

## The genus *Volvarina* (Gastropoda: Marginellidae) in Polynesia

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**KEYWORDS.** *Volvarina*, Tuamotu Archipelago, Cook Islands, Polynesia, live animals, radulae, endemism, distribution patterns.

**ABSTRACT.** *Volvarina paumotensis* (Pease, 1868), a Tuamotu Archipelago endemic species is studied with reference to its original description, and from living populations recently discovered on several atolls in the type locality. The variability of the living animals and the polymorphism of their shells is demonstrated, and the features of its radula are described.

Two species of *Volvarina* discovered in Suvarrow, Northern Cook Islands, are studied. One of these is identified as being the previously described *V. elliptica* (Redfield, 1870), which has until now been considered as a species endemic to Fanning Island in the Line Islands (Kiribati). Additional records of shells from New Ireland and several Indonesian locations that have been provisionally identified by the authors as *V. elliptica* are given and it is cautiously suggested that the range of this species is extended to include these localities.

The animal and shell of the second species, *V. nealei* n. sp. are described and illustrated from a Suvarrow population discovered in an unusual micro-habitat associated with small brain corals in shallow water.

### INTRODUCTION

Polynesia comprises the Tuamotu Archipelago, the Cook Islands, the Society Islands, the Marquesas Islands, and Easter Island (Schilder & Schilder, 1939). This vast area is known to support a variety of marginellid and cystiscid species, almost all of which are endemic to their particular island group.

The Tuamotu Archipelago is a remote group of coral atolls lying immediately East of the Society Islands, and South of the Marquesas Islands in the South Central Pacific Ocean. As well as the cystiscids *Gibberula pacifica* (Pease, 1868), *G. sandwicensis* (Pease, 1860) and *Marginella micros* (Bavay, 1922), the archipelago is known to harbour the marginellids *Serrata translata* (Redfield, 1870), *S. tahanea* (Wakefield & McCleery, 2002) and *Volvarina paumotensis* (Pease, 1868). In December 2000 and August 2003, populations of *V. paumotensis* were discovered in many of the Tuamotu atolls explored for marginelliform gastropods by the second author. The study of these populations revealed the extent of the variability of both the animal chromatism and the shell morphology in this species, and provided information on its preferred habitat.

The Northern Cook Islands (N.Z.) are a remote group of four coral atolls; Tongareva (Penrhyn), Rakahanga, Manihiki, and Suvarrow, lying between the latitudes 8° and 14° South of the equator, approximately mid-way between the Society Islands and Samoa, and on the Western edge of the Polynesian faunal region. The most Northern (Tongareva) and Southern (Suvarrow) of the

Northern Cook Islands were checked for marginellids by the second author in April/May 2001, and a total of four species were discovered; two Cystiscidae (a *Gibberula* and a *Plesiocystiscus*) and two Marginellidae (*Volvarina*). The cystiscid species will be discussed in separate articles dealing with their respective complexes whereas the *Volvarina*, which were all discovered on Suvarrow, will be presented herein. The first is the previously described and very distinctively shaped *V. elliptica* (Redfield, 1870) which has until now been considered to be endemic to Fanning Island in the Line Islands.

The second *Volvarina* is a new species, *V. nealei* n.sp., which was discovered to occupy a unique and fragile microhabitat in a close association with small brain corals. It is described herein from its shell and animal characteristics.

Other Polynesian island localities except Easter Island were also checked for the presence of marginelliforms. No *Volvarina* were discovered in the Southern Cooks (Rarotonga), Society Islands (Tahiti, Moorea, Huahine, and Raiatea) or the Marquesas Islands, but as sampling saturation has not been reached in these areas, the occurrence and future discovery of *Volvarina* here cannot yet be discounted.

### Materials and Methods

*V. paumotensis* and *V. elliptica* (in the Northern Cook Is.) were collected in beach drift material from those beaches exposed to the vital reef. *V. paumotensis* was collected live from dead coral debris, and *V. nealei* from under the edges of brain

coral, using a suction bottle in order to facilitate collection and to avoid causing damage to the coral. The Indonesian specimens of *V. cf. V. elliptica* were collected by sand and coral rubble sampling by Felix Lorenz.

