# MANGAIA NEARSHORE INVERTEBRATE & FINFISH ASSESSMENT

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# 1 PROJECT BACKGROUND

The biodiversity of coastal and marine ecosystems in the Cook Islands is critical to the health and well-being of local communities, often for the provision of natural resources, food, shelter, medicine and cultural traditions.

The use of marine resources in the Cook Islands is concentrated within the coastal zone. Over harvesting can occur and is typically limited to a few select species. This represents a critical need to understand the biology and ecology behind these valuable resources and how population variability of select species may affect the wider marine community and ecosystem.

Some inshore reef fisheries are in a degraded state of health due to over-fishing, poor management practices and a lack of knowledge or awareness of such issues. Compounding the need to secure biodiversity and food resources against poorly managed fisheries is a lack of opportunity to generate household income, leading to increased dependence on subsistence fisheries that cannot be easily accommodated using either traditional or contemporary systems.

The South Pacific is vulnerable to climatic influences such as the El Niño and La Niña cycles due to the underlying geography of most Pacific Island nations. The worsening of extreme climatic events in recent years reinforces the need for a targeted approach to water, land, forest and coastal management. Available research indicates that greenhouse gas emissions will cause a temperature rise that will adversely affect coral reefs and other coastal marine ecosystems and have significant impacts on the biodiversity. Increased seawater temperatures are likely to cause increased coral bleaching, while more extreme and frequent storm events may lead to physical damage, storm surges, inundation and flooding. Bodies of freshwater in the Cook Islands are limited, with no large lakes or rivers. Changes in sea temperatures and currents will likely shift the patterns of migration and occurrence of tuna species, whales and sea turtles on a large scale. Climate change and disaster risks also threaten livelihoods, whether based on agriculture, fisheries, forestry, tourism or trade, and in some cases local populations living on atolls will be required to relocate due to the impacts of climate change and expected sea-level rise. It is likely that climate change and the expected increase in the frequency and intensity of weather-related events (combined with changing rainfall patterns, increased temperatures and coastal erosion) will challenge food security in the Cook Islands over the next few decades.

Effective management of coastal and marine resources is necessary to minimize natural and human-induced impacts on the environment. Management can be directed to meet specific objectives, at both national and community levels and is of the utmost importance for the conservation of protected, endangered or highly impacted species. However, the most important factor to consider is what level of management is appropriate for both the marine resources and the communities whom depend on them.

In the Cook Islands, most inshore marine resources are managed through a traditional/cultural system: *rā'ui*. *Rā'ui* are small-scale areas designated by traditional leaders in conjunction with local communities. Typically *rā'ui* sites are identified for the temporary protection of a particular resource (for example, trochus). Traditional leaders may request that government managers monitor and assess the status of the resource and inform when areas have harvestable stock.

## 1.1 Rationale

Overall, research and monitoring of important marine resources in the Cook Islands is limited and patchy. Efforts to monitor and manage biodiversity in the Cook Islands have made only limited progress to date.

The following marine survey forms a comprehensive assessment for Mangaia. The primary objectives for this assessment were to:

- Identify areas of high abundance and diversity
- Assess the distribution and abundance of species of interest
- Note differences, if any, between *rā'ui*, permanent *rā'ui* and non-regulated areas

This assessment will form a consistent, updated point for reference for future surveys and monitoring programs, as well as inform management regarding the ecological status and stocks of important marine resources. Our work focusses on coastal and inshore zones.

## 1.2 Mangaia Enua

Mangaia is the southernmost island in the Cook Islands group, located approximately 200 km southeast-east of Rarotonga. This island is geologically classified as a raised coral atoll (locally known as *makatea*) due to its fossil coral cliffs. With a terrestrial area of 5,000 ha, Mangaia is the second largest island within the Cook Islands group in terms of landmass. A shallow reef flat encircles the island, varying in width from 30 m along the southeast windward point, to 200 m on the leeward, northwest face.

Mangaia is divided into six districts, locally known as *au puna* (Fig. 1). Each *puna* has its own traditional leadership and management. At the time of our survey, the *au puna* of Tavaenga, Keia, Veitatei and Tamarua each had roughly half of their nearshore waters closed to harvest under *rā'ui*. All nearshore water of *puna* Karanga was closed to harvest under *rā'ui* and all water of *puna* Ivirua was open to harvest.

