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A checklist of near-shore Strombidae (Mollusca, Gastropoda, Neostromboidae) on Green Island, Queensland

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SUMMARY

This study provides a checklist of the distribution and relative abundance of Strombidae from the near-shore environment of Green Island, Queensland, Australia. Historical records indicate that this island has not been surveyed for at least half a century. We used an opportunistic sighting survey method, where we walked the path of the receding tidal line around the island, counting and measuring all species that we observed directly. We also recorded the substrate on which each individual was collected as sand, sand-seagrass or seagrass. Eleven species of Strombidae were found. The survey provided the first record of *Ministrombus athenius* (Duclos, 1844) from North Queensland. This study provides base-line data on the presence and distribution of near-shore Stromboidea that will enable future studies to detect and monitor changes in the composition of near-shore strombid species.

INTRODUCTION

Studies of species distributions can provide essential information for the long-term monitoring and management of populations that have the potential to be impacted by anthropogenic disturbance (Denadai et al. 2004; Kelaher and Cole 2005). While there is significant documented knowledge on substrate preference and species composition of certain marine gastropods on islands associated with the Great Barrier Reef, little is known of localised correlated effects of anthropogenic activity on species distribution patterns (Mapstone et al. 1989). While there has recently been a shift towards gathering baseline knowledge of lesser-known invertebrate taxa (Wolfe and Byrne 2017), data on particular groups, such as the Strombidae, is still lacking.

The Strombidae in North Queensland are gregarious animals, with adult populations occurring in restricted ranges that are defined by habitat type (Catterall and Poiner 1983). The habitat preference of Strombidae has been related to depth, tidal movement, temperature, substrate and the growth of favoured algal taxa (Catterall and Poiner 1983; Stoner and Ray 1993). While the distributional range limits of strombids are known, little is known of the intra-reef distribution and substrate preferences of these animals in Australia, and the little work that has been conducted has been restricted to the widespread common species *Conomurex luhuanus* (Linnaeus, 1758) (Catterall and Poiner 1983).

This survey provides baseline data on the distribution of Strombidae at a key tourist destination, Green Island, on the Great Barrier Reef, Australia. The data obtained from this survey will enable future researchers to detect and monitor changes in the species composition of these ecosystems over time and as a potential index of changes at a more regional scale.

METHODS

Study site

Green Island, and its associated reef, is situated on the inner edge of the Great Barrier Reef off the coast of Cairns, Queensland, Australia (16°45' S, 145°58' E; Figure 1). The 12 hectare island is located on the north-western side of the reef platform. The north-east, east and south sides of the island are bounded by dense seagrass that decreases towards the outer edge of the reef platform, giving way to corals, rubble and sand pockets. The island is a popular tourist destination (Kenchington 1991), and the west and north-west sides of the island are highly impacted by anthropogenic activity, including a resort, water sports and harbour access (Figure 2). These areas have a benthic composition of deep-water sand, rubble and coral.