Photographs were taken of the living animals shortly after collection by the second author, using a Nikon digital single lens reflex camera with a 60mm Nikkor 1:2.8 D macro lens and ring flash.

### Abbreviations

ANSP: Academy of Natural Sciences, Philadelphia, USA.

MCZ: Museum of Comparative Zoology, Harvard, Massachusetts, USA.

NMNZ: National Museum of New Zealand, Wellington.

ad: adult

juv: juvenile

sh: dead shell

spm: live specimen

AWC: Andrew Wakefield Collection

TMC: Tony McCleery Collection

FBC: Franck Boyer Collection

### SYSTEMATICS

Family MARGINELLIDAE Fleming, 1828

Subfamily MARGINELLINAE Fleming, 1828

Genus *Volvarina* Hinds, 1844

Type species *Marginella nitida* Hinds, 1844 = *Marginella (Volvarina) nitida* Hinds, 1844 = *Voluta mitrella* Risso, 1826, subsequent designation Redfield 1870.

*Volvarina paumotensis* (Pease, 1868)

Figs 7, 9-12, 19-30

**Type material.** Lectotype selected and figured by Johnson (1994, Pl. 7, fig. 22), Paumotu's [Tuamotu's], 5.0 x 2.5mm, ANSP 29497. Not examined.

### Figures 1-18

1-5. *Volvarina elliptica* Redfield, 1870

1. *Volutella elongata* Pease, 1868, ANSP 29168, Fanning Is., 9 mm. Holotype (from Kaichers Card No. 2669); 2. Suwarrow, Northern Cook Is., East Coast exposed beach, 8.8 mm;

3. Kavieng, New Ireland, 8 mm; 4. Kambling Is., Alor Strait, Indonesia, 8 mm; 5. Near Pulau Balabangan

Group, W. coast Sulawesi, Makassar Strait, Indonesia, 7.5 mm.

6-8. Columella detail

6. *V. elliptica* (Suwarrow); 7. *V. paumotensis* (Fakarava West); 8. *V. nealei* (Suwarrow)

9-12. *Volvarina paumotensis* Pease, 1868, Fakarava West, demonstrating shell polymorphism (all TMC).

9. 5.2 x 2.45 mm; 10. 5.3 x 2.35 mm; 11. 5.2 x 2.50 mm; 12. 4.8 x 2.20 mm;

13. *Volvarina paumotensis* radula from an adult specimen measuring 5.2 x 2.39 mm, from Fakarava West: 42 plates each bearing 32 cusps, 116µm wide, pitch (dist. between plates) 16.5µm.

14-18. *Volvarina* sp. Suwarrow, East Coast exposed beach. 3.0 mm. TMC.

Paralectotype, ANSP 391050. Paralectotypes, MCZ 297943. Not examined.