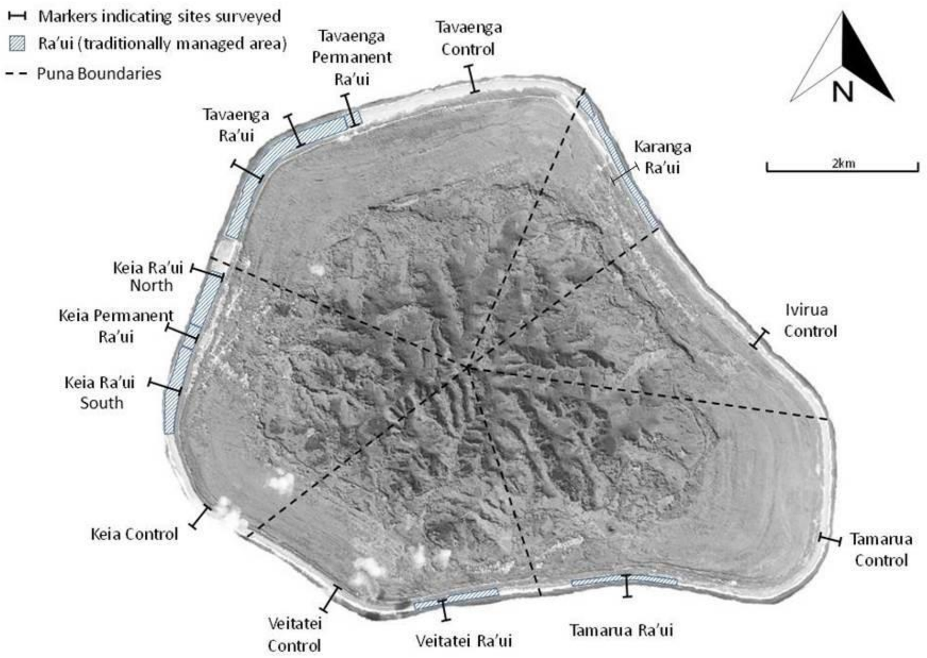


Fig. 1. Mangaia *puna* boundaries, survey sites and traditionally managed areas. Map source: Google DigitalGlobe.

Mangaia *rā'ui* fisheries management system is actively managed and enforced by the Mangaia Island Council and the island's traditional leaders. To allow resource-valuable species to recover, *rā'ui* are formed. When traditional leaders decide stocks have sufficiently recovered, *rā'ui* are lifted and the area is opened to harvest.

Tavaenga Rā'ui was last opened on 22nd December, 2017 and closed on 29th December, 2017. Keia Rā'ui South was opened from 6 am – 6 pm on 24th March, 2018. Keia Rā'ui North was opened from 6 am – 6 pm on 10th March, 2018. The non-permanent Keia *rā'ui* are not generally managed in north and south sections, but when the Mangaia Island Council heard of MMR's survey plans, they postponed opening the southern extent of the *rā'ui* until MMR officers were on island. This allowed us to collect data before and after harvest to quantify harvest impact on reef invertebrate species.

Two permanent closures of the reef flats were recently introduced. Tavaenga's permanent *rā'ui* was implemented in 2017 although briefly opened in early 2018 for paua harvest for sale. The Keia permanent *rā'ui* was implemented in early 2018 (Tuaronga Matepi, MMR Fisheries Officer, Mangaia, personal communication, June 14, 2018). Permanent closures are not traditionally used in this region which indicates an adoption of western management ideas into the local, traditional management system.

# 2 METHODOLOGY

Surveys in Mangaia took place from the 19th to 28th of March, 2018. . Within each *puna*, survey sites were selected to include *rā'ui* and nearby control areas (unregulated areas open to harvest) (Fig. 1). Finfish, invertebrates and substrate data were collected within each survey site. Surveys were conducted with SCUBA, snorkel and walk sampling.

Within each site, three reef habitats were identified as inner reef crest (RBT), reef crest (RFT), and the fore reef. For each habitat within the lagoon (RBT and RFT), invertebrates were surveyed along four 1 x 40 m transects. Lagoon depths were too shallow for finfish surveys or substrate data collection and were therefore omitted. A Garmin etrex 20x was used to record GPS waypoints for each site.

