

The distribution of freshwater gastropods on four Vanuatu islands : Espiritu Santo, Pentecost, Éfate and Tanna (South Pacific)

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Keywords : Pacific, Vanuatu, freshwater, gastropods, distribution.

Streams and rivers on the Vanuatu islands of Espiritu Santo, Pentecost, Éfate and Tanna were sampled for gastropods and the physical and chemical characteristics of the water were investigated between 25/11/95 and 13/12/95. Twenty three species of neritid and fourteen of thiarid prosobranch gastropods were found, together with the pulmonate *Physastra nasuta* and an opisthobranch species *Strubellia*. Six thiarid, two *Clithon* and one *Neritina* species, which are present in the Solomon Islands and South East Asia, but which are absent further south on New Caledonia and the Fiji islands, were found on the Vanuatu islands. On the other hand, *Septaria bougainvillei* and *Clithon pritchardi*, which are present on the Fiji islands and New Caledonia, were found no further north than the southern Vanuatu island of Tanna. This suggests that Vanuatu is a transition zone for both northern and southern freshwater snails. Éfate had many more species (26) than the other islands (16-19). This was partly explained by its central geographical position and the higher ion content of its streams.

La distribution de Gastéropodes d'eau douce dans quatre îles de Vanuatu : Espiritu Santo, Pentecoste, Éfate et Tanna (Pacifique Sud)

Mots-clés : Pacifique, Vanuatu, eau douce, Gastéropodes, distribution.

Les Gastéropodes des cours d'eau de 4 îles de l'archipel de Vanuatu, Espiritu Santo, Pentecoste, Éfate et Tanna ont été échantillonnées et les caractéristiques physico-chimiques des milieux étudiées du 25/11/95 au 13/12/95. Vingt-trois espèces de néritidés et quatorze de gastéropodes prosobranches thiaridés ont été trouvés, avec le pulmonate *Physastra nasuta* et une espèce opistobranch de *Strubellia*. Six thiaridés, deux *Clithon* et une espèce de *Neritina*, qui sont présentes aux îles Solomon et en Asie du sud-est, mais absentes plus au sud en Nouvelle-Calédonie et aux Fidji, ont été trouvés à Vanuatu. En revanche, *Septaria bougainvillei* et *Clithon pritchardi*, qui sont présentes aux îles Fidji et en Nouvelle-Calédonie, n'ont pas été trouvés au nord de l'île méridionale Tanna de Vanuatu. Cela suggère que le Vanuatu est une zone de transition aussi bien pour les gastéropodes septentrionaux que méridionaux. Éfate possède beaucoup plus d'espèces (26) que les autres îles (15-19). Ceci s'explique, en partie, par sa position géographique centrale et la plus forte teneur en ions de ses rivières.

1. Introduction

Land and some freshwater molluscs of Vanuatu (ten New Hebrides) were reviewed by Solem (1959). He mentioned only three species of freshwater gastropods,

Gyraulus montrouzieri (Gassies), *Physastra nasuta* (Morelet) and *Fluviopupa brevior* (Ancey), all found on Espiritu Santo. In his review he did not include the families Neritidae and Thiaridae. Nevertheless, many species of these families e.g. *Neritina pulligera*, *Septaria suffreni* and *Thiara scabra* were later found more than 20 km inland on Viti Levu, Fiji (Haynes 1985).

Starmühlner (1976) investigated some rivers (6 sites) on the island of Éfate and found 18 species including 6 species of thiarids, 10 species of neritids and *P. nasuta* and *F. brevior*.

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Vanuatu is a Y shaped archipelago of 74 inhabited islands and over 200 smaller islands. In this study the streams and rivers of four islands were investigated. The islands were Espiritu Santo, the most northerly and largest, Pentecost to its south east, Éfate about 170 km further south and Tanna 200 km south of Éfate (Fig. 1).

Vanuatu's nearest neighbours are Solomon Islands 540 km to the north, New Caledonia 329 km to the south west and Fiji 600 km to the east (Fig. 1). The freshwater gastropods of the island groups, North and South and South of Vanuatu, had been investigated. Haynes (1993) studied the Solomon Islands of New Georgia, Guadalcanal, Mailata Makira and Haynes (1985, 1988a, 1990) recorded the snails on most high islands of Fiji. Franc (1956), Starmühlner (1976) and Pöllabauer (1986) recorded freshwater snails in New Caledonia.

The previous investigations showed that certain gastropods are present in Solomon Islands but absent from

New Caledonia or Fiji, while others are present in New Caledonia or Fiji but absent from Solomon Islands.

As it is generally believed that neritid and thiarid gastropods arose in South East Asia (Starmühlner 1976, Haynes 1988b, 1990) and were distributed southwards into the south Pacific, it was anticipated that Vanuatu, situated between these three island groups, might be a region of faunal change. To test this eventuality, Vanuatu islands were sampled along a North-South gradient.

2. Study area

The islands of Vanuatu are composed of mainly volcanic rock often overlaid by younger limestone. The East of Espiritu Santo is composed of recent limestone and has few streams while the western part is made of older volcanic rock but is inaccessible by road from Luganville. Sampling sites on Espiritu Santo were in the south and interior of the island (Fig. 2 A).