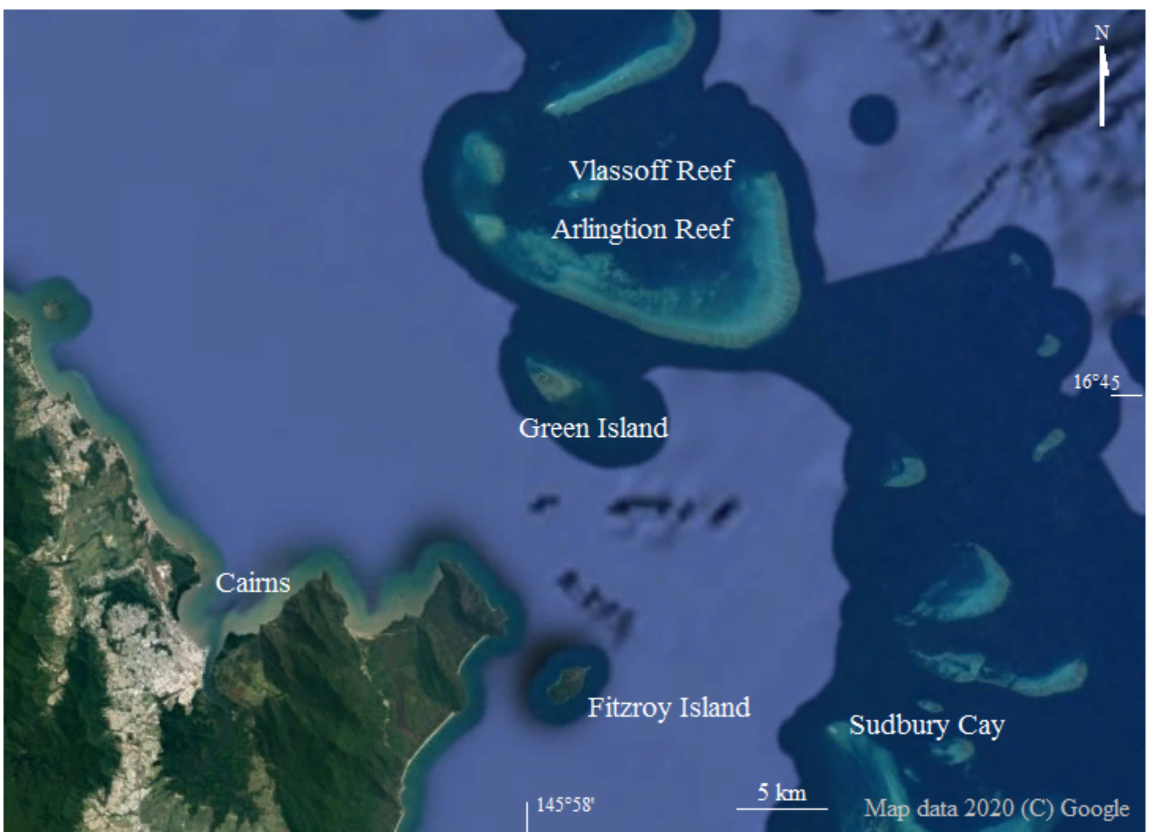

Figure 1. The location of Green Island east of Cairns, Queensland, showing the island position in relation to associated reefs and cays (Base image derived from *https://google-earth.en.softonic.com;* Accessed on 2020-01-10).