For ORT habitats, on the fore reef, SCUBA was used to conduct a single 4 x 50 m transect for finfish surveys. Invertebrate data was collected along the same path, sampling within a 1 x 40 m transect. Substrate data was also collected along the same path, gathering ten 1 x 1 m photoquadrats for substrate analysis. For species of interest (sea turtles, sharks and *Cheilinus undulatus*) observed off transect, observational data was collected but not included in the analyses.

Data collection of all species included identification to the lowest possible taxonomic classification, counts, and measurements when applicable. For finfish, fork length measurements (mm) were visually estimated. For invertebrates, length measurements were recorded (mm) for the first ten individuals of locally harvested species or species of interest.

For invertebrate abundances, raw abundances were standardised to densities per 100 $m^2$ and two analyses were conducted. First, analysis of variance (ANOVA) was used to compare means across *puna* (fixed factor; 6 levels: Ivirua, Karanga, Keia, Tamarua, Tavaenga and Veitatei) and survey sites (nested factor within *puna*; island specific). Within each *puna*, survey sites were classified as Control, *Rā'ui* or Permanent *Rā'ui*. This classification is represented graphically only. A second analysis was performed specifically for the Keia Rā'ui South survey site to compare means before and after resource harvesting on 24th March, 2018 (fixed factor; 2 levels: before and after). Statistical analyses were not conducted for over the reef (ORT) invertebrate abundances due to lack of replication. The length/frequency distribution of invertebrates was visually represented where specific species records were numerous. All analyses were conducted using the statistical package R.

For finfish abundances, raw abundances were standardized to densities per 100 $m^2$. Due to lack of replication, finfish densities over the reef were not statistically analysed.

Photoquadrats were analysed using several software packages that: straighten image perspective, select random points of assessment (n = 16) to record substrate or coral species at each point and determine overall percent coverage of coral and substrates for each replicate photoquadrat. Photoquadrat images were lens corrected with DxO Viewpoint 3 software and analysed with CPCe 4.1 software.

# 3 RESULTS

## 3.1 Invertebrates

A total of 27,718 individuals were observed across 135 transects, representing 46 different invertebrate taxa. The most frequently observed invertebrate was the tube snail, *Dendropoma* spp., where a total of 10,860 individuals were recorded across all transects. The sea urchin, *Echinometra mathei,* was the second most common invertebrate with a total of 7,075 individuals recorded. The blue-black urchin, *Echinothrix diadema*, was the third most common invertebrate observed overall (n = 1,200), but *E. diadema* was the most common invertebrate species recorded on ORT transects (n = 465).

### 3.1.1 Total Abundance: Reef Invertebrates

Total abundance of reef invertebrates ranged from 170.16 ± 51.35 ind./100 $m^2$ at Veitati Rā'ui to 953.44 ± 54.54 ind./100 $m^2$ at Tavaenga Control. Significant differences were detected where reef invertebrate densities recorded at Tavaenga Control and Karanga Rā'ui were both significantly greater than densities at Veitati Rā'ui ($p = 0.006$ and $p = 0.010$ respectively) (survey site: $F_{(8,98)} = 3.31$, $p = 0.002$).

### 3.1.2 Total richness: Reef Invertebrates

Of the 39 different taxa observed across reef transects, Veitatei Control had the greatest richness (9.13 ± 1.44 ind./40 $m^2$) and was significantly greater than Tamarua Control (survey site: $p = 0.001$, Fig. 2).