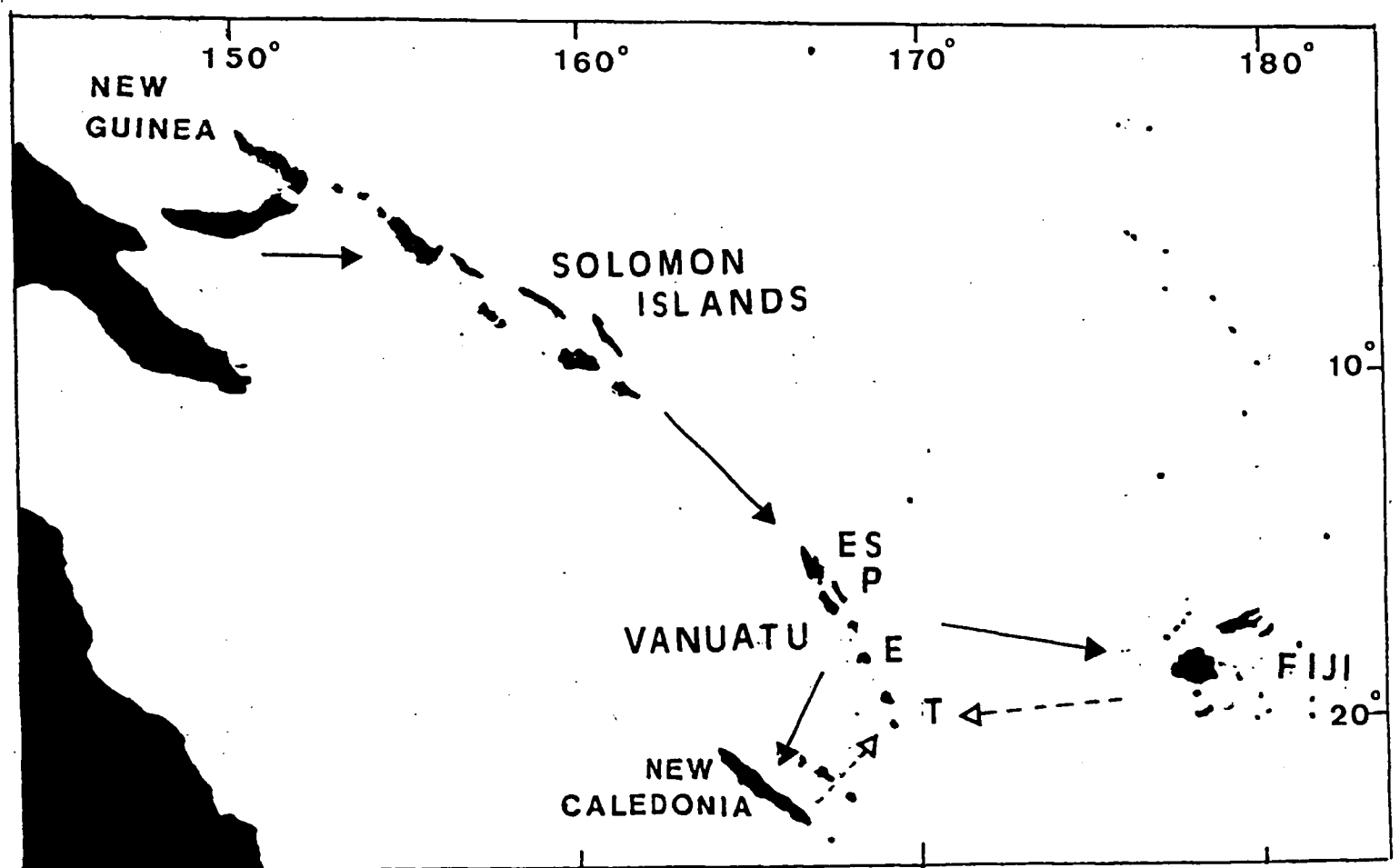


Fig. 1. Map of the South Pacific. Arrows show the direction of dispersal of freshwater neritid and thiarid gastropods from South East Asia and the dotted arrows the possible dispersal to Tanna from New Caledonia and Fiji. ES : Espiritu Santo, P : Pentecost, E : Éfate, T : Tanna.

Fig. 1.-Carte du Pacifique sud-ouest. Les flèches indiquent la direction de répartition des néritidés et thiaridés Gastéropodes d'eau douce à partir de l'Asie du sud-est, et les flèches en pointillés, la dispersion possible vers Tanna à partir de la Nouvelle-Calédonie et des Fidji. ES : Espiritu Santo, P : Pentecoste, E : Éfate, T : Tanna.

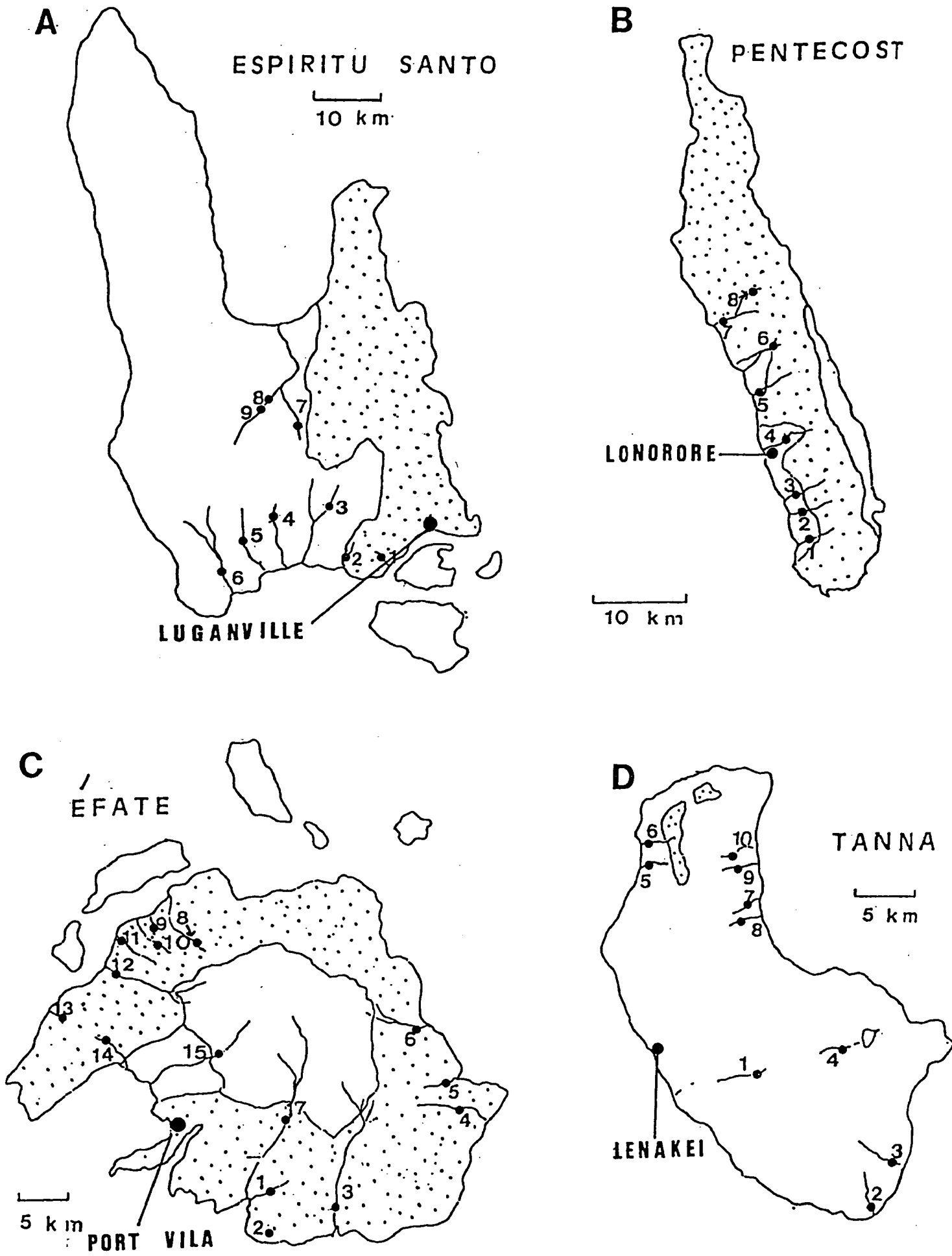


Fig. 2. Maps of the four Vanuatu islands showing the sampling sites. Limestone areas are stippled.

