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An Unusually High Abundance and Diversity of the Terebridae (Gastropoda: Conoidea) in Nha Trang Bay, Vietnam

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Yuri I. Kantor, Alexander E. Fedosov, and Ivan N. Marin (2012) An unusually high abundance and diversity of the Terebridae (Gastropoda: Conoidea) in Nha Trang Bay, Vietnam. *Zoological Studies* **51**(5): 663-670. An unusually high abundance and diversity of the Terebridae (Gastropoda: Conoidea) was found at a sampling site in Nha Trang Bay, southern Vietnam. At a single site at depths of 8-20 m, 328 specimens of terebrids, representing 23 species and 8 genera, were collected. Analyses of the species composition, species accumulation curve, and faunal comparison of the Terebridae at Nha Trang Bay and in Vietnam in general with other local Indo-Pacific faunas were carried out. The Vietnamese terebrid fauna appears to be one of the richest in the Indo-Pacific, and at shallow depths, is excelled only by the well-studied fauna of Japan. The most abundant species of the Terebridae in Nha Trang Bay were radular-less. Evolutionary trends in terebrid feeding are discussed. http://zoolstud.sinica.edu.tw/Journals/51.5/663.pdf

Key words: Biodiversity, Indo-Pacific fauna, Vietnamese fauna, Gastropoda, Terebridae.

Recent attempts to revise the magnitude of marine biodiversity in tropical coastal zones have shown that in terms of species richness, this area is comparable to tropic rainforests (Reaka-Kudla 1997). Identification of marine tropical community richness has led to the conclusion that the vast majority of shallow-water marine species belong to 3 main taxa, the Polychaeta, Crustacea, and Mollusca, of which the latter contributes, according to different estimates, 23% (Bouchet 2006) to 60% (Gosliner et al. 1996) to total biodiversity. Extremely high mollusc diversity in tropical marine environments has caused this group to be a key taxon in marine biodiversity surveys (Wells 1998).

Special attention is being paid to documenting molluscan faunas of the Indo-Pacific zoogeographic region, which is believed to be the world's center of highest marine diversity (Bellwood and Hughes 2001, Mora et al. 2003). Recent field expeditions to certain Indo-Pacific localities, such as New Caledonia, the Philippines (PANGLAO'04), and Vanuatu (SANTO 2006) conducted by the Muséum National d'Histoire Naturelle (MNHN), Paris, have introduced complementary sampling methods that have led to a re-consideration of traditional faunal assessments. A biodiversity survey undertaken in New Caledonia identified 2700-2750 species of molluscs, comprising, accordingly to different statistical approximations, about 70%-80% of the local fauna. This suggests that the number of molluscan species in localities within the so-called "coral triangle" and adjacent areas may exceed 5000 (Bouchet et al. 2002).

Comparison of diversities of local faunas in the Indo-Pacific is problematic. The analysis of biodiversity of intensively sampled localities in New Caledonia (Bouchet et al. 2002), revealed that the majority of the collected species are represented by "micromolluscs", that are smaller than 41 mm (92%), while 33.5% of all species have an adult size of < 4.1 mm. Molluscs of this size category are rarely covered by popular books on local

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faunas, which concentrate on "macromolluscs", reflecting the interest of amateurs and shell collectors. In addition, the most abundant families and groups, which are "turrids" (several families according to the current classification, which were previously assigned to the paraphyletic Turridae) (Bouchet et al. 2011), Triphoridae, Eulimidae, and Pyramidellidae, are usually treated in monographs and rarely in general texts.

Probably the best known marine molluscan fauna is Japanese with its long history of professional malacological activity and several published checklists, the latest being by Higo et al. (1999). This enumerated 4729 species of "prosobranchiate" gastropods (i.e., those excluding the Euthineura). The rich Philippine fauna (well-known due to efforts of commercial shell dealers) is currently under review, and 4 volumes of the *Philippine Marine Molluscs* (Poppe 2008-2011) have been published. In total, it covers around 2910 species of prosobranchiate gastropods, with the focus on large and attractive ones. This probably does not reflect the true faunal richness, since it enumerates about 100 species of the Pyramidellidae (compared to 518 in Japan), 45 species of Triphoridae (110 in Japan), and 207 species of "turrids" (429 in Japan).