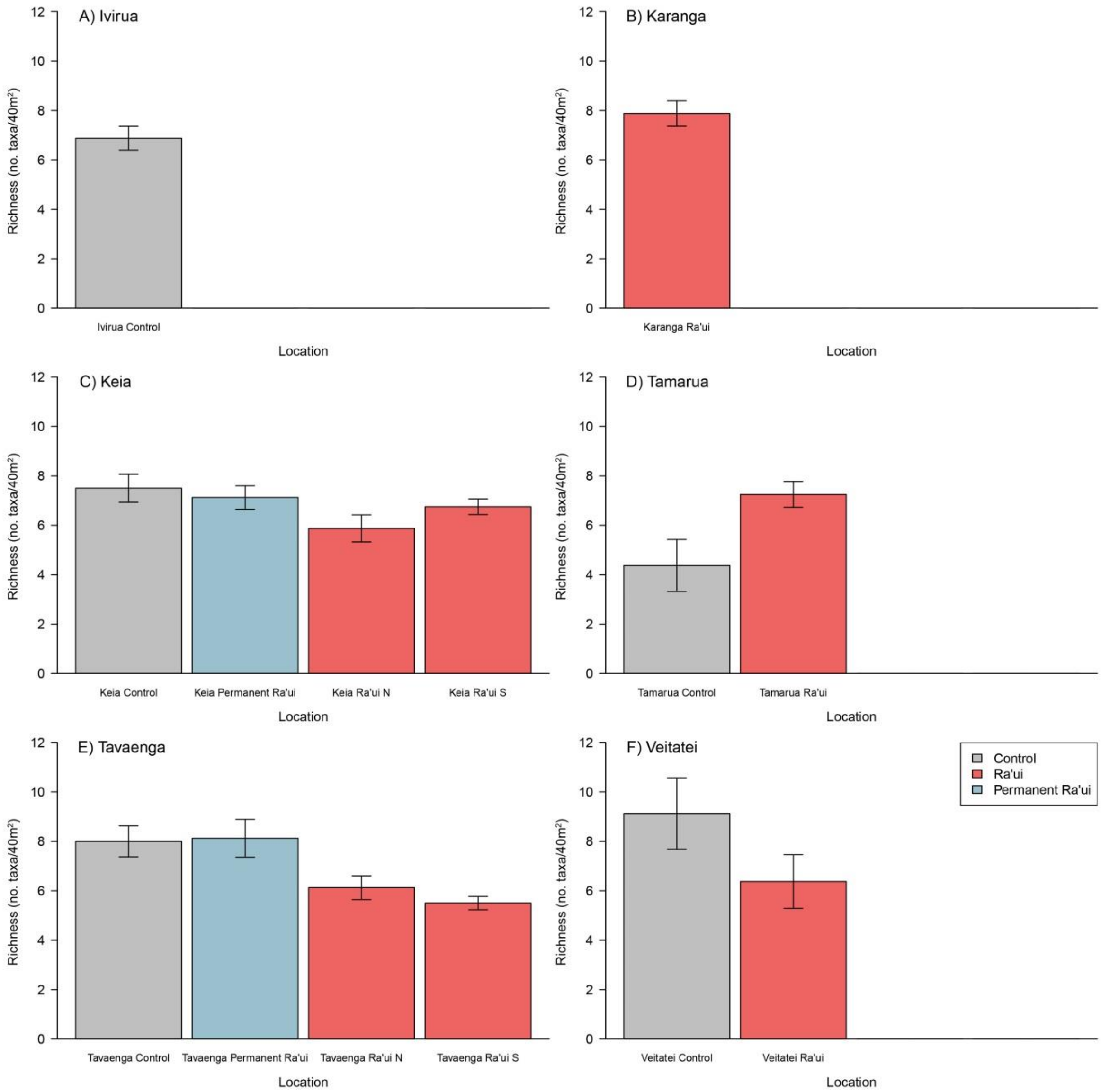


Fig. 2. Mean species richness (± 1 S.E.) of invertebrates from reef survey sites.

### 3.1.3 *Paua* (*Tridacna* spp.)

Overall, *paua* densities were greatest in Keia Rā'ui South (29.69 ± 9.18 ind./100 $m^2$) where densities were at least two times greater compared to all other sites. Significant differences among survey sites were detected (survey site: $p$ < 0.001) where Keia Rā'ui South had significantly greater densities of *paua* than Ivirua Control, Karanga Rā'ui, Keia Permanent Rā'ui, Keia Rā'ui North, Tamarua Control, Tamarua Rā'ui, Tavaenga Rā'ui North, Tavaenga Rā'ui South, Veitatei Control and Veitatei Rā'ui (Fig. 3). *Paua* length frequencies were normally distributed in the puna of Keia and Tavaenga (