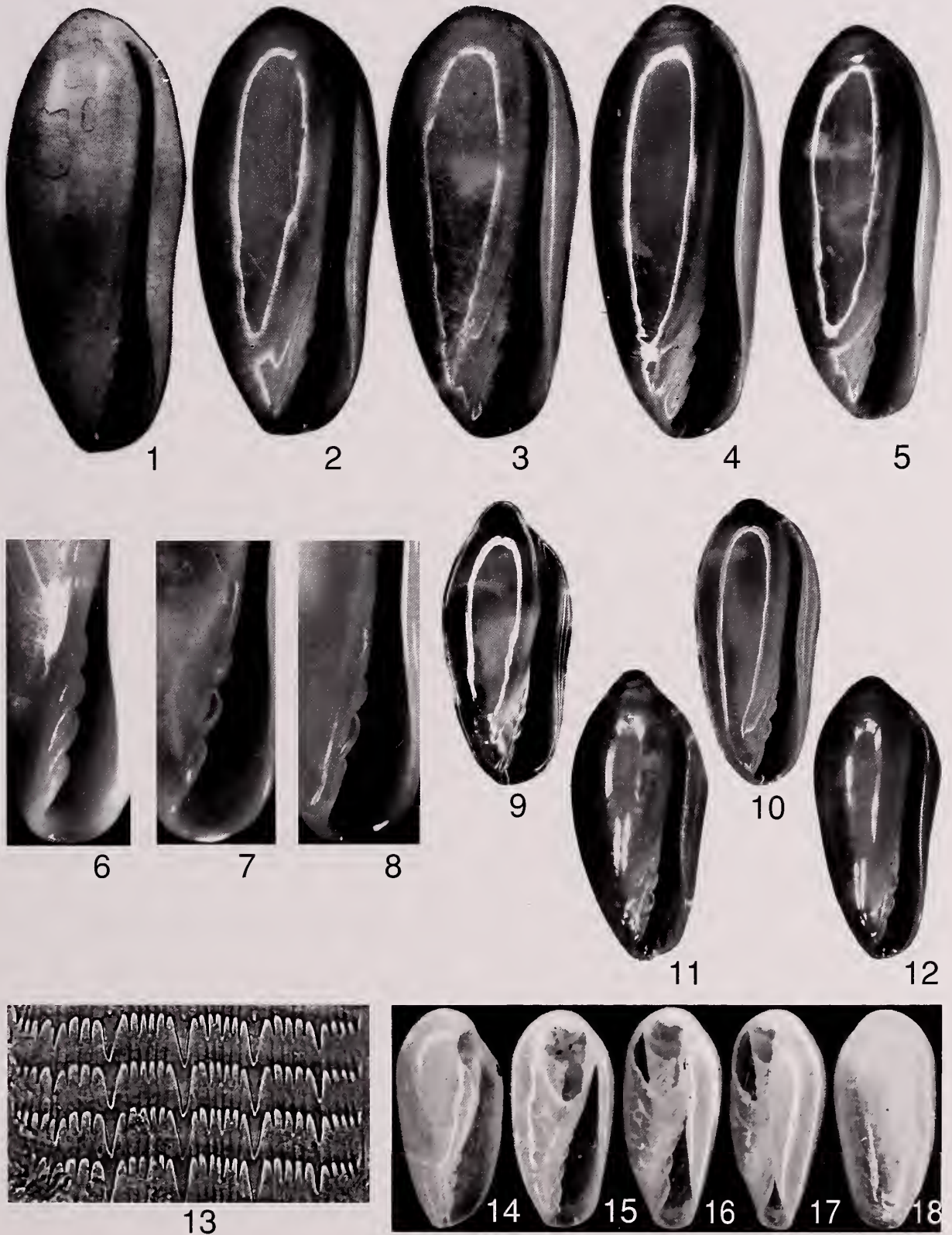
**Other material examined.** Tuamotu Archipelago, Fakarava South, outer reef beach, 1 ad sh, TMC; pass reef area, 30 ad spm, TMC; Fakarava West, inside reef, 5 ad spm, TMC; Fakarava North, inside reef, 20 ad spm, TMC; outside beach, 5 ad sh, TMC; Toau, outside beach, 2 ad sh, TMC; outside reef in 8m, 3 ad spm, TMC; Makemo, outer reef beach, 7 ad sh, TMC; Tahanea, outer reef beach, 4 ad sh, TMC; pass reef area, 33 ad sh, TMC; inner reef beach, 40 ad sh, TMC; Faaite, outer reef beach, 2 ad sh, TMC; pass reef area, 60 ad sh, TMC; Rangiroa, 2 ad sh, L = 4.6 mm & 5.0 mm, FBC; Mururoa, 4 ad sh, L = 4.9 mm, 5.0 mm, 5.0 mm, 5.0 mm, FBC. Gambier Is., 2 ad sh, L = 5.2 mm, 5.5 mm, FBC.

**Type locality.** Paumotu's (Tuamotu Archipelago).

**Distribution.** Endemic and widespread in the Tuamotu's, being most commonly found in Fakarava Atoll. Also occurs down as far as Gambier Is. in the Southeast (FBC).

**Habitat.** It lives in lumps of dead coral where there are many deep fissures between the fronds, in 0.2 to 8m mainly on the outer reefs as evidenced by the number of dead shells found beached there. Populations also have been found to inhabit shallow water on reef flat areas in and around tidal streams which drain off the flats, and living in dead coral which was heavily coated with pink and reddish algae.

