Food Habits of the Gastropods *Turbo argyrostoma* and *T. setosus*, Reported as Toxic from the Tropical Pacific[1]

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Introduction

A few groups of gastropods have been known to cause poisoning when eaten. Examples are the whelks *Buccinum* and *Neptunea, Murex,* Japanese ivory shell (*Babylonia japonica*), abalones (*Haliotis*), and sea hares (*Aplysia*). In these examples the toxin is highly localized. It is found in the salivary glands of whelks, the hypobranchial (purple) gland in *Murex*, the mid-gut gland in the ivory shell and abalones, and the digestive, purple, and opaline glands of sea hares. The resulting illnesses from these various molluscs are not the same as ciguatera which may follow the consumption of certain reef or semipelagic fishes of tropic seas (for a recent review, see Halstead, 1967).

Two species of gastropods are known from the tropical western Atlantic which are reported to have caused illness on rare occasions when eaten. One is the "samba" phase (*i.e.* old individuals) of the queen conch, *Strombus gigas* Linnaeus, and the other the West Indian topshell, *Cittarium pica* (Linnaeus) (sometimes classified in *Livona*). These are the two most important gastropod molluscs used as food in the West Indies. Both are herbivorous. The toxicity of *S. gigas* has been discussed by J. Randall (1958, 1964). According to Halstead (1965), the record of the toxicity of *C. pica* seems to have originated with Poey (1866). Too little is known of the illness resulting from eating these molluscs to say if it is the same as ciguatera. It may be for *Strombus gigas*. It is doubtful, however, that *Cittarium pica* could produce ciguatera, even though the term ciguatera is believed to have originated from the native name "cigua" given to this trochid in Cuba. *C. pica* occurs in the intertidal and upper subtidal zone along rocky shores exposed to wave action (H. Randall, 1964). Fishes which have produced ciguatera occur in deeper, less turbulent zones. Furthermore, some toxic species such as surgeonfishes of the genus *Ctenochaetus* are capable of grazing only on detrital material and fragile algae which are not apt to occur on the bottom in areas of surf. In

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spite of many inquiries of local people at West Indian localities where ciguatera is well known, the junior author could find no reports of any poisoning from eating topshells.

There appear to have been no records in the scientific literature of ciguatera-like illness from eating gastropods in the tropical Pacific until Hashimoto, Kamiya, and Shibōta (1968) reported on the poisoning of men on Marcus Island (Japanese name, Minami Tori Shima) (24° 17′ 30″ N; 153° 58′ E) following the ingestion of the turbinid *Turbo argyrostoma* Linnaeus (Fig. 1). Six men were affected in 1962

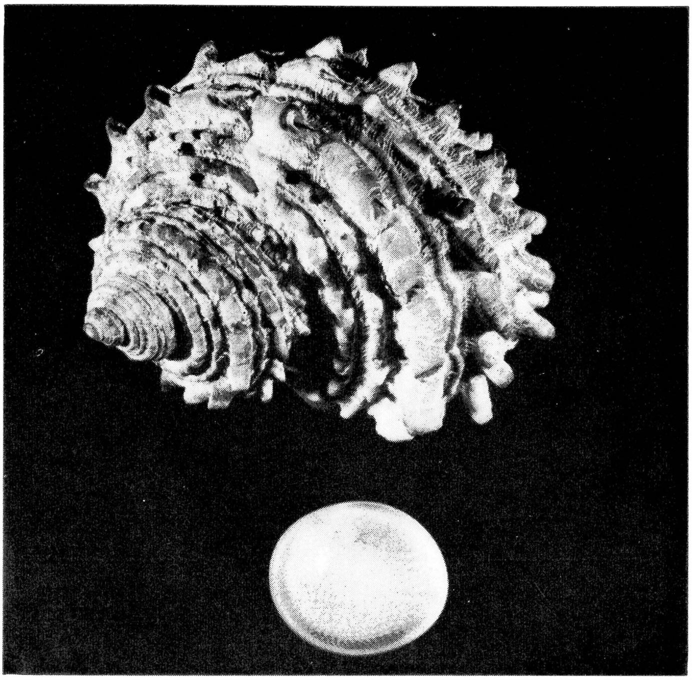

Fig. 1. *Turbo argyrostoma* Linnaeus, 75 mm in shell length, Marcus Island, BPBM 217600.

and two in 1968. Others who had eaten *Turbo* were also ill but they had consumed fishes as well which have been known to be toxic at Marcus Island. The symptoms included fatigue, paresthesia, diarrhea, and itching, although no patient exhibited all of these. These disorders are all characteristic of ciguatera; however, itching is not a very common symptom. A frequent complaint of patients suffering from ciguatera is joint pain. This was not among the symptoms of the men who had eaten the *Turbo*. Although two of the men first developed illness within several hours of eating the shellfish, as is typical of ciguatera, one showed no symptoms for a day, and five were not ill for two to three days. Recovery was slow; five patients still had some bad effects after two months.