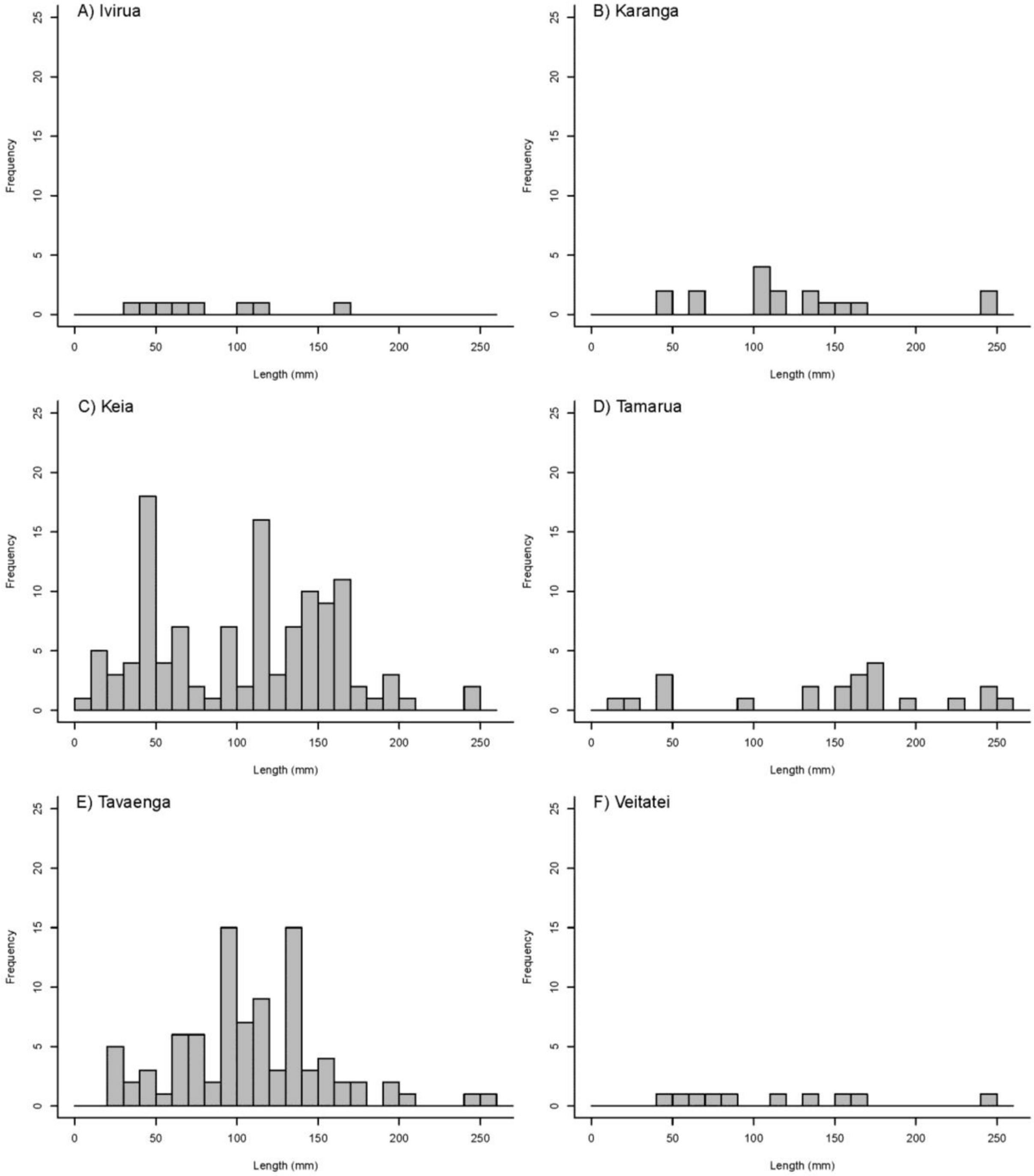


Fig. 4). Within the remaining four *au puna*, a wide range of sizes were observed but in very low frequencies.