Fig. 2. Carte des quatre îles de Vanuatu, indiquant les sites d'échantillonnage. Les zones claires sont en pointillés.

North Pentecost consists mainly of limestone overlying older volcanic rocks and lacks permanent streams. The eastern side is very wet and inaccessible by road. Sampling sites were on the South East side where the substratum was mainly volcanic or volcanic rock overlaid by limestone (Fig. 2 B).

Éfate's rock is mainly pumice breccia overlaid by limestone. The road around the island made it possible to sample all coasts and inland at Lolima cascades (Fig. 2 C : site 7) on the Teowma River.

Tanna's rocks are mainly volcanic ruffs, breccias and basalts with a recently raised reef along the West coast where streams, between Lenakei and Kamera, were dry on the coast but still flowing in the hills (Fig. 2 D : sites 1 & 4).

3. Material and methods

Sampling took place on 25-28 November (Éfate), 2-5 December (Pentecost), 8-11 December (Espiritu Santo) and 11-12 December (Tanna).

Two or more people searched the substratum at each site for at least 30 minutes. Leaf litter, plants, wood and all surfaces of stones and boulders were inspected and sand and gravel were sieved. The specimens collected were killed in magnesium sulphate solution and preserved in 80 % ethanol.

Water velocity and temperature were noted. Water samples collected at each site, were analysed for pH and total ions (conductivity mS m^{-1}) with sensors.

4. Results

The gastropod species found at each site on the four islands are given in Tables 1-4. A total of 39 species of gastropods were collected. Voucher specimens of the gastropods collected have been deposited in the Australian Museum, Sydney. The 23 species of Neritidae were *Clithon bicolor* (Récluz)(C.204240), *C. chlorostoma* (Sowerby)(C.204241), *C. corona* (Linné)(C.204242), *C. diadema*, (Récluz)(C.204243), *C. nucleolus* (Morelet)(C.204244), *C. olivaceus* (Récluz)(C.204245), *C. pritchardi* (Dohrn)(C.204246), *C. squarrosus* (Récluz)(C.204247), *Neritilia rubida* (Pease)(C.204248), *Neritina adumbrata* (Reeve)(C.204249), *N. asperulata* Récluz(C.204250), *N. auriculata* Lamarck(204251), *N. canalis* Sowerby(C.204252), *N. petitii* Récluz(C.204253), *N. porcata* Gould(C.204254), *N. pulligera* Linné(C.204255), *N. squamaepicta* Récluz(C.204256), *N. tahitiensis* Lesson(C.204257), *N. turtoni* Récluz(C.204258), *N. variegata* (Lesson)(C.204259),

Septaria bougainvillei (Récluz)(C.204260), *S. porcellana* (Linné)(C.204261), *S. sanguisuga* (Reeve)(C.204262). The 14 Thiaridae species were *Balanocochlis glans* (v.d.Busch)(C.204263), *Melanoides arctecara* Mousson(C.204264), *M. aspirans* (Hinds)(C.204265), *M. costata* Quoy & Gaimard(C.204266), *M. pallens* (Reeve)(C.204267), *M. plicaria* (Born)(C.204268), *M. punctata* (Lamarck)(C.204269), *M. torulosa* (Bruguère)(C.204270), *M. tuberculata* (Müller)(C.204271), *Melanopsis frustulum* Morelet(C.204272), *Tarebia granifera* (Lamarck)(C.204273), *T. bellicosa* (Hinds)(C.204274), *T. cancellata* Roding(C.204275), *T. scabra* (Müller)(C.204276). The other two species were the Planorbidae *Physastra nasuta* (Morelet)(204277) and an opisthobranch of the genus *Strubellia* (Kuthe)(204278).

The number of species found at each site varied from 1 to 12 (Tables 1-4). The mean water velocity and the mean total ions were calculated to find if there was any correlation between either and the number of species present. The correlation coefficient $r = 0.409$ for the number of species and water velocity was not significant, but $r = 0.698$ for the number of species and total ions indicated a correlation at the 5 % level. Total ion content at some sites, that were less than 0.3 km from the sea, was influenced by tidal sea water.

Fig. 3 shows the distribution of neritid freshwater gastropod species and Fig. 4 of the thiarids throughout the four Vanuatu islands and the adjacent archipelagoes of Solomon Islands, New Caledonia and Fiji. Species present in Solomon Islands are also found in South East Asia (Reich 1937, Starmühlner 1976).

The neritids *N. asperulata*, *C. bicolor*, *C. nucleolus* and *S. porcellana* are not present in Fiji while *C. squarrosus*, *C. chlorostoma* and *N. adumbrata* are absent from both New Caledonia and Fiji. On the other hand, *C. pritchardi* and *S. bougainvillei*, present on New Caledonia and Fiji were only found on the most southerly Vanuatu island Tanna (Fig. 3) and they have not been reported from any island further north.

The thiarids also show a disruptive distribution (Fig. 4). *M. aspirans* and the worldwide species *M. tuberculata* are the only species found in all four countries. Six species (*T. granifera*, *T. cancellata*, *M. punctata*, *M. pallens*, *M. torulosa*, *B. glans*) have not been distributed further South than Vanuatu although *T. granifera* is present in the eastern Pacific on the Society Islands (Pointier & Marquet 1990).

The number of species found on each Vanuatu Island is not only determined by the island area and the number of streams present but also by the number of col-

Table 1. Gastropods, water velocity and total ionic content at the Espiritu Santo island sites .

Tableau 1. Les Gastéropodes, vitesse de l'eau et contenu total en ions pour les sites d'Espiritu Santo.