In a more detailed report, Hashimoto, Konosu, Shibōta, and Watanabe (1970) noted that the men who ate both the viscera and the muscle tissue of *Turbo argyrostoma* were more ill than those who ate just muscle tissue. They have shown further that there are two toxins present in the poisonous *Turbo*, one fat soluble and the other water soluble.

Bagnis (1969 and personal communication) has reported that occasional individuals of *Turbo setosus* Gmelin (Fig. 2) have caused an illness of ciguateric type with a predominantly neurological syndrome and a prolonged convalescence at Hao (18° 10′ S; 140° 55′ W) in the Tuamotu Archipelago during an outbreak of ciguatera which began in 1967 at this atoll. Specimens collected in the toxic zone in September, 1969 were tested on cats. The mantle and muscle tissue were non-toxic, but the mid-gut gland and other digestive viscera produced a toxic reaction of 2 in the test animals (on a scale of 0=no reaction, to 5=death; see Banner *et al.*, 1960). Later two cases of poisoning were reported from the same atoll from eating *T. argyrostoma.*

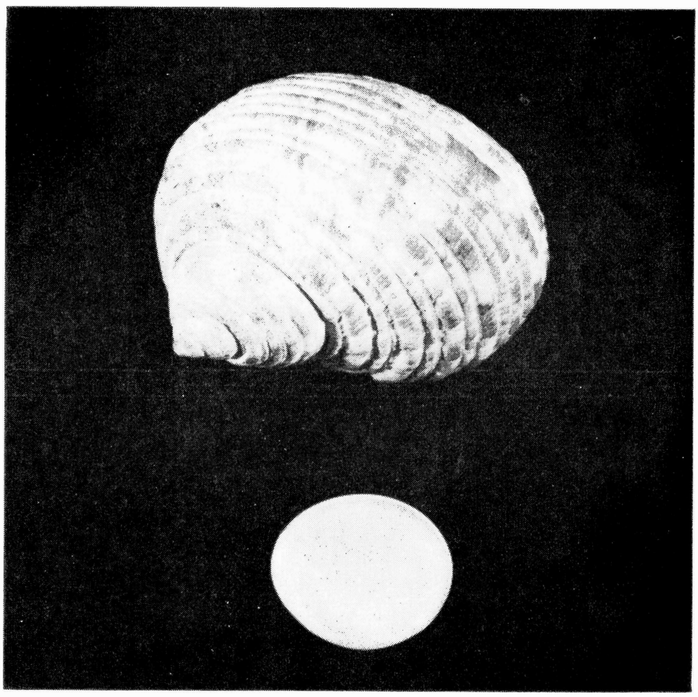

Fig. 2. *Turbo setosus* Gmelin, 55 mm in shell length, Guam, BPBM 204339. (Tuamotu specimen unavailable at time of photography).

Jean Tapu of Tahiti informed us that *Turbo setosus* has made persons ill when consumed at Hikueru Atoll (17° 32′ S; 145° W), also in the Tuamotus. The first cases occurred in 1961 in the region between the village and the pass. *T. setosus* is still not eaten from this area today.

It has been clearly demonstrated by Helfrich and Banner (1963) that fishes acquire ciguatera toxin via feeding. Whether the toxins of *Turbo* are ultimately shown to be the same as those in reef fishes or not, it is natural to suspect that their source will be found in the diet of these snails. The main objective of the present paper, therefore, is an investigation of the food habits of *Turbo argyrostoma* and *T. setosus*.

Through the courtesy of the Office of Naval Research of the U. S. Navy and the U. S. Coast Guard, the junior author visited Marcus Island for two weeks beginning August 29, 1968, to obtain *Turbo argyrostoma*, fishes, and algae. Studies of other turbinids such as those of Morton (1955) and Ino (1958) suggested that *T. argyrostoma* would be a herbivore, hence the interest in algae.

Marcus is a low island (10 meters at the highest point), triangular in shape, only 1.6 km on the longest side. There is a fringing reef with a maximum depth over the reef flat of less than two meters. Seas were rough during the entire two-week period, therefore, nearly all collections were confined to the northwestern shore which was the calmest.