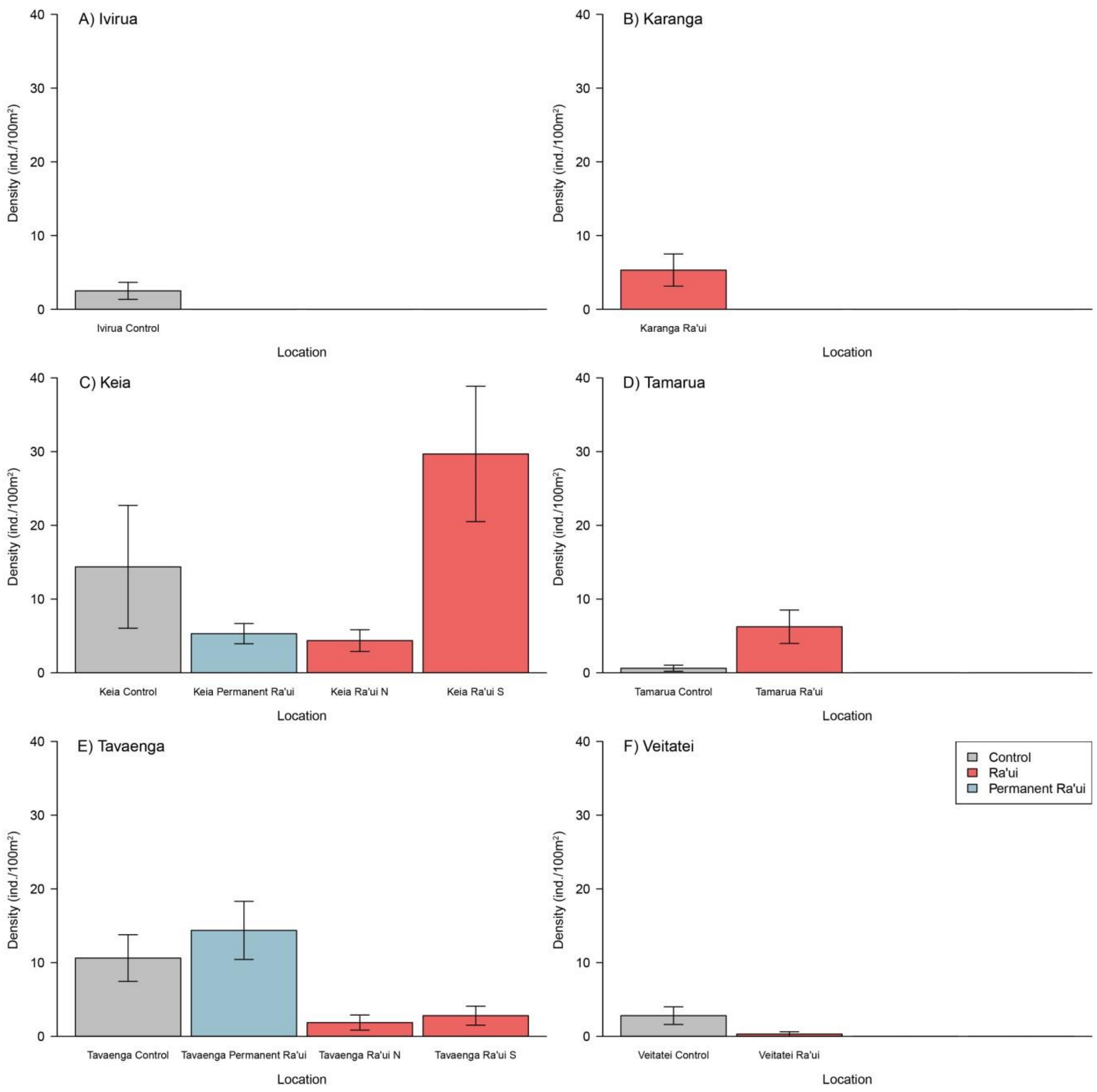


Fig. 3. Mean *Tridacna* spp. densities (± 1 S.E.) from reef habitats.