Vast, potentially rich areas of the Indo-Pacific remain barely touched by professional studies, among which are the coastal waters of Vietnam. The coastline of Vietnam is around 3250 km long, with more than 3000 islands and 1120 km^2 of shallow-water coral communities. To date, biodiversity of these waters is insufficiently studied. The 1st checklist of Vietnamese molluscs (Hylleberg and Kilburn 2003) included a total of ~2200 species. Two books by N.N. Thach on the shells of Vietnam published later (in 2005 and 2007), although centered on groups popular among shell collectors, listed 1477 species of prosobranchiate gastropods. This number is probably still an underestimation of the true gastropod diversity. Micromolluscs were barely considered, since only 13 species of the Pyramidellidae, a single species of the Triphoridae, and about 80 species of turrids were mentioned in the books.

Overall, extensive sampling in Vietnamese waters is a future task, which will be resource- and time-consuming. Some alternative ways to assess the magnitude of molluscan diversity can be applied. The idea is to select certain indicator groups, which are comparatively easy to collect, have a large shell size, and are sufficiently diverse. The Terebridae was found to match these criteria: because members of the family are relatively easy to identify and sort to species. At the same time, the group is diverse enough (well-documented tropical faunas contain 50 to about 100 species). Most importantly, many common species of the Terebridae are widely distributed in the Indo-Pacific at similar shallow depths and on similar bottom types; they are mostly intertidal to upper-subtidal sand dwellers and may; thus, be relatively well sampled in a few collection efforts, and the faunas can be readily compared.

The aim of the present study was to estimate the diversity of the Terebridae in 1 locality in southern Vietnam and compare it with existing checklists of this family in order to make a comparative assessment of the magnitude of southern Vietnamese molluscan faunal richness.

MATERIALS AND METHODS

The collection site was located in Nha Trang Bay around 50-100 m off Mun Is. at a dive site called Murray Beach (12°10.084'N, 109°17.771'E). In the present study, an area of about 150 × 150 m was investigated. The studied area is a gradual sandy slope at depths of 8-19 m. At the upper limit of this zone, sediments consist of clear washed sand, while at depths below 15 m, sediments are a slightly muddy sand.

The 1st test dive (station D3, collecting was done indiscriminately by 3 divers) at night, revealed an unexpectedly rich terebrid fauna. Therefore, several additional dives were conducted. In order to calculate the species accumulation curve and estimate the activity of terebrids at different times of the day, each dive's collection was treated separately. All live specimens of the Terebridae were collected. Molluscs were manually picked up using scuba in Oct. and Nov. 2010, at night and during the daytime.

Total efforts were estimated at about 10 dive person-hours, of which 6 person-hours were conducted at night, 1 person-hour at dusk, and 3 person-hours in the daytime.

When inactive, terebrids are buried and difficult to see. At dusk and at night, they begin crawling and are either exposed on the surface of sediments or leave easily-detectable tracks. Therefore the presence of a specimen in a sample reflects its activity. Due to the high nocturnal activity of the Terebridae, greater attention was paid to collecting at night. Specimens were relaxed in an isotonic solution of magnesium chloride, drilled if required, and fixed in 95% ethanol.

Specific identifications were made according to Bratcher and Chernohorsky (1987) and Terryn and Holford (2008), and generic assignments were based on Terryn and Holford (2008) and personal communication with Y. Terryn. It should be noted that generic classification of the Terebridae is now in the state of flux, and therefore the position of some species is unclear at the moment. They were conditionally attributed to the genus *Terebra* (for these species, we use the genus name in a broad sense, sensu lato (s.l.), following Terryn and Holford 2008).

A species accumulation curve was constructed with the Primer 6.0 software package (Clark and Warwick 2001).

RESULTS

Abundance and local diversity of the Terebridae at Murray Beach

In total, 410 specimens were collected, representing 23 species and 8 genera of the Terebridae (Fig. 1, Table 1).

Seven species were not previously recorded from Vietnam, namely *Hastulopsis amoena*, *Myurella flavofasciata*, *Terebra* (s.l.) *funiculata*, *T.* (s.l.) *punctatostriata*, *T.* (s.l.) *quoygaimardi*, *T.* (s.l.) aff. *unicolor*, and *T.* (s.l.) aff. *textilis*.