Marcus has a tropical Indo-Pacific fauna and flora, but is distinctly impoverished, as one might expect from its isolation, small size, and limited environments (no lagoon or bays, no brackish areas, very little sand).

Only 25 species of algae were collected (Tsuda, 1968). The algae of the reef flat are heavily grazed by acanthurid fishes (mainly *Acanthurus triostegus* and *A. nigroris*), scarids (principally *Scarus jonesi*), kyphosids, and pomacentrids; consequently it was difficult to obtain any substantial amounts of plant material. Only two species of algae were abundant enough to collect in moderate quantities, and both were blue-greens. One was *Porphyrosiphon miniatus* which grew as soft whispy reddish strands up to about 10 cm long from coral rock surfaces, especially the upper dead edges of doughnut-shaped heads of *Porites* coral. The other was *Schizothrix calcicola*, an alga of many growth forms. At Marcus it was found as solid hemispherical clumps.

Turbo argyrostoma was the largest mollusc collected at Marcus. It was not uncommon, occurring mainly in the outer zone of the reef flat. It was usually found beneath small ledges. In spite of the cases of poisoning from eating this gastropod, it was still being used as food by the staff of the Japanese Meteorological Station on the island.

Acknowledgement

We are very grateful to Drs. Yoshiro Hashimoto, Shoji Konosu, and Yuzo Komaki, of the Laboratory of Marine Biochemistry of the University of Tokyo for supplying us with additional samples of *T. argyrostoma* from Marcus Island collected in June, 1968, and June, 1969, (the latter as a result of a trip to the island by Dr. Komaki) and for collections of the *Turbo* and algae from the islands of Ie and Minna in the Ryukyu Islands where this turban shell is not known to be poisonous.

Mr. Jean Tapu of the Service de la Pêche in Papeete, Tahiti, kindly responded to our request for specimens of *Turbo setosus* from the atolls of Hao and Hikueru

in the Tuamotus, and we wish to express our special thanks to him for this material. He obtained the shellfish in March and June of 1969. They were taken from shallow water on exposed outer reef.

We thank Drs. A. H. Banner, Y. Hashimoto, and S. Konosu for review of the manuscript.

Materials and Methods

The gut contents of the *Turbo* from each collections were pooled for study. Thus, there are three analyses based on a total of 103 individuals of *T. argyrostoma* from Marcus Island, one analysis of 30 individuals from Ie and one of two individuals from Min-na in the Ryukyus, two analyses of a total of 59 individuals of *T. setosus* from Hao, and one of 28 individuals from Hikueru. Ranges in weight are given for all samples except one from Marcus. These include the weight of both the shell and soft parts. Most of the total weight of these animals is in the shell. One specimen of *T. setosus*, for example, had a shell length of 77 mm and a total weight of 150 grams, but the soft parts (less both shell and operculum) weighed only 21.2 grams.

In our analyses we have used a modification of the method of quantifying algal stomach-content material developed by Jones (1968). This consists of making a homogeneous preparation of the stomach material, taking samples and mounting them on microscope slides with cover slips, and counting the algal fragments that fall upon points of intersection of a 1 mm ocular grid when the slide is viewed under the low power of a compound microscope. Instead of using 17 points of intersection as Jones did for the study of stomach contents of herbivorous fishes, we used 81 points. In addition, all algae present in the pooled gut contents from each island were recorded even if they constituted less than 1% of the food items.

Results and Discussion

The results are summarized in Tables 1 and 2 for *T. argyrostoma* and *T. setosus*, respectively.

Unidentified organic matter represented 66 to 80% of the gut contents of *T. argyrostoma* and 36 to 91% of the gut contents of *T. setosus*. The percentage of inorganic sediment, which we list as Calcareous Material in the tables, was also high, 6 to 22% in *T. argyrostoma* and 3 to 14% in *T. setosus*. Nearly all of the remaining material consisted of recognizable benthic algal filaments. With the exception of a few foraminifera and copepods, animals were absent.

Examination of the unidentified organic matter under high power ($\times 400$) and oil immersion ($\times 1000$) revealed some material of apparent algal origin. This was probably, in part, algal cells rasped by the snails and, in part, digested by them. Undoubtedly much of the organic material was detrital, however, when it was ingested by the gastropods.

All of the algal species reported from the gut contents are relatively common algae found on calcareous substratum. Although it is likely that much of the calcareous material was ingested as sediment, it is possible that some is rasped from the coral rock by the radulae; in which case, these gastropods would be minor contributors to the production of sand.