**Original description.** 'Shell oblong, somewhat cylindrical, polished smooth, white, with three faint yellowish bands; spire short; lip inflexed at the middle, smooth within; columella laminately callous at base, three plaited. Dimensions Long. 5, diam. 2.25 mill.'



**Complementary descriptive notes.** Shell small (adult size, min. 4.5mm, max. 5.3mm in length). Pease described this shell as having three columellar plications when in fact as with most other *Volvarina* groups there are four (Fig. 7). The first is weak, oblique, very slightly kinked and is in close proximity to the second plication. The second and third plications are less oblique, stronger and weakly sinusoidal. The fourth is very oblique, weak, very straight and being positioned almost parallel to the parietal surface, easily missed. The colour of the shell varies from transparent or translucent white through various pale shades of yellow and brown, to the banded variety which has three more or less equally spaced reddish brown bands. The shell itself varies morphologically from ovate through elongate to sub-pyriform (Figs 9-12), although the inflexion of the lip is present regardless of the shell shape.

Animal; from a study of several animals from Fakarava West (Figs 19-30): Type 2 animal. Tentacles long and slender, either clear or with up to 4 white spots, more or less obvious in terminal half. Eyes small and black, in lateral bulge at base of tentacles. Siphon moderately long, tapering slightly, profusely spotted with white, pale yellow and red spots (Fig. 30). The red spots were very faint or lacking in some paler specimens (Fig. 29). Foot slightly less densely spotted with white, pale yellow and red, with most white spots found in clusters of 4 or 5 on metapodium and propodium. External mantle red spotted, fringed with alternating white and red spots, the red ones being single and the white ones in clusters of 4 or more (Fig. 28). Internal mantle deeply coloured to very pale, in its darkest phase showing through semi-transparent shell as dense dark purple-brown spots coinciding with the yellowish bands on the dorsal aspect of the shell, with similarly densely packed creamy white spots in between.

Radula: The radulae of three adult specimens from Fakarava were studied. Type 6 (after Covert & Covert, 1995), uniserial, short (42-44 plates), flat and broad (103-122µm wide) radula, each comblike plate bearing 30-32 sharp cusps (Fig. 13).

**Remarks.** The intensity of the colouration of the internal mantle is variable (Figs 19-24), those with the darker mantle also exhibiting the stronger banding on the shell. Both strongly and weakly coloured specimens were found in the same localities.

*V. paumotensis* is a polymorphic species, but the combined features of the columella, the three bands, the marked labial inflexion and accurate locality data will all help to identify this shell.

*Volvarina elliptica* (Redfield, 1870)  
Figs 1-6, 37

Syn: *Volutella elongata* Pease, 1868: 281. pl. 23, fig. 23 [non *Marginella elongata* Bellardi & Michelotti, 1841].

**Type material.** *Volutella elongata* (Pease, 1868); Academy of Natural Sciences, Philadelphia No. 29168, Holotype (Fig. 1, from Kaicher Card No. 2669). Not studied.

**Other material examined.** Suvarrow, Northern Cook Islands, East Coast exposed beaches, 34 ad and 1 juv sh (min 7.0 x 3.1mm, max 8.8 x 3.45mm), TMC, AWC, and Voucher material deposited in NMNZ (Figs 2, 37).

Baudisson Bay, Kavieng, New Ireland, Papua New Guinea, in coral rubble in 15-35 m, 2°44.55'S 150°39.45'E, 1 ad sh, 8mm in length, AWC, (Fig. 3). Kambling Island, West of Pantar Island, Alor Strait, Indonesia, 8°25' 51.7"S 123°53' 44.9", 4 ad. sh. (all 8.0mm in length), AWC (Fig. 4).

Point Lobe, North Sulawesi, Indonesia, in sand/rubble in 5-35m, 01°3'56"N 122°06'38"E 1 ad sh 7.5mm in length, AWC.

N. E. Talisei Islands, North Sulawesi, Bangka Strait, Indonesia, on sandy slope next to coral in 3-25m, 01°52'77"N 125°05'97"E, 1 ad sh 7.5mm in length, AWC.

Near Pulau Balabangan group, West Coast of Sulawesi, Makassar Strait, Indonesia, on sand patches amongst coral at 5-25m, 02°26'19"S 117°25'18"E, 1 ad sh 7.5mm in length, AWC (Fig. 5).