Site & river	Map reference	Distance from sea (km)	Water speed (m s ⁻¹)	Total ions (m S ⁻¹)	Gastropods
1. Stream on south coast	15° 34' S 167° 7' E	0.3	0.1	54.5	<i>N. auriculata</i> , <i>N. rubida</i> , <i>C. oliveaceus</i> , <i>T. cancellata</i> .
2. Road ford	15° 36' S 167° 4' E	0.2	0.3	45.4	<i>C. bicolor</i> , <i>M. punctata</i> , <i>T. scabra</i> .
3. Adson R.	15° 33' S 166° 57' E	5.0	0.4	27.2	<i>C. bicolor</i> , <i>C. squarrosus</i> , <i>M. punctata</i> <i>C. oliveaceus</i> , <i>M. plicaria</i> , <i>B. glans</i> , <i>N. pulligera</i> .
4. Wailapa R.	15° 32' S 166° 55' E	5.0	0.6	29.3	<i>C. bicolor</i> , <i>C. oliveaceus</i> , <i>S. porcellana</i> , <i>M. punctata</i> , <i>M. torulosa</i> , <i>T. scabra</i> .
5. Baialo R.	15° 34' S 166° 53' E	2.0	0.6	31.3	<i>S. bicolor</i> , <i>C. squarrosus</i> , <i>C. oliveaceus</i> , <i>N. rubida</i> , <i>M. punctata</i> , <i>M. aspirans</i> , <i>M. plicaria</i> , <i>B. glans</i> , <i>T. scabra</i> , <i>T. granifera</i>
6. Navaka R.	15° 36' S	1.0	0.8	25.2	-
7. Lape R.	15° 17' S 166° 55' E	15.0	0.4	31.3	<i>M. tuberculata</i> , <i>M. torulosa</i> , <i>T. scabra</i> , <i>T. granifera</i> , <i>T. bellicosa</i>
8. Ora R.	15° 16' S 166° 53' E	13.0	0.4	26.4	<i>M. tuberculata</i> , <i>T. granifera</i> , <i>P. nasuta</i> , <i>T. bellicosa</i> .
9. Pool by Ora R.	15° 16' S 166° 53' E	13.0	0	33.3	<i>T. granifera</i> , <i>T. bellicosa</i> , <i>P. nasuta</i> .

Table 2. Gastropods, water velocity and total ionic content at the Pentecost island sites.

Tableau 2. Les Gastéropodes, vitesse de l'eau et contenu total en ions pour les sites de Pentecoste.

Site & river	Map reference	Distance from sea (km)	Water speed (m s ⁻¹)	Total ions (m S ⁻¹)	Gastropods
1. Warbot R.	15° 58' S 168° 12' E	0.3	0.6	36.3	<i>C. bicolor</i> , <i>C. squarrosus</i> , <i>C. oliveaceus</i> , <i>N. variegata</i> , <i>M. tuberculata</i> , <i>T. granifera</i>
2. Pambo R.	15° 55' S 168° 12' E	0.3	0.3	37.4	<i>C. bicolor</i> , <i>C. corona</i> , <i>C. oliveaceus</i> , <i>C. canalis</i> , <i>M. plicaria</i> , <i>M. pallens</i>
3. Walap R.	15° 53' S 168° 11' E	0.3	0.5	35.3	<i>C. bicolor</i> , <i>C. squarrosus</i> , <i>C. oliveaceus</i> , <i>S. porcellana</i> , <i>M. torulosa</i> .
4. Airport R. at Lonorore	15° 52' S 168° 10' E	0.4	0.7	32.3	<i>C. bicolor</i> , <i>C. squarrosus</i> , <i>C. oliveaceus</i> , <i>N. canalis</i> , <i>S. porcellana</i> , <i>M. punctata</i> .
5. Whitewater R.	15° 49' S 168° 10' E	0.2	0.5	35.3	
6. Waterfall R.	15° 48' S 168° 10' E	1.0	0.6	29.3	<i>M. tuberculata</i>
7. Melsisi R.	15° 45' S 168° 8' E	0.3	0.5	29.3	<i>C. bicolor</i> , <i>C. squarrosus</i> , <i>C. oliveaceus</i> , <i>C. chlorostoma</i> , <i>S. porcellana</i> , <i>M. aspirans</i> , <i>M. plicaria</i> , <i>M. punctata</i> , <i>M. tuberculata</i>
8. Melsisi R. gorge	15° 44' S 168° 9' E	1.0	0.6	32.3	<i>S. porcellana</i> , <i>M. tuberculata</i> , <i>M. punctata</i> , <i>M. arctecara</i> .

Table 3. Gastropods, water velocity and total ionic content at the Éfate island sites .
 Tableau 3. Les Gastéropodes, vitesse de l'eau et contenu total en ions pour les sites d'Éfate.

Site & river	Map reference	Distance from sea (km)	Water speed (m s ⁻¹)	Total ions (m S ⁻¹)	Gastropods
1. Small stream	17° 48' S 168° 22' E	0.2	0.1	14.0	<i>N. tuberculata</i> , <i>M. costata</i> , <i>T. bellicosa</i>
2. Pond at White Sands	17° 49' S 168° 23' E	0.1	0	11.2	<i>M. costata</i> .
3. Japanese R.	17° 45' S 168° 27' E	0.2	0.3	48.0	<i>C. diadema</i> , <i>N. auriculata</i> , <i>T. scabra</i> , <i>n. tahitiensis</i> .
4. Ewor R.	17° 42' S 168° 33' E	0.5	0.4	50.0	<i>C. nucleolus</i> , <i>C. squarrosus</i> , <i>C. corona</i> , <i>N. variegata</i> , <i>M. tuberculata</i> , <i>M. plicaria</i> .
5. Forari R.	17° 41' S 168° 31' E	0.3	0.3	31.0	<i>M. plicaria</i> , <i>M. tuberculata</i> .
6. Tufala R. at Epao	17° 37' S 168° 29' E	0.3	0.5	36.0	<i>C. corona</i> , <i>C. diadema</i> , <i>C. squarrosus</i> , <i>S. porcellana</i> , <i>M. plicaria</i> , <i>M. tuberculata</i>
7. Lolima falls Taouma R.	17° 43' S 168° 24' E	5.0	0.5	48.0	<i>M. tuberculata</i> , <i>M. pallens</i>
8. La Marona R. (N. West)	17° 34' S 168° 17' E	3.0	0.3	64.0	<i>C. corona</i> , <i>C. diadema</i> , <i>C. nucleolus</i> , <i>C. squarrosus</i> , <i>N. asperulata</i> , <i>N. porcata</i> , <i>N. canalis</i> , <i>N. pulligera</i> , <i>N. squamaepicta</i> , <i>M. plicaria</i> , <i>Strubellia</i> <i>Sp.</i> , <i>M. aspirans</i> , <i>T. bellicosa</i>
9. Outlet of American pool	17° 35' S 168° 16' E	0.5	0.3	62.0	<i>N. adumbrata</i> , <i>N. variegata</i> , <i>N. rubida</i> , <i>M. tuberculata</i> , <i>Melanopsis</i> sp., <i>Strubellia</i> sp.
10. Sunai stream	17° 35' S 168° 17' E	1.0	0.7	48.0	<i>N. adumbrata</i>
11. Stream at Ulei school	17° 35' S 168° 16' E	0.1	0.3	56.0	<i>C. corona</i> , <i>C. squarrosus</i> , <i>N. rubida</i> , <i>N. variegata</i> , <i>M. aspirans</i> , <i>M. plicaria</i> , <i>M. tuberculata</i> , <i>T. bellicosa</i>
12. Ai creek	17° 37' S 168° 14' E	0.5	0.4	37.0	<i>C. corona</i> , <i>C. squarrosus</i> , <i>C. chlorostoma</i> , <i>N. petitii</i> , <i>N. variegata</i> , <i>M. tuberculata</i> , <i>S. porcellana</i> , <i>M. punctata</i> , <i>N. rubida</i> .
13. Buria village	17° 38' S 168° 12' E	0.2	0.5	44.0	<i>C. corona</i> , <i>C. chlorostom</i> , <i>S. porcellana</i> , <i>M. tuberculata</i> .
14. Cascades stream	17° 41' S 168° 15' E	0.5	0.5	38.0	<i>C. corona</i> , <i>N. petitii</i> , <i>N. variegata</i> , <i>M. aspirans</i> , <i>M. punctata</i> .
15. Savaroa R.	17° 42' S 168° 18' E	5.0	0.4	22.0	-

