17)	0.6 (28)	0.7 (28)	0.5 (29)	TR	0.1	

size increase from the center toward the margin of the geographic range (R. Tucker Abbott and Alan Kohn, pers. comm.).

There appears to be a distinct size dimorphism between fully grown males and females in the Suva Harbor population. Three

of the captured females show sutural approximation. The smallest (#23), weighing 353 g, has 30 septa with the final two septa strongly approximated. Another female (#15) is only slightly heavier, weighing 381 g and having 29 septa. In contrast, the smallest male with



FIGURE 4. Shell coloration patterns. Variant A—figs. A-F; Variant B—figs. G-L.

approximated septa (#27) weighs 496 g and has 29 septa.

The striking preponderance of males over females has previously been observed in *N. pompilius* by Willey (1902) and Haven (1973). Reasons for the paucity of females remain unknown; perhaps they simply avoid the traps, or perhaps the sexes separate during egg-laying. The near-absence of individuals less than 400 g in weight is also a paradox, for we used several traps with reduced openings with little success. The smallest individual (163 g) captured in 1975 was from

400–500 m; recently (Nov. 1976) a specimen of 132 g was captured from 400 m. A depth segregation between adults and juveniles is suggested.

The slight, but consistent, negative buoyancy of the Fijian *Nautilus pompilius* closely coincides with that of freshly captured *N. macromphalus* (Denton and Gilpin-Brown 1966; Ward and Martin 1976). It is improbable, therefore, that the animal uses positive buoyancy as an aid to upward movement. Also, it seems evident that copious feeding would have a profound effect on overall buoyancy and, thus, vertical movement under normal conditions.

The very small volumes of cameral liquid in adult, as compared to immature animals, suggests gradual removal of the liquid in adult animals until the shell is essentially empty. To compensate for this loss of weight (gain in buoyancy), the body chamber and ultimate septum are thickened (Stenzel 1964) and the body chamber probably adds a growth increment (Westermann, in press). This is probably also true for Philippine *N. pompilius* and New Caledonian *N. macromphalus*; the slightly, but consistently, higher liquid content of the adults of the latter is unexplained.

An examination of Table 2 reveals a significant discrepancy between the weight of the newly captured *Nautilus*, and the combined weights of the separately weighed soft parts, cameral fluid, and completely dried shell. In several animals this discrepancy approaches 10% of the total weight. Part of this weight difference is caused by the drying of the shell. Denton and Gilpin-Brown (1966) showed that shells weighed after extraction of cameral fluid with a hypodermic syringe, and again after complete drying, showed weight losses of up to 5%. These observations suggest that the siphuncle and septal faces including the pellicle act as significant reservoirs of liquid, even after cameral fluid

TABLE 5. Swimming Speeds of *Nautilus pompilius*.

Animal	Runs	Mean (M/sec)	High	Low	Mean Respiratory movements/min
11	4	.20	.25	.17	
12	5	.12	.17	.10	
24	5	.17	.25	.13	96
26	6	.20	.25	.17	116

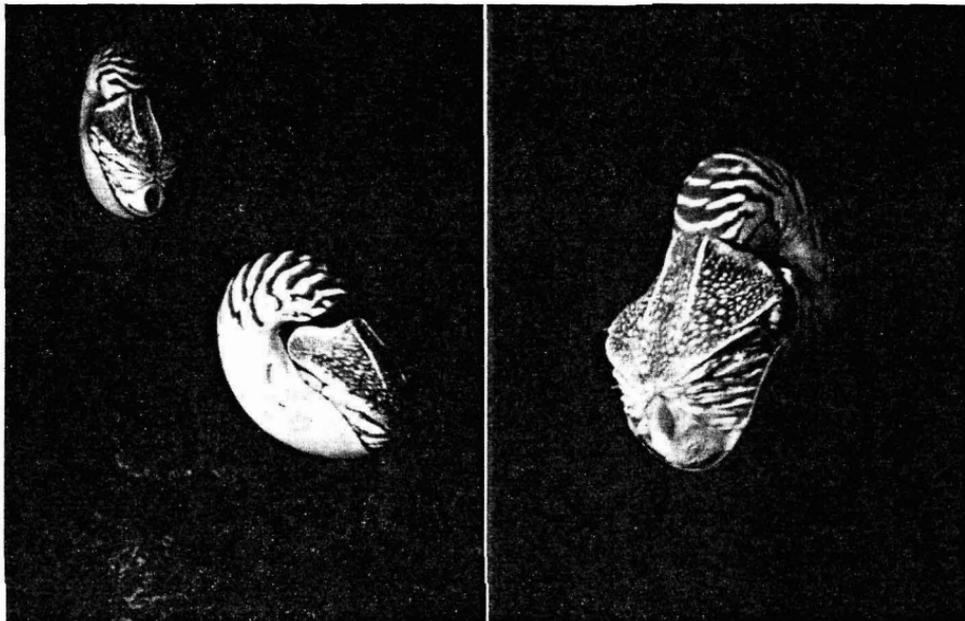


FIGURE 5. Living specimens brought into shallow water for photography.

removal. However, even with this factor taken into account, most of our specimens still have an unaccounted weight loss.