**Type locality.** Fanning Island (Line Islands).

**Distribution.** From Fanning Island in the Line Islands to Suvarrow in the Northern Cook Islands, with a possible range extension Westwards across the Pacific to New Ireland and Sulawesi, Makassar Strait, Indonesia.

**Habitat.** Unknown

**Original description.** 'Shell elongate, somewhat cylindrical, smooth, white, faintly banded with yellowish: spire very short, outer lip slightly thickened externally, involute: aperture narrow, linear, slightly expanded at base; columella four-plaited, laminately callous at base. Dimensions; long. 9 ½, diam. 3 ½ mill.'

**Complementary descriptive notes.** The four very gently curving columellar plications are extremely oblique (Fig 6). The fourth plication in this species is stronger than the same plication in *V. nealei* and *V. paumotensis*. The parietal surface is very straight, or weakly concave at the mid-apertural point, and bears a thin callus wash. The posterior end of the lip inserts very high on the spire giving the shell a fusiform profile. When viewed laterally the fine lip has a sinuous curve along its length and is inflexed slightly below mid-body. The aperture is wide anteriorly, becoming very narrow and fine before its posterior termination at about the level of the suture. The

length of the shell varies between 7 and 9 mm across the range. Mature specimens appear to develop stouter shells (Fig. 37).

**Remarks.** *Marginella elongata* Bellardi & Michelotti, 1841 is a large (length of type = 29.3mm with a broken base, projected actual length approx. 32mm) fossil *Volvarina* from the lower Miocene of Turin, Italy (Ferrero Mortara et al., 1982). Hence Pease's description in 1868 of *Volutella elongata* for a species that was also a *Volvarina* was invalid as it was preoccupied. Thus the name *Marginella elliptica* (Redfield, 1870) was proposed as a replacement name for *Volutella elongata* (Pease 1868), and this stands as the valid name.

The species has a very distinctive shell morphology and Suwarow shells are comparable to the type specimen (Fig. 1), figured by Kaicher (1981), card No. 2669. They were dead collected on beaches exposed to the vital reef in several places along the East coast of Suwarow. A few were hand dredged in sand on the inside of the vital reef. This species probably lives either in the vital reef itself or in the turbulent shallow water immediately on the inside of it. The best shells collected were glossy and semi-transparent, but four of them (including the juvenile) showed three very pale yellowish brown bands and an overall pale translucent brown tint. It is therefore likely that as with *V. paumotensis* from the Tuamotu's, only some of the specimens are banded. Consequently, when discovered, the animals will probably bear a pattern and colours varying from faint to intense. Kaicher (1981) comments that *V. elliptica* is 'white; maybe yellowish banded', so it would appear that the observations on the chromatism of *V. paumotensis* would also apply to the Fanning Island population of *V. elliptica* (in fact Pease's original description of *Volutella elongata* also refers to the faint bands).

Four examples of a species bearing a shell which is morphologically indistinguishable from *V. elliptica*, and which we are currently referring to as *V. cf. V. elliptica*, have recently been discovered in the Alor Strait, West of Pantar Is., Indonesia (recolt of F. Lorenz, now in AWC, Fig. 4). Three more slightly smaller specimens have also been obtained from North and West Sulawesi (Fig. 5). In addition another single shell with the same morphology and size (albeit slightly wider) has been discovered in New Ireland (Fig. 3) and it too is similarly identified. These new records were made from empty shells only, taken in coral debris, amongst an overall recolt of other live taken marginellid species, and therefore as with *V. elliptica* from Suwarow and Fanning, are likely to have had a cryptic and possibly inaccessible habitat. Due to lack of live animal population data and the monomorphic nature of the shell it is not yet possible to definitively state that we are dealing with a single species with an extremely wide geographic distribution or a cline of multiple sibling species.

There is, however, no doubt that there is a wide distribution of populations of very similar shells from the Central Pacific to the Eastern side of the Makassar Strait, Indonesia. Further fieldwork in Central Pacific Island localities such as the Gilbert, Phoenix and Marshall Islands will be required to assess whether this range is continuous or fragmented, and further exploration in Nusa Tenggara and on the Indian Ocean side of Bali, Java and Sumatra will be of use in discovering how far West it is found and whether or not it has managed to cross the Wallace line.