lecting sites visited (Table 5). The number of species found on Éfate increased sharply as the first sites were sampled but increased slowly after sampling 9 sites (Fig. 5). Twenty four (62 %) species had been found after 9 sites were sampled. The result would have been the same whether sampling occurred in an easterly or westerly direction from Port Vila. If site 8 had been missed, only 22 (85 %) of the total species would have

been found (Fig. 5). However, as no less than eight sites were investigated on an island, the number of species found is not far short of the actual number present.

When the sites are classified according to distance from the sea, sites 6 km or more from the sea have four species of thiarids and *P. nasuta* only, while neritids have not colonized the rivers farther than 5 km from the sea (Table 6).

Table 4. Gastropods, water velocity and total ionic content at the Tanna island sites.

Tableau 4. Les Gastéropodes, vitesse de l'eau et contenu total en ions pour les sites de Tanna.

Site & river	Map reference	Distance from sea (km)	Water speed (m s ⁻¹)	Total ions (m S ⁻¹)	Gastropods
<u>South Coast</u>					
1. Below water-fall Custom village	19° 36' S 169° 22'E	5.0	0.4	21.1	<i>C. corona</i> , <i>M. tuberculata</i> , <i>P. nasuta</i> .
2. Stream 1 km from Kwamera	19° 39'S 168° 24'E	0.1	0.3	16.1	<i>C. corona</i> , <i>C. olivaceus</i> , <i>S. porcellana</i> , <i>S. sanguisuga</i> , <i>M. tuberculata</i> .
3. Kwamera stream	19° 39'S 169° 26'E	0.1	0.3	19.2	<i>C. corona</i> , <i>C. olivaceus</i> , <i>S. porcellana</i> , <i>C. squarrosus</i>
4. Iakaplalaken str., Isaka	19° 33'S 169° 25'E	6.0	0.8	23.3	<i>P. nasuta</i>
<u>North Coast</u>					
5. Lembo stream	19° 23'S 169° 25'E	0.1	0.4	54.5	<i>C. corona</i> , <i>C. squarrosus</i> , <i>N. variegata</i> , <i>S. porcellana</i> , <i>M. aspirans</i> , <i>M. plicaria</i>
6. Loanatanu stream	19° 22'S 169° 14'E	0.1	0.3	49.5	<i>C. corona</i> , <i>C. squarrosus</i> , <i>C. bicolor</i> , <i>N. canalis</i> , <i>N. pulligera</i> , <i>N. variegata</i> , <i>S. porcellana</i> , <i>S. bougainvillei</i> , <i>M. punctata</i> , <i>M. aspirans</i>
<u>East Coast</u>					
7. Nowanatanu stream	19° 26'S 169° 20'E	0.1	0.3	30.3	<i>C. corona</i> , <i>C. squarrosus</i> , <i>N. turtoni</i> , <i>N. variegata</i> , <i>S. porcellan.</i>
8. Locknaula stream	19° 26'S 169° 21'E	0.2	0.3	29.3	<i>C. corona</i> , <i>C. olivaceus</i> , <i>C. bicolor</i> , <i>S. porcellana</i> , <i>S. bougainvillei</i> .
9. Itnime stream	19° 25'S 169° 20'E	0.2	0.4	38.4	<i>C. corona</i> , <i>C. bicolor</i> , <i>C. pritchardi</i> , <i>S. porcellana</i> , <i>S. bougainvillei</i> , <i>B. glans</i> , <i>M. aspirans</i> , <i>M. pallens</i> .
10. Noh-keiu stream	19° 24'S 169° 20'E	0.2	0.3	27.3	<i>C. corona</i> , <i>N. variegata</i> , <i>S. porcellana</i> , <i>S. sanguisuga</i> , <i>M. aspirans</i> , <i>M. plicaria</i> , <i>B. glans</i> .

Table 5. The number of freshwater gastropod species found, the areas and stream length of each island, the number of sites visited and range of pH and temperature for four Vanuatus islands.

Tableau 5. Le nombre de Gastéropodes d'eau douce trouvés, la superficie et longueur des ruisseaux, le nombre de sites visités et les valeurs du pH et de la température dans les quatre îles de Vanuatu.

Island	River & stream Length (km)	Area (km ²)	Number of species	Number of sites	pH	Température (°C)
Espiritu Santo	2300	6840	18	9	7.0-7.3	23-29
Éfate	370	900	26	15	7.0-7.8	24-26
Éfate (Starmühlner 1976)	370	900	18	6	6.8-7.2	23-27
Tana	170	560	19	10	6.9-7.4	22-27
Pentecost	90	430	16	8	7.0-7.4	23-27