The 3 most abundant species, represented in 6 of 7 individual samples were *M. affinis* (138 specimens), *M. kilburni* (72 specimens), and *M. nebulosa* (57 specimens). Other common species, represented in 5 or more samples and comprising > 15 specimens in total were *T. subulata*, *T. babylonia*, and *M. columellaris* (Table 1). Seven species contributed 5-9 specimens each, 4 species comprised 2 or 3 specimens, and 6 were represented by single specimens. It should be noted that *Oxymeris maculata* was present in all dives, but not all specimens were collected (and correspondingly counted) due to the very large size of the specimens.

It is noteworthy that the yield per dive-hour significantly depended on the time of day. The average number of terebrid specimens caught during daylight hours (13:00-14:00) was 23 (n = 3), at dusk (16:00-17:00), it was 40 (n = 1), while in an average dive-hour at night, 67 specimens (n = 3) were collected.

The activity of certain species was similar in the daytime and nighttime, e.g., *M. affinis* (with corresponding 12 and 17 specimens per dive), *T. babylonia* (with corresponding 1.7 and 2.7 specimens per dive), and *T. subulata* (with corresponding 1.7 and 3.3 specimens per dive). Counts of the 3 most abundant species except *M. affinis* were much higher at night. Thus during the daytime, an average of 2 specimens of *M. kilburni* per dive was collected compared to 19 at night; similar number were 1 and 11 for *M. nebulosa*, and 1 and 8.3 for *M. columellaris*. At dusk, the abundance of terebrids was closer to that of daytime.

A species accumulation curve (Fig. 2), calculated for the 7 individual dives was generally rather flat, suggesting a good saturation of samples and increments of a single species between the penultimate and last sample. Projections from the species accumulation curve extrapolated the total richness at the site to be 24 (Jack 1 re-sampling method) to 26 species (Jack 2 re-sampling method).

A high abundance and sympatry of numerous species suggest the presence of effective resource partitioning and specialization of species. The diet of the Terebridae is poorly studied, and few species were examined in this respect (Miller 1975 1979, Taylor 1990). At the same time, it is known that the foregut anatomy of terebrids is quite variable, and many species lack a venom apparatus and radula (Taylor 1990, Castelin et al. 2012). Both prey preference and feeding mechanism differ in radulate and radular-less species. We analyzed the presence/absence of the radula apparatus in species of terebrids (Table 1) we collected based on original and published data (Holford et al. 2009, Castelin et al. 2012).

For 3 species, represented by a single specimen in our material, the presence of the radula was not determined. Among the remaining ones, 11 species possessed a radula and venom apparatus, and 9 lacked the radula and venom apparatus.

DISCUSSION

The present results demonstrate a high abundance and diverse fauna of the Terebridae at Murray Beach as well as in Vietnam in general. Combined lists of the Terebridae (Hylleberg and Kilburn 2003, Thach 2005 2007) identify a total of 60 species in the family, and with the addition

Fig. 1. Shells of the Terebridae collected at a dive site at Murray Beach off Mun Is., Nha Trang Bay, southern Vietnam. **1.** *Oxymeris dimidiata*; **2.** *O. areolata*; **3.** *Hastula lanceata*; **4.** *Terebra* (s.l.) cf. *unicolor*; **5.** *Cinguloterebra triseriata*; **6.** *Duplicaria raphanula*; **7.** *Hastulopsis amoena*; **8.** *Myurella affinis*; **9.** *M. nebulosa*; **10.** *M. kilburni*; **11.** *M. columellaris*; **12.** *M. flavofasciata*; **13.** *M. undulata*; **14.** *O. cerithina*; **15.** *Terebra argus*; **16.** *O. maculata*; **17.** *Terebra* (s.l.) *babylonia*; **18.** *T.* (s.l.) *funiculata*; **19.** *T.* (s.l.) *quoygaimardi*; **20.** *T.* (s.l.) *punctatostriata*; **21.** *T. subulata*; **22.** *T.* (s.l.) aff. *textilis*; **23.** *C.* cf. *anilis*.

of newly found ones, this is increased to 67. Of these, 41 species were previously found at a similar depth range (5-20 m), for a new total of 48 species now known from this depth range. Finding relatively large numbers of species new to a particular fauna from the detailed examination of a single site suggests that the total diversity of Vietnamese terebrids may be much higher than is documented to date.