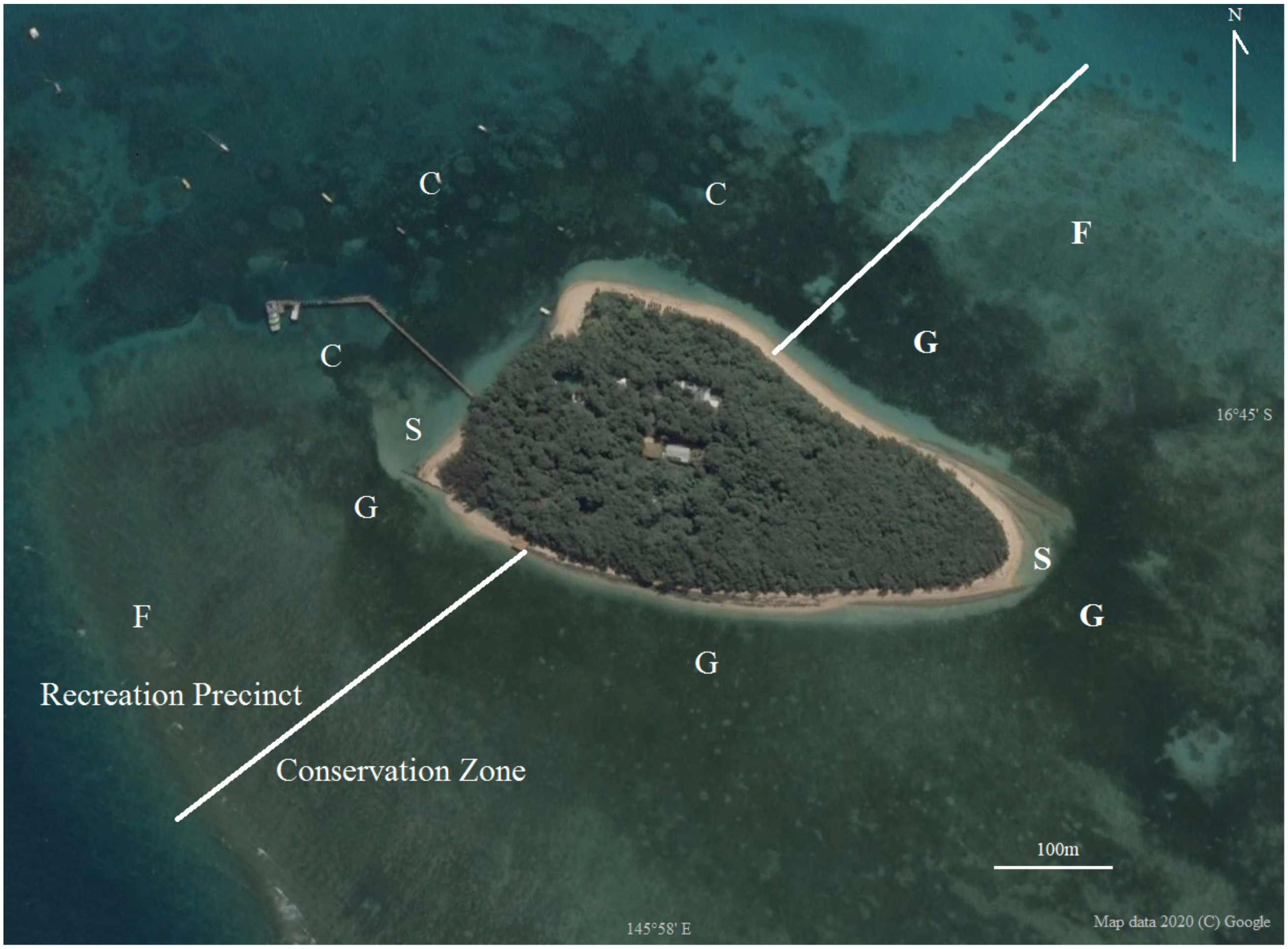

Figure 2. The location of Green Island current management zones and the dominant benthos: C – deep water corals and sand with sporadic small seagrass patches not exposed at low tides; F – Reef flats consisting of coral and coral rubble with sand patches exposed at low tides; G – areas dominated by sand and seagrass exposed at low tides; S – sandy areas exposed at low tides (Base image derived from *https://google-earth.en.softonic.com;* Accessed on 2020-01-10).

Historical surveys

A survey of the literature on strombids was undertaken to find historical records of strombid species found on Green Island. Specimens held in institutions from which literary sources have been drawn include the Academy of Natural Sciences of Philadelphia (ANSP, Abbott 1960) and the Museum of Comparative Zoology (MCZ, Abbott 1960).

Furthermore, the Atlas of Living Australia (ALA, www.ala.org.au) was examined for institutional records containing strombid data from Green Island. Records were obtained from the Australian Museum Malacology Collection (AM), Museum and Art gallery of the Northern Territory (MA), Queensland Museum (QM) and the Queen Victoria Museum and Art Gallery (QV). These records are presented with date of collection and institutional catalogue number.

Population survey

Six surveys were conducted between March and June 2017 during low tides at night. On each sampling occasion, an opportunistic method was used to locate animals. The survey involved walking the receding tide line clockwise around the island collecting all strombid species observed. This process resulted in passes that were spaced approximately 4 m apart, which reflects the distance the tide retreated on each pass. The search commenced at the base of the beach foreshore and extended out to approximately 20 m, equating to five circuits of the island.

Surveyed areas were classified based on the substrate: a) sand, which included sand and rubble, but no seagrass; b) sand-seagrass, which consisted of areas with seagrass and patches of visible sand (excluding areas of recent disturbance, such as stingray feeding holes); and c) seagrass, which consisted of areas where seagrass dominated and where little, or no underlying sandy substrate was visible. Strombid abundance for each survey of each habitat was recorded categorically as: 1) abundant (A), many individuals throughout the sampled habitat (> 5 individuals observed on each pass of the island); 2) common (C), individuals present and not difficult to find (1-5 individuals observed with each pass of the island); 3) sporadic (S), few individuals present in total survey; and 4) absent (X), no observed individuals. These results were collated and tabulated. Where dead (D) individuals were found, no inference was drawn on the originating habitat, or potential impacts associated with the tourist zone, although the species was still recorded.

Species identification

A reference specimen of each species and its observed phenotypes were retained during each survey for taxonomic identification and vouchered in the systematic collection of Stephen Maxwell (SM Coll.). Those not retained were released. Species were compared to material from the systematic collection of Stephen Maxwell in the first instance to gain provisional identification. Identification was then checked against the current literary status for each species (Kira 1959; Abbott 1960, 1961; Walls 1980; Willan 2000; Dekkers and Maxwell 2020; Liverani et al. 2021). Where taxa identifications were problematic in terms of classification, an explanation is provided to ensure taxonomic clarity.

RESULTS

Historical survey

The literary and institutional records for Strombidae are presented and provide a checklist on known species across the entire island (Table 1). However, there are four limitations on the use of digital and literary historical records: first, the lack of detailed information that enable the determination of whether the shell was collected live or dead; second, any inference on the location across the island that the specimens referred to were collected cannot be drawn; third, the correctness of the species identification underpinning each record has not been confirmed; and fourth, there is a reliance on the accuracy of the data provided with each specimen.