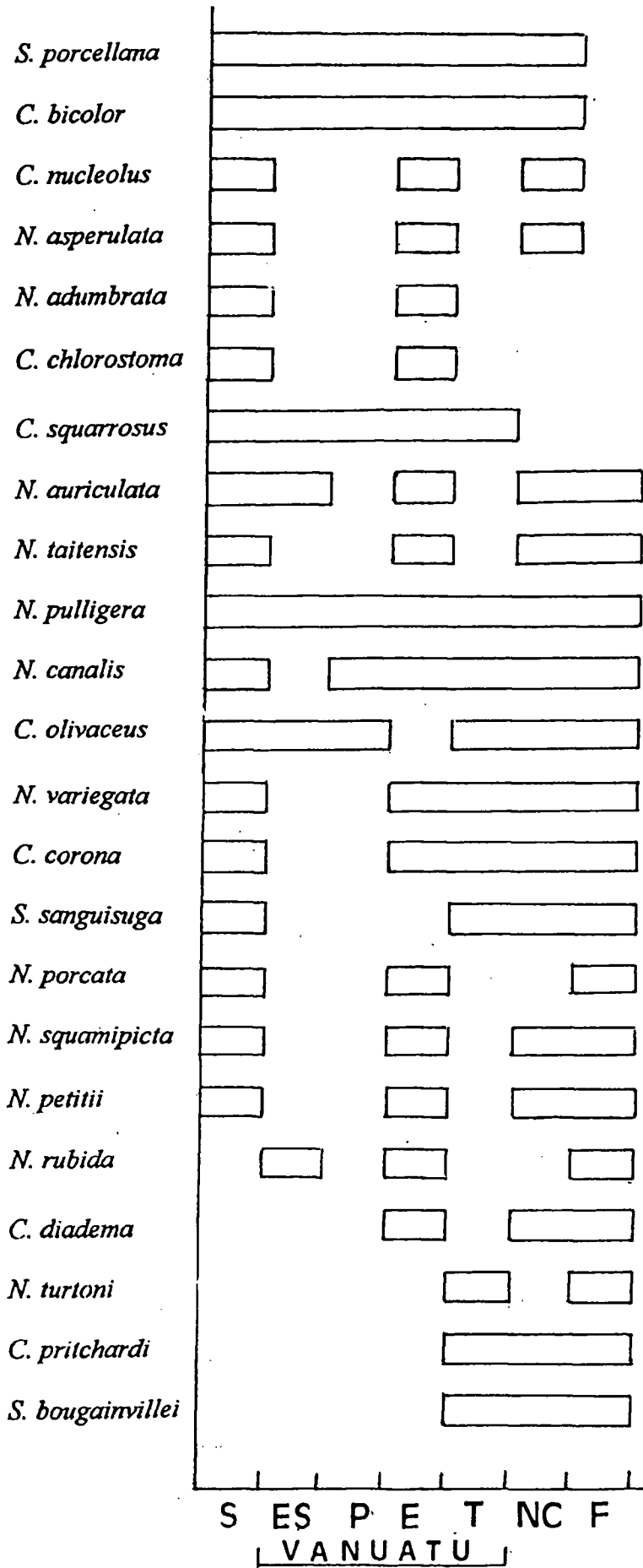


Fig.3. The distribution of freshwater neritid gastropod species on four Vanuatu islands. (ES : Espiritu Santo, P : Pentecost, E : Éfate, T : Tanna) and the adjacent island groups of Solomon Islands (S), New Caledonia (NC), and Fiji (F).

Fig. 3. La distribution des espèces de Gastéropodes néritidés d'eau douce sur quatre îles de l'archipel de Vanuatu (ES : Espiritu Santo ; P : Pentecoste, E : Éfate, T : Tanna) et dans les archipels voisins des Salomon (S), Nouvelle-Calédonie (NC) et Fidji (F).

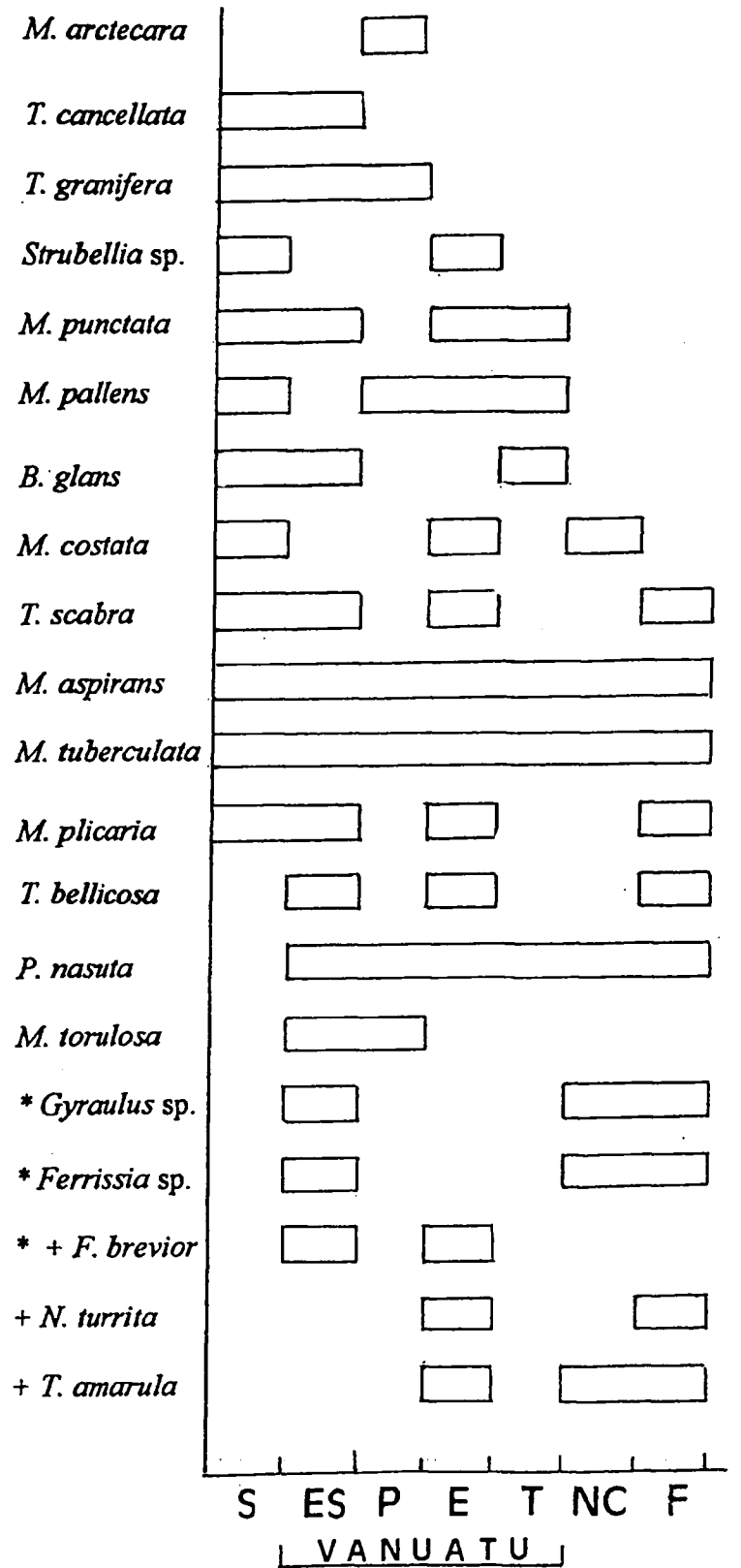


Fig.4. The distribution of freshwater thiarid and some gastropod species on four Vanuatu islands. (ES : Espiritu Santo, P : Pentecost, E : Éfate, T : Tanna) and on the adjacent groups of Solomon Islands (S), New Caledonia (NC), and Fiji (F). * Solem (1959), + Starmühlner (1976).

Fig. 4. La distribution des thiaridés d'eau douce et autres espèces de Gastéropodes sur quatre îles de l'archipel de Vanuatu (ES : Espiritu Santo ; P : Pentecoste, E : Éfate, T : Tanna) et les archipels voisins des Salomon (S), Nouvelle-Calédonie (NC) et Fidji (F).