A detailed account of the Terebridae collected in Santo-Vanuatu (including the number of species collected at each station) during the SANTO 2006 expedition was recently published (Terryn and Holford 2008). The work also contains data on the total number of Terebridae species in the Philippines and New Caledonia based on material collected by the MNHN (Table 2). Comparison of species collected at similar depths demonstrated that only in Japan is the known fauna richer than in

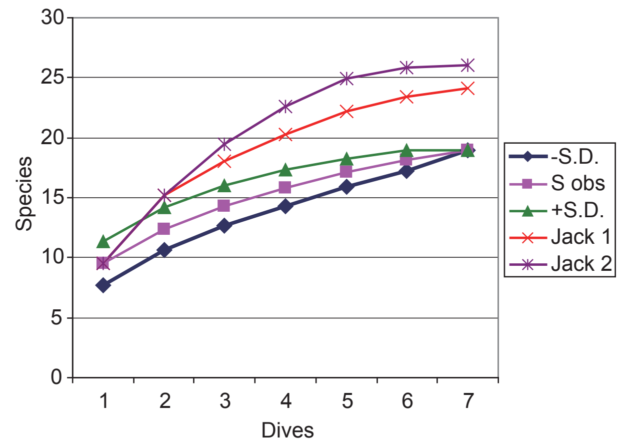

Fig. 2. Accumulation curve of species number at a dive site at Murray Beach, Mun Is., Nha Trang Bay, southern Vietnam. Permuted species accumulation curve with 1000 permutations. S.D., standard deviation; S obs, number of species observed; Jack 1, Jack 2, Jackknife richness estimators.

Table 1. Summary of the collected material

Species	Total during the day (3 dives)	Total at dusk (1 dive)	Total at night (3 dives)	Total for 7 dives	Station ND3	Total at Murray Beach	Presence of the radula
1 *Terebra* (s.l.) aff. *textilis* Hinds, 1844	1	0	0	1	1	2	+
2 *Terebra* (s.l.) *babylonia* Lamarck, 1822	5	1	8	14	5	19	+
3 *Terebra* (s.l.) cf. *unicolor* Preston, 1908	1	0	0	1	0	1	?
4 *Terebra* (s.l.) *funiculata* Hinds, 1844	0	0	1	1	2	3	+
5 *Terebra* (s.l.) *punctatostriata* J.E. Gray, 1834	3	1	2	6	1	7	+
6 *Terebra* (s.l.) *quoygaimardi* Cernohorsky et Bratcher, 1976	0	0	2	2	1	3	+
7 *Cinguloterebra* cf. *anilis* (Röding, 1798)	0	0	0	0	1	1	?
8 *Cinguloterebra triseriata* (J.E. Gray, 1834)	0	0	2	2	3	5	+
9 *Duplicaria raphanula* (Lamarck, 1822)	0	0	0	0	1	1	+
10 *Hastula lanceata* (Linnaeus, 1767)	2	0	0	2	5	7	+
11 *Hastulopsis amoena* (Deshayes, 1859)	0	2	2	4	2	6	-
12 *Myurella affinis* (J.E. Gray, 1834)	37	26	51	114	24	138	-
13 *Myurella columellaris* (Hinds, 1844)	3	0	25	28	3	31	-
14 *Myurella flavofasciata* (Pilsbry, 1921)	0	0	1	1	0	1	?
15 *Myurella kilburni* (R.D. Burch, 1965)	6	3	57	66	6	72	+
16 *Myurella nebulosa* (Sowerby, 1825)	3	2	33	38	19	57	-
17 *Myurella undulata* (J.E. Gray, 1834)	1	0	1	2	7	9	-
18 *Oxymeris areolata* (Link, 1807)	0	0	0	0	1	1	-
19 *Oxymeris cerithina* (Lamarck, 1822)	1	0	1	2	1	3	-
20 *Oxymeris dimidiata* (Linnaeus, 1758)	0	0	2	2	2	4	-
21 *Oxymeris maculata* (Linnaeus, 1758)	4	1	3	8	1	9	-
22 *Terebra argus* Hinds, 1844	0	0	0	0	1	1	+
23 *Terebra subulata* (Linnaeus, 1767)	5	4	10	19	10	29	+
No. of specimens	70	40	201	313	97	410	
No. of species	12	8	16	19	21	23	

Vietnam.