*Volvarina nealei* n. sp.

Figs 31-36

**Type material.** Anchorage Island reef, Suwarow, Northern Cook Islands, 0.6m, holotype (4.45 x 1.95mm), ref. no. M.273210, NMNZ (Figs 34, 35), and 2 paratypes (4.35 x 2.0 mm, 4.35 x 1.95 mm), ref. no. M.273211, NMNZ. Paratypes (4.40 x 1.95mm, 4.35 x 1.95mm) AWC.

**Other material examined.** Anchorage Island reef, Suwarow, Northern Cook Islands, 0.6m, 5 ad spm, 4 ad sh TMC: East large pass reef, 0.2 – 1.0m, 1 ad spms, 2 ad sh, TMC.

**Type locality.** Anchorage Island, Suwarow, Northern Cook Islands, 13°15.2' S 163° 06.3' W.

**Distribution.** Only so far found at type locality. Possibly endemic.

**Habitat.** In dead coral pieces in shallow water (0.3 – 1.0m), and also in association with small brain corals on algae covered limestone flats.

**Description.** Shell smooth, glossy, ovate and elongate, spire moderately high, weakly concave or convex sided, nucleus bluntly rounded. Shoulders weak, body whorl either tapering gently to base or widening slightly to mid way then tapering to base. Labrum thickened internally, inflexed centrally, joining body whorl at suture. Aperture narrow, nearly parallel in its posterior half, flaring anteriorly. Base rounded, weak elongate, narrow posterior notch, siphonal notch absent. Parietal surface concave above columella. Columella with 4 very oblique placations; first weak, almost straight. Second strongest, sinusoidal. Third weaker than second, sinusoidal. Fourth very oblique, weak, fusing to the third anteriorly. Columella bordered to its left by a groove. Colour pale translucent golden tan, becoming deeper from mid-dorsal to labrum. Colour absent in columellar region.

Animal: Type 2 animal, foot just wider than shell, back of foot extending a short way beyond shell apex. Foot, head, tentacles all translucent white, siphon long, relatively thick, translucent, middle third

with diffuse, extremely faint reddish-brown reticulation, Eyes small, black, ringed very faintly with orange-yellow, situated laterally at base of tentacles.

Radula not observed.

**Remarks.** This species was found at two localities in Suwarrow: In the large Eastern pass area it was found alive in grit from dead coral lumps taken from 0.3 to 1.0m. It was also found during shallow night dives on the South side of Anchorage Island where the species occupies a specialized niche. This is an area of algae covered limestone flats and the live specimens were collected (using a special suction bottle) from under the edges of small brain corals which were attached to the limestone. A few specimens were found out in the open on the algae, but always in close proximity to the coral. The area was subject to little current but considerable wave action and the water was clean and fresh. It was also noted that no specimens were found near the shore where the algae was thicker, and none in deeper water where the cover was thinner or bare. Where the animals were in evidence, there was a thin algal layer present, and whereas live *Volvarina* are normally highly mobile animals, those of *V. nealei* appeared to be motionless in their natural environment.

**Etymology.** *V. nealei* is named for the local character Tom Neale who was the sole inhabitant of Anchorage Island, Suwarrow.

## DISCUSSION

All three of these *Volvarina* have a particularly distinctive columellar morphology (Figs 6-8). The thickened, raised columella bears four very oblique columellar plications, most evident in *V. elliptica* where all of the plications appear to weaken and fuse together into a ridge as they emerge (Fig. 6). To its left the columella ridge is bordered by a groove which extends beyond the fourth plication posteriorly and obliquely to just below the mid-apertural point.

All of these shell characters are shared by the Northern Caribbean species *V. subtriplicata* (Orbigny, 1842) and it is possible that they share an ancestral relationship.