One possible explanation is operator error during weighing, even though care was taken to dry and drain the specimens of seawater before the weighings in air. A second possibility is that appreciable quantities (10–20 ml) of liquid were retained within the mantle cavity or between the mantle cavity and the shell during the weighing of the entire animal, but that this liquid was lost during removal of the soft parts from the shell. It is known that *Nautilus* forms new chambers by 1) secreting fluid into a space between the posterior mantle and the previously formed septum, and then 2) laying down a septum sealing this liquid into the new chamber, until 3) sufficient shell material has been secreted on the new septum to withstand ambient pressure, and hence allow 4) the removal of the cameral fluid behind the new septum by the osmotic mechanism proposed by Denton and Gilpin-Brown (1966). An integral part of this process is the movement of the posterior mantle away from the septal face following the completion of septal se-

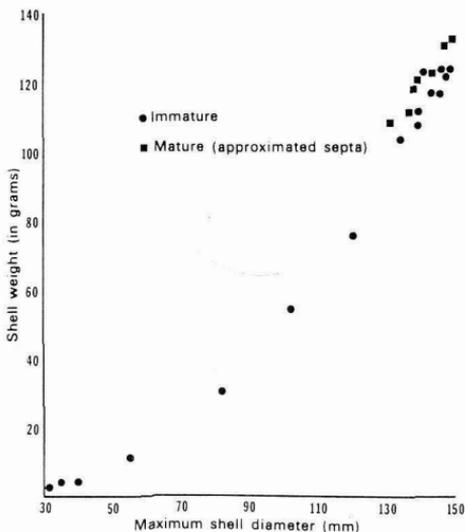


FIGURE 6. Shell weight (dried) vs. maximum shell diameter for *Nautilus pompilius* from the Fiji and Philippine Islands. Philippine Island specimens are those weighing less than 60 g and were included in the graph because of the absence of shells this size in the sampled population from Fiji. Shells with approximated septa are considered mature.

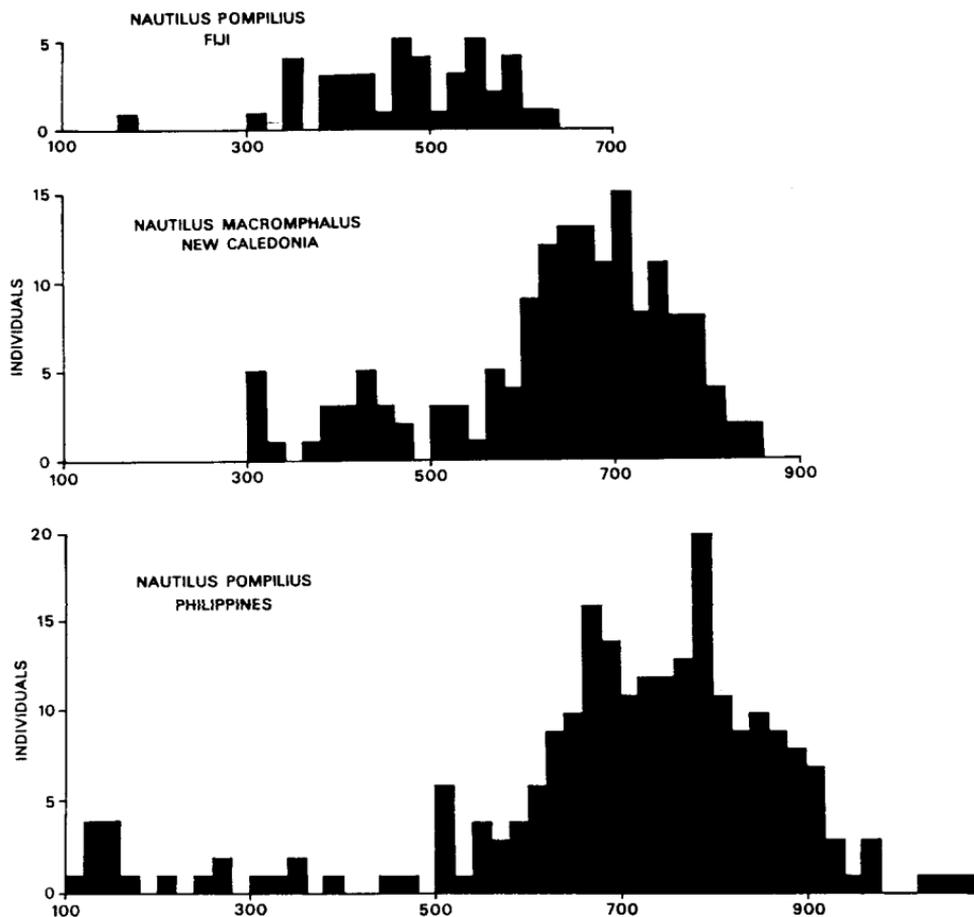


FIGURE 7. Weight distributions of *Nautilus pompilius* from the Fiji Islands, *N. macromphalus* from New Caledonia, and *N. pompilius* from the Philippine Islands (*Alpha Helix* expedition).

cretion and subsequent filling of the vacated space by saline body fluids. Removal of the soft parts would liberate any fluid behind the posterior mantle. Although we have no direct evidence of its presence, it seems possible that some of our unexplained weight loss is related to such a phenomenon.