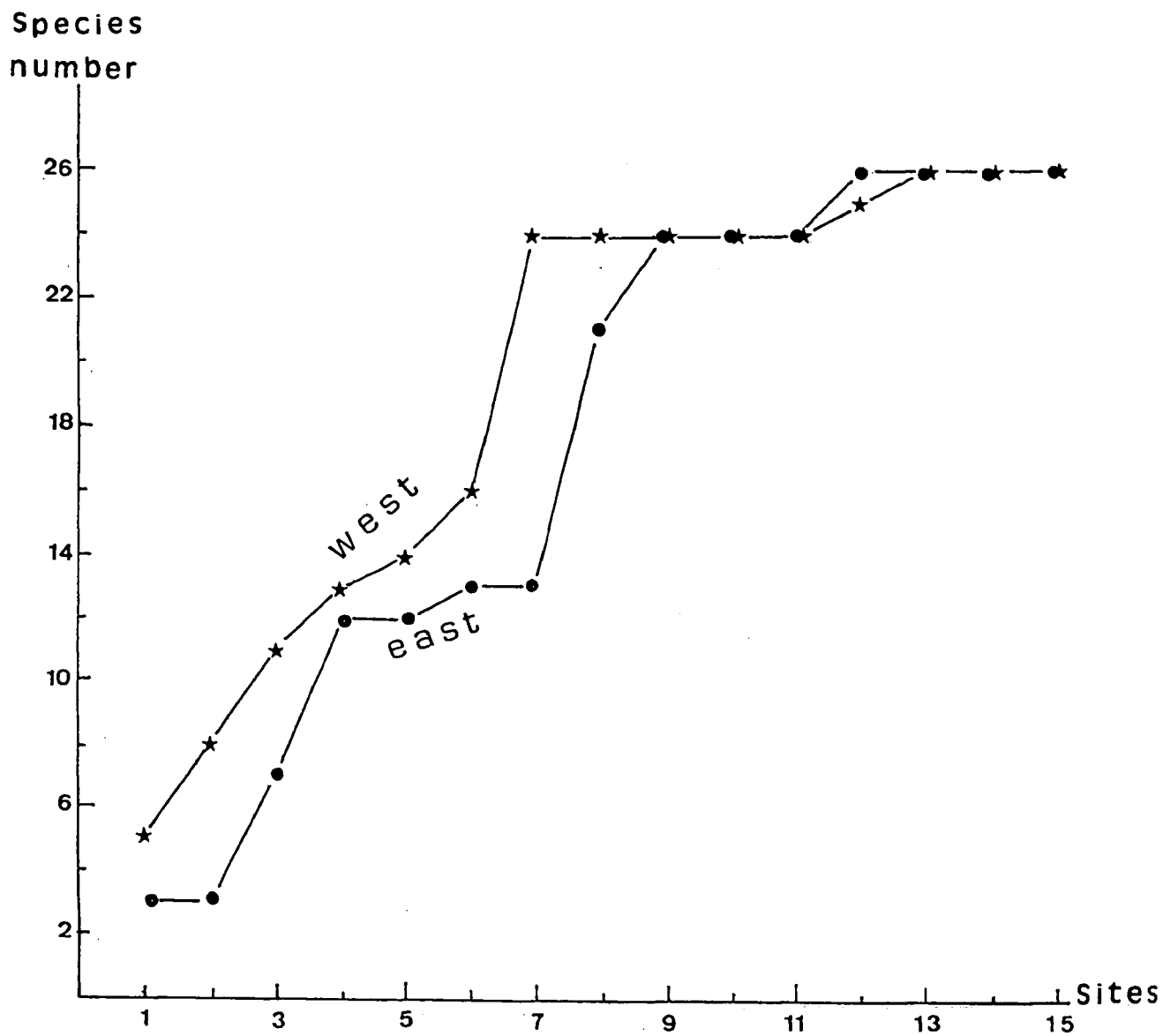


Fig. 5. The cumulative number of species found from sampling 15 sites in both easterly and westerly directions from Port Vila on Éfate.

Fig. 5. Nombre cumulé d'espèces découvertes en échantillonnant 15 sites dans des directions est et ouest à partir de Port Vila sur Éfate.

Shells of both neritids and thiarids were encrusted with lime where CaCO_3 was high. This was noted on Pentecost at site 6, Waterfall R. and on Éfate at site 4, Ewor R. and site 7, Lololima Falls (Tables 2, 3).

4. Discussion

As well as the 39 species of gastropods recorded in this investigation, Solem (1959) found on Espiritu Santo the pulmonates *Gyraulus montrouzieri* and *Ferrissia noumeensis* previously recorded in slow moving water and ponds in Fiji and New Caledonia (Starmühlner 1970, Haynes 1985). Starmühlner (1976) found *F. breviar*, *T. amarula* and *N. turrita* on Éfate.

More species (26) were discovered on Éfate than on any of the other islands. Starmühlner (1976), who visited only 6 sites on Éfate found 17 species, compared

with 18 species from 9 sites on Espiritu Santo and 19 species from 10 sites on Tanna in this study. The higher number of species on Éfate may be partly due to the general higher ion content of its waters. A weak correlation between total ions and species number was shown to exist. Other possible factors are its geographical position in the main line of any southward movement of gastropods, its composition of pumice breccia (not porous limestone as on other islands) and its relatively gentle slope near the coast.

Tanna, the most southerly island, had two neritid species, *S. bougainvillei* and *C. pritchardi* which were not found on other Vanuatu islands or further North in the Solomon Islands and South East Asia, but are common in New Caledonia (Pöllabauer 1986) and Fiji (Haynes 1988a, 1996, 1997). These two species appear to have originated in this southern region.

Table 6. The number of times each freshwater gastropod species was found at sites classified according to their distance from the sea.

Tableau 6. Nombre de récoltes de chaque espèce de Gastéropodes dans 12 sites répartis en fonction de leur éloignement de la mer.