*V. paumotensis* and *V. nealei* share very similar columellar morphology and are likely to be closely related. *V. nealei* does, however, differ from *V. paumotensis* in other respects. *V. nealei* is polymorphic (Figs 32, 35) though not quite to the same extent as *V. paumotensis* (Figs 9-12). *V. nealei* tends to have a higher spire with a more rounded nucleus, and the lip inflexes more. The parietal surface in *V. paumotensis* has a slightly concave profile but that of *V. nealei* tends to be very concave, imparting a noticeable bend in the long axis of the shell. *V. nealei* is smaller, averaging 4.45mm in length (compared to 5mm for *V. paumotensis*), with the siphon being noticeably longer and thicker, and the tentacles shorter than the Tuamotu species. The chromatism of the shells is different; *V. nealei* is never banded like *V. paumotensis*, and it develops more yellowish colour on the body whorl towards the lip in mature shells.

By virtue of their longitudinal position and lying just South of the Equator, the Northern Cook Islands lie at an important conjunction of four faunal regions; Polynesia to the Southeast, the group of archipelagos forming Samoa, Tonga and Fiji to the Southwest, the Hawaiian chain including the Line and Kingsmill Islands to the North, and the Gilbert, Phoenix and Marshall Islands of the Central Pacific region to the Northwest. From a faunal point of view the Cook Islands are considered to be within the Polynesian region, but since they lie on its Western edge it would not be surprising to encounter some overlap of other regionally representative species in such a place. The occurrence in the Northern Cooks of *V. elliptica*, previously considered endemic to Fanning Island in the Line Islands, is a good example of this. Its appearance in the Cook Islands, however, is a little unusual since as a general rule the molluscan fauna

## Figures 19-37

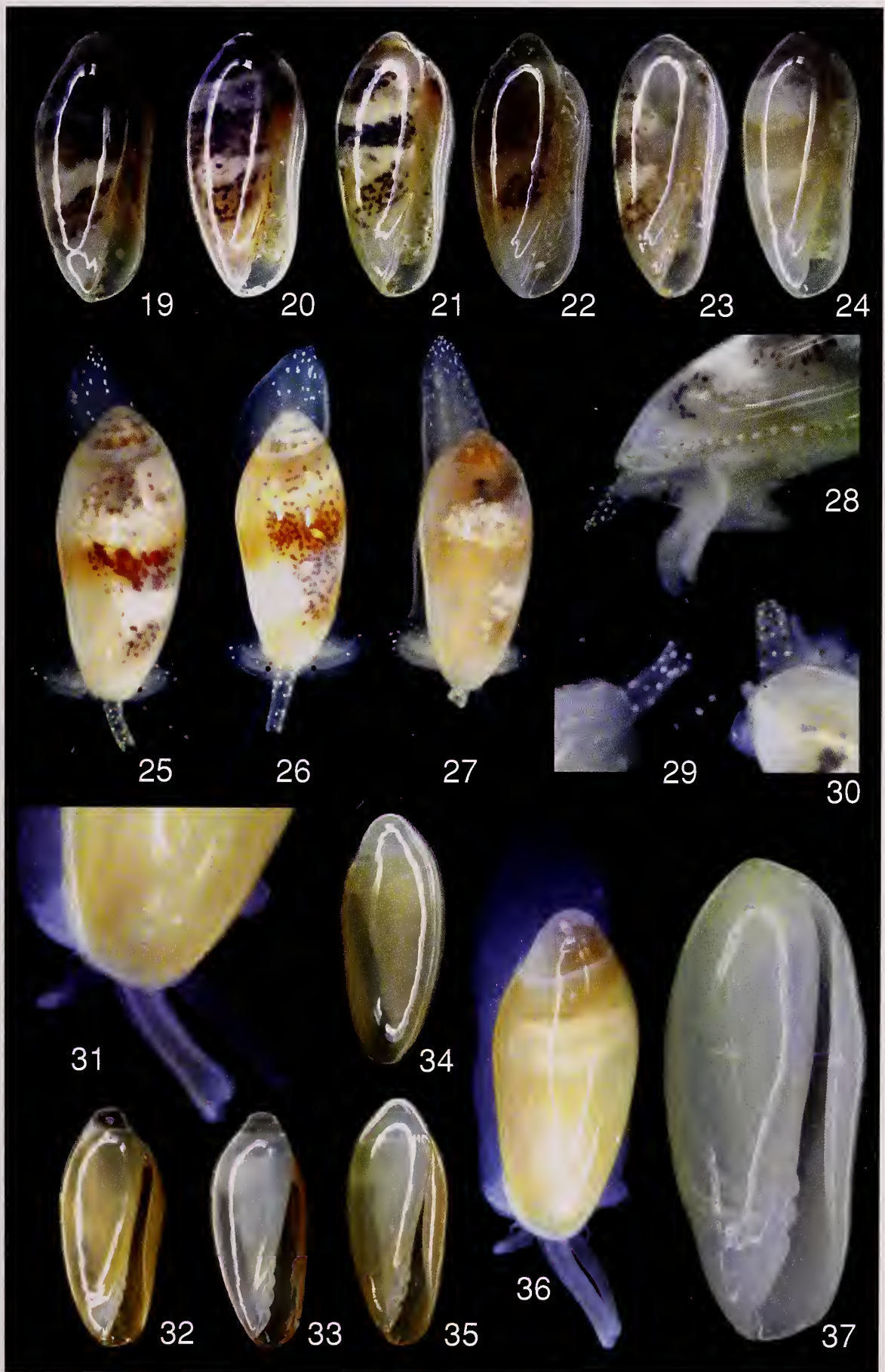
**19-30** *Volvarina paumotensis* Pease, 1868, Fakarava West, demonstrating the variability of colouration and pattern of internal mantle (all TMC).