We found four literary references to Strombidae on Green Island, all published prior to 1972. Two were locality records contained within species distributions drawn from large scale monographic studies detailing the genera *Strombus* Rafinesque, 1815 (Abbott 1960) and *Lambis* Röding, 1798 (Abbott 1961). The remaining two were illustrative texts for general species identification (Rippingale & McMichael 1961; Cernohorsky 1972). Thirteen strombid taxa are listed in the literature as coming from Green Island: *Lambis lambis* (Linnaeus, 1758) (MCZ, Abbott 1961); *Harpago chiragra* (Linnaeus, 1758) ('Tony Marsh in litt.' in Abbott 1961); *C. luhuanus* (ANSP, Abbott 1960; Rippingale & McMichael 1961); *Euprotomus aratrum* (Röding, 1798) (ANSP, Abbott 1960; Cernohorsky 1972); *Lentigo lentiginosus* (Linnaeus, 1758) (Rippingale & McMichael 1961); *Lentigo pipus* (Röding, 1798) ('Tony Marsh in litt.' in Abbott 1960); *Terestrombus fragilis* (Röding, 1798) (Rippingale & McMichael 1961); *Terestrombus terebellatus* (Linnaeus, 1758) (ANSP, Abbott 1960); *Canarium erythrinum* (Dillwyn, 1817) (= *Canarium elegans* (Sowerby, 1842); MCZ, Abbott 1960); *Canarium microurceus* Kira, 1959 (MCZ, Abbott 1960); *Canarium mutabile* (Swainson, 1821) (MCZ, Abbott 1960); *Pacificus dilatatus* (Swainson, 1821) (= *Dolomena hickeyi* (Willan, 2000); Cernohorsky 1972); and *Ministrombus variabilis* (Swainson, 1820) (ANSP, MCZ, Abbott 1960).

Twenty-two taxa contained within the ALA and belonging to Strombidae were identified in databases as having come from Green Island, institutional accuracy in identification is assumed correct: *C. erythrinum* (= *C. elegans*; 1929, AM – C.399724; 1949, AM – C.399732; 1952, AM – C.216907; 1957, AM – C.399726; 1960, AM – C.399725; 1973, QM – DM.11576021); *Canarium labiatum* (Röding, 1798) (1901, AM – C.9665; 1929, AM – C.400361; 1961, AM – C.400152; 1969, QM – MO.83431; 1973, QM – DM.11576062; 1975, AM – C.400362; 1978, QV – QVM.9.9932); *C. mutabile* (1949, AM – C.216532; 1973, QM – DM.11576053); *Canarium wilsoni* (Abbott, 1967) (1960, AM – C.318710); *C. luhuanus* (1949, AM – C.433398; 1961, AM – C.96488; 1961, AM – C.217385; 1973, QM – DM.11576603; 1978, QV – QVM.9.9929); *D. hickeyi* (1948, AM – C.122114). *P. dilatatus* (1980, QM – MO.56557); *Doxander campbelli* (Grifffith and Pidgeon, 1834) (1946, AM – C.122257; 1970, AM – C.105631); *Doxander vittatus* (Linnaeus, 1758) (1980, QM – MO.56558, MO.56560, MO.56561); *E. aratrum* (1949, AM – C.122354); *Euprotomus aurisdianae* (Linnaeus, 1758) (MA – P.036980; 1949, AM – C.122323); *Euprotomus bulla* (Röding, 1798) (1961, AM – C.217384); *Gibberulus gibbosus* (Röding, 1798) (1949, AM – C.433417; 1957, AM – C.105024; 1961, AM – C.217219; 1970, AM – C.462921; 1973, QM – DM.11576712; 1974, AM – C.422113); *H. chiragra* (1970, AM – C.65492); *Laevistrombus canarium* (Linnaeus, 1758) (= *Laevistrombus vanikorensis* (Quoy and Gaimard, 1834); 1947, AM – C.216558; 1949, AM – C.121865); *L. lambis* (QM – MO.32036; 1948, AM – C.217432; 1961, AM – C.217213; 1974, AM – C.433237; 1990, AM – C.217248); *Lambis truncata* (Humphrey, 1876)(= *Lambis sowerbyi* (Mörch, 1872); 1960, AM – C.114982); *L. lentiginosus* (1960, QV – QVM.9.17657; 1961, AM – C.93578); *M. variabilis* (1901, AM – C.9664; 1946, AM – C.217537; 1948, AM – C.217538; 1949, AM – C.217539; 1962, AM – C.105026; 1969, QM – MO.83568; 1970, AM – C.122140; 1970, QM – DM.11576140; 1973, QM – DM.11576140); *Sinustrombus latissimus* (Linnaeus, 1758) (QM – MO.18968). *T. fragilis* (1946, AM – C.323324; 1957, AM – C.539490; 1974, AM – C.399938); and *T. terebellatus* (1960, AM – C.400122; 1975; AM – C.323336).

Population survey

During the field surveys described herein, eleven species from five genera of Strombidae were found, with *Canarium* and *Dolomena* containing the largest number of species (Table 2). Only two abundant populations of nearshore strombids were identified: *C. labiatus* and *G. gibbosus*, which were on the eastern side of the island in the conservation zone (Table 2). *Canarium labiatus* and *G. gibbosus* occurred in abundance in each of the surveys. Both *C. labiatus* and *G. gibbosus* demonstrated an observable degree of aggregation. One species was found to be common, *L. lambis*, but was sporadically distributed. Two Strombidae species were represented by only a single living example each: *C. mutabile* and *C. luhuanus*. The remaining seven species identified were found dead and were represented by only a single example.