Comparison of the species list recorded by us at the examined site with published lists of other local faunas show that only the Japanese Terebridae checklist includes all species covered here, while some of them were absent from other local faunas (Table 3). All of the species on our list are widely distributed in the Indo-Pacific. Therefore, one could suggest that the absence of some of the species from our list in other faunas is an artifact of collecting.

The only other region for which comparable data (number of species collected at each station) are published is Vanuatu. The richest of the 76 examined stations at similar depths in Vanuatu contained 13 species, the second 8, while from the majority of other stations (61, or 80%) 3 or fewer species were collected. We calculated an accumulation curve for Vanuatu species collected from similar depths and compared it with the species accumulation curve of Murray Beach (Fig. 3). It is clear that the curve for Murray Beach is steeper, and the species number accumulated much faster.

True abundance or an artifact of the collecting effort?

Such a high local abundance of Terebridae at Mun I., Vietnam can be either a natural phenomenon or just a consequence of focused collecting efforts.

It is nearly impossible to make a correct comparison of local abundances in different regions based on published checklists and general books. The total number of known terebrids in Vietnam is lower than those in Japan, the Philippines, and China (although higher than those in New Caledonia and Vanuatu), but it is remarkable that the number of shallow-water species (in the 5-20-m depth range) is exceeded only by Japan. This suggests that despite incomplete studies of the Vietnamese malacofauna, there is a high diversity of the Terebridae and if extrapolated, of molluscs in general. There is no doubt that the coastal waters of Vietnam are potentially important areas for future investigations of biodiversity.

The collecting efforts carried out at our site are probably much higher then at any other well-documented one. In Vanuatu, during the SANTO 2006 expedition, the richest station was sampled by only 3 divers during 1 dive (which was about 3 person-hours), compared to ~10 person-hours at Mun I., six of which were undertaken during

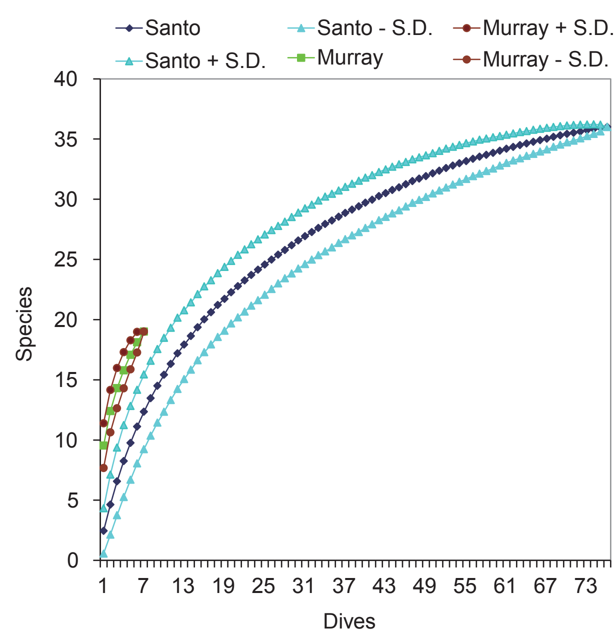

Fig. 3. Comparison of species accumulation curves at Santo (Vanuatu) and Murray Beach, Vietnam.