Table 1. Relative abundance (%) and occurrence (+) of ingested items found in separately pooled gut content samples of *Turbo argyrostoma* from Marcus Island and the Ryukyu Islands.

	Relative Abundance (%) and Occurrence (+)				
Islands	Marcus			Ie	Min-na
Date of Collection	VI–1968	IX–1968	VI–1969	V–1969	IV–1969
Number in Sample	20	33	50	30	2
Range in Weights (g)	127–297	—	85–250	90–190	80–116
Unidentified Organic Matter	70%	70%	80%	66%	67%
Calcareous Material	11%	19%	6%	22%	11%
CYANOPHYTA					
Calothrix confervicola (Roth) Ag.	5%	—	—	—	—
Entophysalis deusta Drouet & Daily	+	+	—	—	—
Gomphosphaeria aponina Kütz.	+	+	—	—	—
Microcoleus lyngbyaceus (Kütz.) Crouan	11%	1%	1%	1%	—
Microcoleus vaginatus (Vauch.) Gomont	—	—	—	—	17%
CHLOROPHYTA					
Caulerpa ambigua Okamura	—	—	—	+	4%
Cladophora sp.	—	—	—	+	—
PHAEOPHYTA					
Lobophora variegata (Lamx.) Womersley	+	+	7%	1%	—
Sphacelaria sp.	3%	5%	6%	5%	1%
RHODOPHYTA					
Centroceras clavulatum (C. Ag.) Montagne	—	—	—	2%	—
Jania spp.	+	5%	+	2%	+
Laurencia sp.	—	—	+	+	—
Polysiphonia spp.	—	—	+	1%	—
Pterocladia sp.	+	+	—	—	—

Although no single alga occurred in all of the pooled samples, the browns *Sphacelaria* sp. and *Lobophora variegata* (=*Pocockiella variegata*) were present in all but one of the samples, and the blue-green *Microcoleus lyngbyaceus* (=*Lyngbya majuscula*), and the red *Jania* spp. in all but two.

Fourteen species of algae were collected from the reef flat area of Marcus Island where *Turbo argyrostoma* occurs (collection numbers 2420 and 2422–2441 of Tsuda, 1968), yet only four of these: *Gomphosphaeria aponina, Calothrix confervicola, Lobophora variegata*, and *Jania* sp. were found in the gut contents. Neither of the two most common algae, the blue-greens *Porphyrosiphon miniatus* and *Schizothrix calcicola*, were taken from the gut material. In the case of *P.*

miniatus, an explanation may lie in its position toward the upper part of the submerged prominent coral rocks of the reef. *Turbo argyrostoma* was not observed to move upward onto the sides of such rocks (no observations were made at night, however, due mainly to the abundance of the gray reef shark *Carcharhinus amblyrhynchos*).

Table 2. Relative abundance (%) and occurrence (+) of ingested items found in separately pooled gut content samples of *Turbo setosus* from the Tuamotu Archipelago.

	Relative Abundance (%) and Occurrence (+)		
Islands	Hao		Hikueru
Date of Collection	III–1969	VI–1969	III–1969
Number in Sample	15	44	28
Range in Weights (g)	88–146	24–160	75–150
Unidentified Organic Matter	46%	36%	91%
Calcareous Material	12%	14%	3%
CYANOPHYTA			
Calothrix confervicola (Roth) Ag.	–	3%	–
Microcoleus lyngbyaceus (Kütz.) Crouan	+	25%	–
Schizothrix calcicola (Ag.) Gomont	30%	–	–
Spirulina subsalsa Oerst.	+	–	–
CHLOROPHYTA			
Cladophora sp.	–	–	3%
PHAEOPHYTA			
Lobophora variegata (Lamx.) Womersley	3%	6%	+
Sphacelaria sp.	9%	15%	–
RHODOPHYTA			
Jania spp.	–	+	–
Laurencia sp.	–	1%	3%

A special effort was made to find the *Porphyrosiphon* in the gut contents of the *Turbo* from Marcus Island because of the relatively high toxicity demonstrated for a frozen sample by Lionel Low of the Hawaii Institute of Marine Biology. An intravenous injection of the water portion of an extraction of the alga with a benzene/water mixture into mice caused death in 2 to 5 minutes at the level of 120 micrograms per gram of body weight of the test animals.