Taxa	Distance from sea (km)												Total	
	0.1	0.2	0.3	0.4	0.5	1.0	2.0	3.0	5.0	6.0	13.0	15.0		
<i>Clithon bicolor</i>	1	3	4	1			1							10
<i>C. chlorostoma</i>		1	1											2
<i>C. corona</i>	6	4	1					1	1					13
<i>C. diadema</i>		1	1					3						5
<i>C. nucleolus</i>					1			1						2
<i>C. olivaceus</i>	2	1	5	1			1		2					12
<i>C. pritchardi</i>	1													1
<i>C. squarrosus</i>	4		4	1	2		1	1	1					14
<i>Neritilia rubida</i>	1		1		1		1							4
<i>Neritina adumbrata</i>					1	1								2
<i>N. asperulata</i>								1						1
<i>N. auriculata</i>		1	1											2
<i>N. canalis</i>	1		1					1						3
<i>N. petitii</i>					2									2
<i>N. porcata</i>								1						1
<i>N. pulligera</i>	1							1	1					3
<i>N. squamaepicta</i>								1						1
<i>N. tahitiensis</i>		1												1
<i>N. turtoni</i>	1													1
<i>N. variegata</i>	4	1	1		4									10
<i>Septaria bougainvillei</i>	1	2												3
<i>S. porcellana</i>	5	4	3	1	1	1			1					16
<i>S. sanguisuga</i>	1	1							1					3
<i>Balanocochlis glans</i>		1				1			1					3
<i>M. arctecara</i>						1								1
<i>M. aspirans</i>	2	2	2		2									8
<i>M. costata</i>	2													2
<i>M. pallens</i>		1	1											2
<i>M. plicaria</i>	2	2	3		1		1	1	1					11
<i>M. punctata</i>	1	1	1	1	2	1	1		2					10
<i>M. torulosa</i>			1						1					2
<i>M. tuberculata</i>	2	3	3		3	2			2		1	1		17
<i>Melanopsis frustulum</i>					1									1
<i>Tarebia granifera</i>			1				1				2	1		5
<i>Thiara cancellata</i>			1											1
<i>T. bellicosa</i>	2										2			4
<i>T. scabra</i>		2							1			1		4
<i>Physastra nasuta</i>									1	1	2			4
<i>Strubellia sp.</i>					1			1						2
Total	40	32	36	5	22	7	7	13	16	1	7	3		189

Vanuatu is as far South as many thiarid species have been distributed. The six species absent from both New Caledonia and Fiji may be poor dispersers, possibly because their young hatch as young adults rather than veligers or because the sometimes colder water temperatures : 16° C in New Caledonia (Starmühlner 1970) and 19° C in Fiji (Haynes 1985), has prevented them from becoming established.

Although the planorbid *P. nasuta* was present exclusively 5 km and more from the sea in Vanuatu, it lives in ponds and Sago swamps as near as one km from the sea on Viti Levu, Fiji (Haynes 1985). *P. nasuta* is not found in Solomon Islands but is present in New Caledonia (Starmühlner 1970), Tonga, Samoa and Cook Islands (Haynes 1990, Starmühlner 1993) as well as Fiji (Haynes 1985, 1988a). Other species of *Physastra* are found in Australia (Walker 1984).

Similarly, the genus *Fluviopupa* is a southern genus with endemic species in New Caledonia and Fiji as well as Vanuatu (Ponder 1982). It is not found further North than Vanuatu.

New Caledonia has at least two species of the thiarid, *Melanopsis* (Franc 1959, Starmühlner 1970) and one of these was present on Éfate. The opisthobranch, *Strubellia* sp., found in two streams on Éfate may be *Strubellia paradoxa*, which was found by Starmühlner (1976) on the island of Guadalcanal, Solomon Islands and which was discussed by Wawra (1974, 1988). The anatomy of the Vanuatu *Strubellia* has not been fully investigated.

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References

Franc A. 1956. — Mollusques terrestres et fluviatiles de l'Archipel Néo-Calédonien. *Mémoires Mus. Nation. Hist. Nat.*, ser. A, Zoologie, 13 : 1-200.

- Haynes A. 1985. — The ecology and local distribution of non-marine aquatic gastropods in Viti Levu, Fiji. *The Veliger*, 28 (2) : 204-210.
- Haynes A. 1988a. — The gastropods in the streams and rivers of five Fiji islands (Vanua Levu, Ovalau, Gau, Kadavu and Taveuni). *The Veliger*, 30 (4) : 377-383.
- Haynes A. 1988b. — Notes on the stream neritids (Gastropoda ; Prosobranchia) of Oceania. *Micronesica*, 21 : 93-102.
- Haynes A. 1990. — The number of freshwater gastropods on Pacific islands and the theory of island biogeography. *Malacologia*, 31 : 237-248.
- Haynes A. 1993. — The gastropods in the streams and rivers of four islands (Guadalcanal, Makira, Malaita and New Georgia) in the Solomon Islands. *The Veliger*, 36 (3) : 285-290.
- Haynes A. 1996. — Reproductive strategies in the freshwater genus *Septaria* (Neritidae). *Molluscan Reproduction, Malacological Review*, Suppl. 6 : 1-7.
- Haynes A. 1997. — The distribution of five species of *Septaria* (Gastropoda : Neritoidea) in Fijian streams. *The Veliger*, 40 (1) : 71-76.
- Pointier J.-P. & Marquet G. 1990. — Taxonomy and distribution of freshwater mollusks of French Polynesia. *Venus*, 49 : 215-231.
- Pöllabauer C. 1986. — Beitrag zur Taxonomie, Biologie und Ökologie mixohaliner polymorpher Neritiden (Archeogastropoda : Mollusca). Doctoral Dissertation, Universität Wien : 1-84.
- Ponder W.F. 1982. — Hydrobiidae of Lord Howe Island (Mollusca : Gastropoda : Prosobranchia). *Aust. J. Mar. Freshwater Res.*, 33 : 89-159.
- Reich E. 1937. — Systematische, anatomische ökologische und tiergeographische Untersuchungen über die Süßwasser-Mollusken Papuasiens und Melanesiens. *Arch. Fur Naturgeschichte (N.F.)*, 6 : 37-153.
- Solem A. 1959. — Systematics and zoogeography of the land and fresh-water Mollusca of the New Hebrides. *Fieldiana : Zoology*, 43 : 1-359.
- Starmühlner F. 1970. — Études hydrobiologiques en Nouvelle-Calédonie. *O.R.S.T.O.M., sér. Hydrobiologie*, 4 (3/4) : 3-127.
- Starmühlner F. 1976. — Beiträge zur Kenntnis der Süßwasser-Gastropoden pazifischer Inseln. *Ann. Naturhist. Mus. Wien.*, 80 : 473-656.
- Starmühlner F. 1993. — Beiträge zur Kenntnis der Süßwasser-Gastropoden der Tonga- und Samoa-Inseln (SW-Pazifik). *Ann. Naturhist. Mus. Wien*, 80 : 94/95B : 217-306.
- Walker J.-C. 1984. — Geographical relationships of the buliniform planorbids of Australia, In Solem A. & A.C. Van Brugge, *World-wide snails : Biogeographical Studies on non-marine Mollusca*. Brill/Backhuys, Leiden : 189-197.
- Wawra E. 1974. — The rediscovery of *Strubellia paradoxa* (Strubell) (Gastropoda : Euthyneura : Acochliidae) on the Solomon Islands. *The Veliger*, 17 (1) : 8-10.
- Wawra E. 1988. — *Strubellia paradoxa* (Strubell 1892) (Gastropoda : Opisthobranchia) von den Solomon-Inseln. *Zool. Anz.*, 220 3/4 : 163-172.