19. 4.80 x 2.22 mm; 20. 5.11 x 2.40 mm; 21. 5.15 x 2.35 mm; 22. 4.90 x 2.23 mm;  
23. 5.10 x 2.30 mm; 24. 5.10 x 2.35 mm; 25. 5.15 x 2.35 mm; 26. 5.10 x 2.30 mm;  
27. 5.10 x 2.35 mm; 28. lateral view showing external mantle edge; 29. animal with no red spots on tentacles and siphon; 30. animal with red spots on tentacles and siphon.

**31-36.** *Volvarina nealei* n. sp., Suwarrow, Northern Cook Is.

31. detail of siphon and tentacles; 32. 4.50 x 2.1 mm; 33. 4.35 x 2.0 mm; 34. Holotype, NMNZ no. M.273210, 4.52 x 1.96 mm, dorsal; 35. Holotype, NMNZ no. M.273210, 4.52 x 1.96 mm, ventral; 36. 4.45 x 1.9 mm, live animal.

**37.** *Volvarina elliptica* Redfield, 1870, in beach drift, Suwarrow, N. Cook Is, 8.8 x 3.45 mm. TMC.



of the Line Islands is similar to that found in the Islands of the Central Pacific rather than to the Polynesian fauna (Kay, 1971). So, unlike many species, *V. elliptica* appears to have been able to disperse across the equator to the Cooks (or vice versa), and due to the lack of appreciable traffic between both localities there seems no reason to believe that this phenomenon is anything other than natural dispersion. We are unaware if *V. elliptica* occurs in Jarvis Is., an outlier some 400 miles South of Fanning Is, or if it is also found in the outliers which are South of the Equator (Malden, Starbuck and Flint Is.) which form a geographic link to the Cooks. More Central Pacific Island groups therefore need to be checked for marginellids and it will be interesting to see if *V. elliptica* or a sibling species is present.

The ability of *V. paumotensis* and *V. nealei* to adapt to a variety of local microhabitats and depths seems to be contrasted with that of *V. elliptica* whose habitat appears to be restricted to an unknown niche somewhere in the vital reef, possibly in association with a particular coral morphology or species.

A single unusual shell (*Volvarina* sp.) was found beached on the North coast of Suvarrow (Figs 14-18). This shell appears to be of a shape which resembles the Cystiscid genus *Plesiocystiscus* (Covert & Covert, 1995) but this is clearly not the case since it does not have Cystiscid internal whorls. Neither is it a juvenile of *V. nealei* which is an altogether different shape (Fig. 33). The labrum is beginning to inflex at its growing edge, leading to the conclusion that it is reaching maturity, but the columellar region looks quite juvenile due to its very concave shape. This shell may prove to be another new species of *Volvarina* or *Hyalina*, or may simply represent the juvenile form of *V. elliptica*. Further searching along the beaches of Suvarrow may turn up further shells for comparison and identification.

#### ACKNOWLEDGEMENTS

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