Although *Schizothrix calcicola* was not found in the gut contents of *T. argyrostoma*, it represented 30% of the gut material of the first sample of *T. setosus* from Hao. The proliferation of this blue-green alga on a reef of the atoll of Marakei in the Gilbert Islands was noted by native fishermen to coincide with the onset of ciguatera in the area (Cooper, 1964).

Five species of algae were taken from the guts of *T. argyrostoma* from Marcus that were not collected at the island: *Entophysalis deusta*, *Microcoleus lyngbyaceus*, and unidentified *Sphacelaria*, *Laurencia*, and *Pterocladia*.

Collections of algae at Min-na and Ie in the Ryukyu Islands at the same place where the *Turbo argyrostoma* were taken provides a similar comparison (Table 3). Of ten species of algae from Min-na Island, three were found in the gut contents of the two turban shells collected. Of 14 species of algae at Ie, eight were identified from the pooled gut contents of 30 specimens of the gastropod. Two species,

Table 3. Comparison of ingested algae to algae found on reef area on Min-na Island and Ie Island, Ryukyu Islands.

Species	Min-na Island			Ie Island		
	Sand	Coral	Ingested	Sand	Coral	Ingested
CYANOPHYTA						
Calothrix confervicola (Roth) Ag.	−	−	−	−	+	−
Microcoleus lyngbyaceus (Kütz.) Crouan	−	−	+	+	+	+
Schizothrix mexicana Gomont	−	−	−	−	+	−
CHLOROPHYTA						
Acetabularia parvula Solms-Laubach	−	+	−	−	−	−
Caulerpa ambigua Okamura	+	+	+	+	−	+
Cladophora sp.	−	−	−	−	−	+
Enteromorpha sp.	−	+	−	−	−	−
PHAEOPHYTA						
Dictyota patens J. Ag.	−	+	−	+	+	−
Lobophora variegata (Lamx.) Womersley	−	+	−	−	+	+
Sphacelaria tribuloides Menegh.	−	+	+	+	+	+
Turbinaria ornata (Turn.) J. Ag.	−	−	−	−	+	−
RHODOPHYTA						
Actinotrichia fragilis (Forsskal) Boerg.	−	−	−	−	+	−
Centroceras clavulatum (C. Ag.) Montagne	+	−	−	+	−	+
Ceramium fimbriatum Setchell & Gardner	−	−	−	+	−	−
Jania capillacea Harvey	+	+	+	+	+	+
Laurencia sp.	+	−	−	−	+	+
Polysiphonia spp.	+	+	−	+	+	+

Microcoleus lyngbyaceus and *Cladophora* sp. were taken from the gut contents but not found on the rock and sand areas at the islands. Of the two coral rocks from Min-na which were examined, *Dictyota patens* covered about 90% of one and *Sphacelaria tribuloides* about 80% of the other. *Polysiphonia* spp. made up about 5 to 15% of the remainder of the algae on the second rock and was also the predominant algae found in the sand sample (may represent thalli that were detached from coral rock). *Dictyota patens, Sphacelaria tribuloides*, and *Jania capillacea* covered 75 to 90% of each coral rock examined from Ie Island. *Polysiphonia* spp. were also abundant on one of the corals and made up 90% of the algae found in the sand sample. As may be seen from Table 3, no *Dictyota* was found in the digestive tracts of the *Turbo* from either island, and *Polysiphonia* was absent from the *Turbo* diet at Min-na.

Conclusion

We conclude from our study that both *Turbo argyrostoma* and *T. setosus* are herbivores and detritus feeders. Their occurrence on the lower part of the reef flat and abundance of detrital organic material and calcareous sediment in their gut contents suggest that they feed in the lower levels where such detritus and sediment accumulate. We doubt that they exhibit much selectivity in their feeding. The presence of certain algae in their general habitat but absence from their gut contents is probably due to these species being inaccessible to them during normal feeding. A gastropod of the size of *Turbo*, restricted as it is to solid substratum would probably have difficulty grazing on an alga with a high flexible thallus.

A number of authors have proposed that marine algae are a likely source of the toxin or toxins that produce ciguatera, and some such as Randall (1958) have suggested that the Cyanophyta warrant the closest scrutiny among the algae. If the toxins of *Turbo* that have caused the illness are the same or related to ciguatera toxin, then additional evidence of algal origin is provided by the results of this food habit study. Not only are algae the primary food, but blue-greens represent the dominant algae ingested.

It is well to point out, however, that the large amount of unidentified organic matter of the *Turbo* gut contents represent an ample source of other organisms such as bacteria, yeasts, and fungi which could be responsible for producing the toxins that have ultimately affiected man.

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