Table 2. Abundance of the Terebridae in different faunas of the Indo-Pacific based on published data

Locality	Total number of Terebridae	Number of species in the 5-20-m depth range	Source
The Philippines	80	Not available	Terryn and Holford 2008
The Philippines	88	32	Terryn in Poppe 2008
Japan	95	68	Higo et al. 1999
New Caledonia	58	Not available	Terryn and Holford 2008
Santo-Vanuatu	54	38	Terryn and Holford 2008
Vietnam	67	48	Combined from Thach 2005 2007, Hylleberg and Kilburn 2003, present study
China	77	Not available	Liu 2008

the night, when terebrids are most active. During daylight hours (3 person-hours), a similar number of species were collected (i.e., 12), although in much higher numbers. In this case, it is interesting to consider the 1st test dive, which was conducted at night (Table 1, station ND3). Although no special efforts were paid to collecting terebrids along with all other molluscs, we identified 21 species (out of a total of 23), and 4 species were not recollected during the additional 7 dives.

Thus, the conclusions may be that the very high diversity and abundance of Terebridae at Murray Beach on Mun I. were the combined result of both a rich fauna and high collecting efforts especially at night.

Remarkable abundance of radula-less species

The Terebridae, being members of the Conoidea, typically possess a specialized foregut complex, providing the peculiar feeding mechanism of the Conoidea. A separate marginal tooth gripped by the proboscis tip is used for stabbing prey and envenomation with a secretion from the venom gland (Taylor et al. 1993). However, anatomical studies of the Terebridae revealed a clear tendency towards reduction and loss of the radula and venom gland in many of its members (Taylor 1990, Castelin et al. 2012). To the present, the relative abundance of radula-less terebrids was never estimated.

The most abundant species of the Terebridae at Murray Beach were those lacking the radula and foregut complex. The 3 most abundant species in our dataset, i.e., *M. affinis*, *M. nebulosa*, and *M. columellaris* (55% of specimens), have no radula. This suggests that the lack of a radula and of the entire foregut complex probably renders certain evolutionary advantages to the Terebridae. Prey specialization is considered to be the main evolutionary prerequisite for the extreme diversity of the Conoidea (Kohn 1959, Duda et al. 2001), and this was demonstrated for the Terebridae (Taylor 1990). Published data suggest that terebrids with different foregut anatomy specialize on prey from different taxa. Species of *Hastula* were shown to feed on certain species of spionid polychaetes (Miller 1979), while radula-less *Oxymeris areolata* and *O. dimidiata* are specialized enteropneust feeders (Taylor 1990). For *Myurella*,

Table 3. Presence of species in different fauna lists

Species	Philippines	New Caledonia	Santo	Japan	China	Murray Beach	Vietnam (published previously by Thach 2005 2007, Hylleberg and Kilburn 2003)
Terebra (s.l.) *babylonia*	x	x	x	x		x	x
Terebra (s.l.) cf. *unicolor*						x	
Terebra (s.l.) *funiculata*	x	x	x	x	x	x	
Terebra (s.l.) *punctatostriata*	x	x	x	x		x	
Terebra (s.l.) *quoygaimardi*	x	x	x	x		x	
Cinguloterebra cf. *anilis*	x	x	x	x	x	x	x
Cinguloterebra triseriata	x	x	x	x	x	x	x
Duplicaria raphanula	x	x		x	x	x	x
Hastula lanceata	x	x	x	x	x	x	x
Hastulopsis amoena		x	x	x		x	
Myurella affinis	x	x	x	x	x	x	x
Myurella columellaris	x	x	x	x	x	x	x
Myurella flavofasciata			x	x		x	
Myurella kilburni	x	x	x	x		x	x
Myurella nebulosa	x	x	x	x	x	x	x
Myurella undulata	x	x	x	x	x	x	x
Oxymeris areolata	x	x	x	x	x	x	x
Oxymeris cerithina	x	x	x	x	x	x	x
Oxymeris dimidiata	x	x	x	x	x	x	x
Oxymeris maculata	x	x	x	x	x	x	x
Terebra argus	x	x	x	x	x	x	x
Terebra subulata	x	x	x	x	x	x	x
Terebra (s.l.) aff. *textilis*	x	x		x	x	x	

the only available data are for *M. affinis*, which feeds on cirratulid polychaetes (Taylor 1986).

Highly specialized predatory molluscs are known to be sparsely distributed, as shown for other turriform conoideans (Bouchet et al. 2002). We suggest that either radular-less *Myurella* are less specialized, in terms of their diet, than other syntopic less-abundant species, or they have shifted to feeding on more-abundant prey which avoids competition for resources.

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