Table 1. A checklist of Strombidae from Green Island indicating most recent literary and institutional records, and the species identified in this study (P = present).

Species	Literary Record (Latest year)	Collection Record (Latest year)	Present This Study
Canarium elegans	1960	1973	P
Canarium labiatum		1978	P
Canarium microurceus	1960		P
Canarium mutabile	1960	1973	P
Canarium wilsoni		1960	
Conomurex luhuanus		1978	P
Dolomena hickeyi	1972	1948	P
Euprotomus aratrum	1972	1949	
Euprotomus aurisdianae		1949	
Euprotomus bulla		1961	P
Gibberulus gibbosus		1974	P
Harpago chiragra	1961	1970	
Lambis lambis	1961	1990	P
Laevistrombus vanikorensis		1949	
Lambis sowerbyi		1960	
Lentigo lentiginosus	1961	1961	
Lentigo pipus	1960		
Ministrombus athenius			New Record
Ministrombus variabilis	1960	1973	P
Pacificus dilatatus		1980	
Terestrombus fragilis	1961	1974	
Terestrombus terebellatus	1960	1975	

Table 2. Relative abundance and habitat preference of Strombidae on Green Island.

Species	Sand Conservation Zone	Sand Recreational Zone	Sand and Seagrass	Seagrass
Canarium elegans	X	D	X	X
Canarium labiatum	X	X	LC, S	LA, S
Canarium microurceus	X	X	D	X
Canarium mutabile	S	X	X	X
Conomurex luhuanus	X	X	S	X
Dolomena hickeyi	D	X	X	X
Euprotomus bulla	D	X	X	X
Gibberulus gibbosus	LA, S	S	LC, S	S
Lambis lambis	S	X	S	C
Ministrombus athenius	D	X	X	X
Ministrombus variabilis	X	D	D	X
A = Abundant; C = Common; S = Sporadic; D Dead; L= Localised; X = Absent				

Systematic Part

Canarium labiatum (Röding, 1798)

Figures 3 A-D

MATERIAL EXAMINED: AUSTRALIA, 49, 31.5mm – 38 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 23.043. Live specimens were locally abundant on the eastern side of the island (SM Coll. 23.043), but only a few sporadic specimens were found within the northern and southern survey areas. The observed habitat was dominated by seagrass, where specimens could be found at the base or climbing on the seagrass stems. While also common in localised areas of sand-seagrass, this species was not located on sand.

IDENTIFICATION: The biconic shell is small and axially plicate to smooth. The columella is orange with fine dark lirae the entire length. Aperture with dark lirae over an orange base. The outer lip does not reach the shoulder, and the anterior sinus is moderately developed. The aperture is the best way to differentiate members of the genus *Canarium*, with the orange columella the disguising feature of *C. labiatum* (Abbott 1960).

Canarium mutabile (Swainson, 1821)

Figure 3 E

MATERIAL EXAMINED: AUSTRALIA, ♀1, 34.0 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 30.002. Three dead specimens were observed.

IDENTIFICATION: The triangulate shell is small and smooth with a few well-developed shoulder nodules. The aperture is coloured with pink tones. The columella is white with coloured lirae of grey/pink (Abbott, 1960). The triangulate shell form is consistent with other reef samples from the comparative collections, but contrasts with the coastal shells, which are typically smaller and ovate to rectangular.

Canarium microurceus Kira, 1959

Figure 3 F

MATERIAL EXAMINED: AUSTRALIA, 1 dead, 23.5 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 38.019.

IDENTIFICATION: The fusiform shell has a smooth body with small raised nodules on the dorsal shoulder. The taxon is most recognisable by the two-toned columella being yellow outward, and with a dark purple/brown inner (Abbott 1960). The aperture has dark band of lirae that give way to a creamy interior. The anterior sinus is well developed.

Canarium elegans (G.B. Sowerby II, 1842)

Figure 3 G

MATERIAL EXAMINED: AUSTRALIA, 1 dead, 23.5 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 22a.005.

IDENTIFICATION: The shell is strongly rugose, fusiform, and with strong shoulder nodules. The columella is two toned: being white on the outer axial length, and with a dark red wine colour the length on the inner columella. *Canarium elegans* is much more rugose than *C. microurceus* and is much more elongated than that species. The white columella of *C. elegans* is typical of the Queensland form that appears universally to lack the dark or yellow shades of those of the Northern Territory or northern Pacific. Abbott (1960) saw the synonymizing of three district species under *Canarium erythrinum* (Dillwyn, 1817), based on morphology and type locality information: *Canarium elegans* (G.B. Sowerby

II, 1842) from new Caledonia and Queensland; *Canarium erythrinum* (Dillwyn, 1817) from the Red Sea and Eastern Africa; and *Canarium radians* (Duclos, 1844) from the Philippines.