Denton and Gilpin-Brown (1961a) have shown that in *Sepia*, the osmolarity of the cameral liquid varies with depth: animals captured or kept in deep water showed lower osmolarity (salinity). A similar observation was made by Ward and Martin (1976, and

in press) for *N. macromphalus* in New Caledonia. The relatively low salinity of cameral liquid in the Fijian *N. pompilius*, compared to those of the Philippine population and *N. macromphalus* from New Caledonia (Fig. 8), suggests that the Fiji population may have a consistently deeper habitat than the other two.

The volume of the cameral liquid in Fijian *N. pompilius* also appears to be lower than in the Philippine population and in *N. macromphalus* from New Caledonia. It is difficult, however, to compare the values for the most

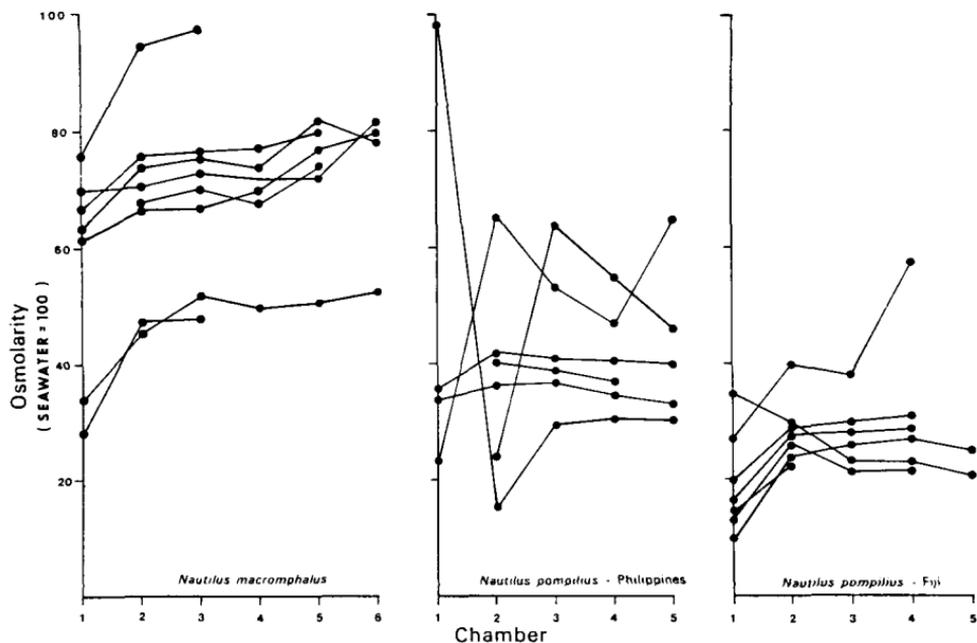


FIGURE 8. Comparison of cameral liquid salinities in sampled specimens of *Nautilus macromphalus*, New Caledonia; *N. pompilius*, Philippine Islands, and *N. pompilius*, Fiji Islands. Chamber 1 refers to most recently formed chamber. Seawater osmolarity = 100.

recently formed chamber because of the rapid changes in both volume and osmolarity immediately after cameral formation.

## Conclusions

The observations presented above suggest that the population of *Nautilus pompilius* in the Suva Harbor region lives in deep water (100–500 m), on a soft substrate, probably as predators on large concentrations of shrimp and crabs in that area. We have no evidence that these *Nautilus* migrate into shallow waters at night. At all the growth stages we have observed, members of this population possess slightly negative buoyancy. Positive uplift from the air-filled chambers is offset by the weight of shell, soft parts, and cameral liquid. In adults, cameral liquid has largely been removed, and its absence is offset by an increase in shell secretion on the aperture and on the penultimate septum.

The size of adult Fijian *Nautilus* with ap-

proximated septa is less than that of adults in any other *Nautilus* populations known, regardless of species. Females of this population seem to attain maturity at a size smaller than males. The small size, and also the occurrence of forms with a low degree of coloration compared to *N. pompilius* from the Philippine Islands, may be related to the great depths at which the Fijian *Nautilus* appears to live. Based on a comparison of cameral-fluid salinities, the habitat of the Fijian *N. pompilius* may be deeper than the depth from which *N. pompilius* of the 1976 *Alpha Helix* expedition were captured, and certainly greater than the habitats of *N. macromphalus* in New Caledonia. In New Caledonia, optimal depths of capture for the latter species were 50–75 m, on coral, reef talus, or coralline sand substrates very near the reef. In Fiji our optimal catch was from much deeper water and mud bottoms as many as several kilometers offshore of the barrier reef.

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