Euprotomus bulla (Röding, 1798)

Figure 3 H

MATERIAL EXAMINED: AUSTRALIA, 1 dead, 56.0 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 3.016.

IDENTIFICATION: The aperture has thick callus that extends onto the spire reaching the apex. The aperture is smooth, and dorsum has five distinct axially compressed pyramidal knobs on the shoulder. The outer aperture and columella are uniformly white, while the inner aperture carries a rosy hue. This shell differs from *E. aurisdianae* in the extent of the ventral callosity that rarely attains the spire in *E. aurisdianae* (Abbott 1960). Similarly, *Euprotomus vomer* Röding, 1798 has a large dark blotch on the columella absent in *E. bulla* (Abbott 1960). Green Island *E. bulla* is somewhat more rugose than those from more southern and northern reef systems. This rugose form is reflected in examples from nearby Sudbury Cay and Vlasoff Cay. These consistent differences between regional populations in shell dorsal morphology have not been taxonomically explored.

Conomurex luhuanus (Linnaeus, 1758)

Figure 3 I

MATERIAL EXAMINED: AUSTRALIA, ♀1, 62.0 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 57.006. Five dead specimens were also observed.

IDENTIFICATION: The medium sized shell is conical with a bright red aperture. The outer lip is thickened, and the anterior sinus is well developed. The columella is black in colour. The body whorl is smooth with indistinct axially elongated shoulder knobs. There is only one member of the genus *Conomurex* in the Pacific, with the Indian Ocean taxa all possessing white or red columella (Abbott 1960; Kronenberg et al. 2009). This species is abundant on the reef flat further from the island but is known to be highly migratory across its home range (Catterall and Poiner 1987). It is reasonable to expect that localised populations will migrate in and out of the survey area through time, skewing abundance and density estimates (Catterall and Poiner 1983). Found on sand-seagrass, the specimen was located on the north-eastern side of the island.

Dolomena hickeyi (Willan, 2000)

Figure 4 A

MATERIAL EXAMINED: AUSTRALIA, 1 dead, 42.0 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 57.006.

IDENTIFICATION: The medium sized shell has a quadrate shoulder and acute spire. The spire whorls are angulate, and the dorsal knobs are knob-like. This specimen also shares some affinities with *Pacificus dilatatus* in the shape of the outer lip and rounded body whorl, but the spire is less rib-like than in typical *P. dilatatus*. While hybridisation is well established within the wider Strombidae, this specimen is not considered a hybrid between the similar *P. dilatatus* and *D. hickeyi* (Dekkers and Maxwell 2018; Maxwell et al. 2019).

Ministrombus variabilis (Swainson 1820)

Figure 4 B

MATERIAL EXAMINED: AUSTRALIA, 3 dead, one shell was intact 40.5 mm;

Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 52.028.

IDENTIFICATION: The medium sized shell has a spire that is strongly shouldered and coronated. The columella is thicker anteriorly. The ventral shield is flattened, with a strong keel at the edge. The anterior sinus is well developed. The pattern and general shape are consistent with other regional examples of the species.

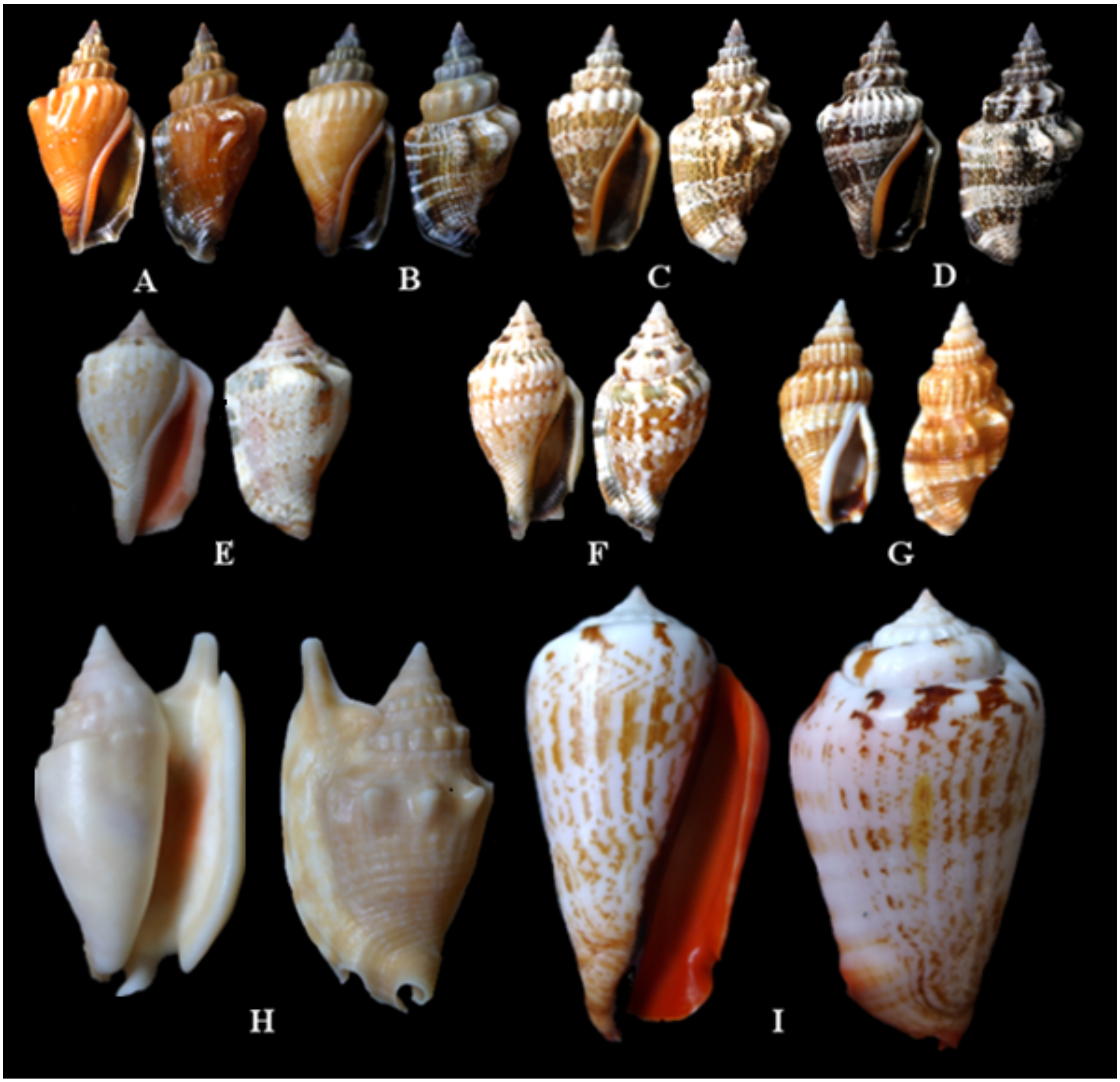

Figure 3. Green Island Strombidae (gender, length, not to scale): A) *Canarium labiatum*: an atypical colour form (male, 31.5 mm); B) *Canarium labiatum*: an atypical colour form (female, 38.0 mm); C) *C. labiatum*: a typical colour form (male, 35.5 mm); D) *C. labiatum*: a typical colour form (female, 37.5 mm); E) *Canarium mutabile*: a typical form (female, 34.0 mm); F) *Canarium microurceus*: a typical colour form (dead, 23.5 mm); G) *Canarium elegans*: a typical form (dead, 33.0 mm); H) *Euprotomus bulla*: a typical form (dead, 56.0 mm); and I) *Conomurex luhuanus*: a typical form (female, 62.0 mm).

Ministrombus athenius (Duclos, 1844)

Figure 4 C

MATERIAL EXAMINED: AUSTRALIA, 1 dead, 32.5 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 53.004.

IDENTIFICATION: The ovoid shell is relatively heavy for its size, with weakly shouldered whorls with diminished nodules. The columella is relatively uniform in thickness, and the ventral shield is rounded with a strong keel preceding the shoulder. The anterior sinus is well developed. The sides of the spire are more convex than in the similar *M. variabilis* (Abbott, 1960). Collection records indicate that this species is rare in northern Queensland, and more often anecdotally associated with eastern Papua New Guinea and the southern end of the Great Barrier Reef in the Swains Reef system (collected pre-1990, Marg Peach Coll., Mackay ex Doug Thorn). This fills a gap in the known current distribution of this species.

Gibberulus gibbosus (Röding, 1798)

Figures 4 D-I

MATERIAL EXAMINED: AUSTRALIA, abundant; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM. 49.034/49.035.

IDENTIFICATION: The shell has an inflated penultimate whorl and dorso-ventrally compressed body whorl. The outer lip is thickened, and the anterior sinus is well developed. Varices are restricted to the early whorls. The columella is smooth. This taxon is the only member of the genus *Gibberulus* in the south Pacific (Abbott 1960). *Gibberulus gibbosus* were found around the entire island, in all habitat types, with most of the population on the eastern and south-eastern sides. There were two predominant colour phenotypes. A purple shell with a dark-coloured aperture, and an orange shell with a white aperture. However, unusual colour forms, such as orange apertures, were also observed.

Lambis lambis (Linnaeus, 1758)

Figures 4 J -K

MATERIAL EXAMINED: AUSTRALIA, ♀ 122.0mm, ♂ 67.5 mm; Green Island; 16°45' S, 145°58' E; 2017; Stephen Maxwell leg.; SM Coll. 85.012.

IDENTIFICATION: The shell is solid and large bearing seven long projections: six digitations are located at the edge of the aperture and one is an extension of the anterior canal and are separated by a well-formed anterior sinus. The columella and aperture are both smooth. The taxon differs from *Lambis crocata* (Link, 1807) being much larger and lacking the ventro-dorsal compression typical of that taxon (Abbott 1961). It differs from the larger *Lambis sowerbyi* (Mörch, 1872) in lacking the broad flaring lip, heavy thickened shell and short spines of that species (Abbott 1961). While found in all habitat types, most were in seagrass or near the island rocky shore to the north, with only one being found on a sandy substrate (Table 2). The morphology of the shell differed between males and females, as is typical of the species (Abbott 1961), with females being larger and having spines that were curved upward, while males tended to have spines that were on the dorsal plane, with one notable exception that had up-curved spines.

Figure 4. Green Island Strombidae (gender, length, not to scale) continued: A) *Dolomena hickeyi* (dead, 42.0 mm); B) *Ministrombus variabilis*: a typical form (dead, 40.5 mm); C) *Ministrombus athenius*: a typical form (dead, 32.5 mm); D) *Gibberulus gibbosus*: the typical purple shell with dark aperture (male, 38.5mm); E) *G. gibbosus*: the typical purple shell with dark aperture (female, 42.5 mm); F) *G. gibbosus*: an atypical colour form (female, 44.5 mm); G) *G. gibbosus*: an atypical colour form (male, 38.5mm); H) *G. gibbosus*: an atypical colour form (male, 34.5 mm); I) *G. gibbosus*: the typical orange shell with white aperture (male, 35.0 mm); J) *Lambis lambis*: a typical form (female, 122.0mm excluding spines); and K) *L. lambis*: a typical form (male, 67.5 mm excluding spines).

DISCUSSION

The distribution of living Strombidae on Green Island was variable, with species not evenly distributed around the island. We found a general higher abundance and density of *G. gibbosus* and *L. lambis* within the conservation zone (Table 2). There are two possible explanations for the observed aggregations of individuals of these species at this location. That they were mating clusters was ruled out due to a lack of observable copulation. Firstly, aggregation could be impacted by anthropogenic activities on different parts of the island. Swimmers tend to stir the sand with their feet, disturbing the molluscs buried in the sand (Cipriani et al. 2008). This could cause molluscs to move away from these areas of disturbance to the less disturbed areas on the eastern side of the island within the conservation zone. Second, aggregations could be impacted by the type of substrate. There is some evidence of substrate preference in adult populations of Strombidae (Catterall and Poiner 1983; Stoner and Ray 1993; Cob et al. 2012). The greatest observed numbers of *G. gibbosus* in this study were found in association with sand away from the main areas of human activity. *Canarium labiatum* occurred on or near rocks and dense seagrass, often attached or at the base of seagrass blades, reflecting its non-infaunal lifestyle. Furthermore, *L. lambis* rarely completely buries, and was found in association with substrates that would have inhibited burial, such as rock platforms and areas with significant seagrass coverage. No specimens of *C. labiatum* or *L. lambis* were found on sand without the association of either rocks or seagrasses immediately nearby.

Prior to this study there has been a reliance on historical records that typically refer to collections made more than half a century ago (Table 1). The information gathered provides an update on the known Strombidae with reference to particular ecotones. Furthermore, the results increase the number of known taxa from Green Island, bringing the total known strombid taxa on the island to 23. In addition, this study provides the first record of *M. athenius* in North Queensland. While other strombid genera are known from Green Island, the survey did not locate any specimens of the genera *Doxander*, *Lentigo*, *Harpago*, or *Terestrombus* in the near shore survey area.

The limited number of species found in the near-shore habitat when compared to the known historical record highlights a significant knowledge gap on the life history and distribution of Strombidae on Green Island. This lack of distributional data on many species, is matched with the need for further studies on the diversity and abundances of current Strombidae species across the entire Green Island reef system that are affected by mating clustering and depth preference for example (Abbott 1960; Catterall and Poiner 1983). Furthermore, the potential anthropogenic impact on Green Island, suggested by the distribution patterns of the near shore species *G. gibbosus*, indicates that a wider assessment of invertebrate biodiversity on the island would be beneficial.

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AUTHOR CONTRIBUTIONS

All authors contributed equally to the planning of the project and preparation of the manuscript. SM conducted the survey and undertook the identification of specimens.

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