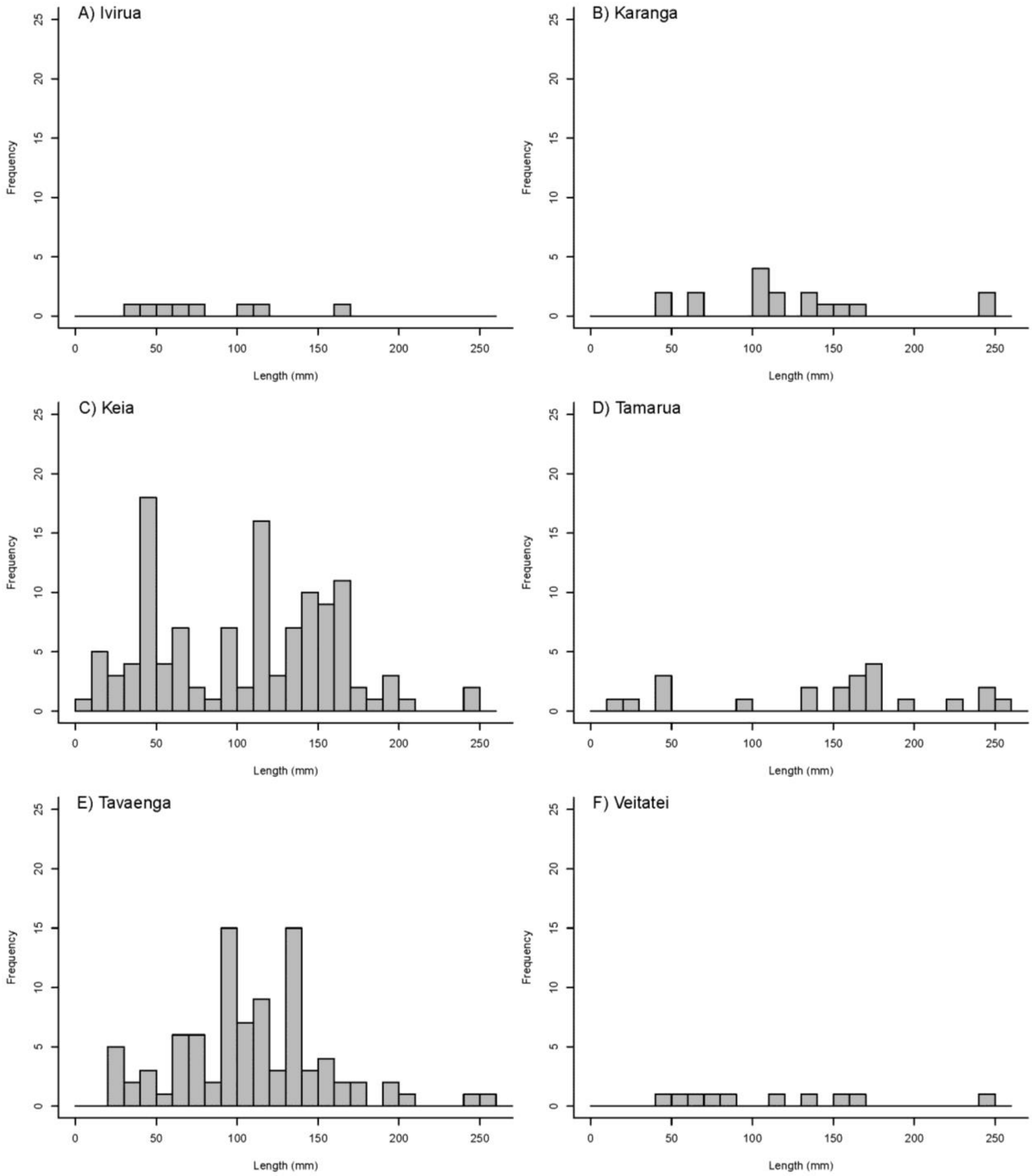


Fig. 4. *Tridacna* spp. length-frequencies within each *puna*.

### 3.1.4 Trochus (*Tectus niloticus*)

Trochus were only observed over the reef in the Keia Rā'ui North site (n = 2).

### 3.1.5 *Ariri* (*Turbo* spp.)

Within reef habitats, *ariri* density averaged 0.7 ind./100 $m^2$ and were recorded only within the Veitatei Rā'ui, Veitatei Control, Tavaenga Control, Tamarua Rā'ui, Tamarua Control and Karanga Rā'ui. *Ariri* density was greatest at Veitatei Control (3.44 ± 2.79 ind./100 $m^2$) driving significant differences among *au puna* (*puna*: $p$ = 0.035). Within ORT sites, *ariri* density averaged 1.96 ind./100 $m^2$ and recorded within the Tavaenga Control, Tamarua Rā'ui, Tamarua Control, Keia Rā'ui South, Keia Control and Ivirua Control survey sites. *Ariri* density was greatest at Tavaenga Control (n = 3).

### 3.1.6 *Ungakoa* (*Dendropoma* spp.)

Within reef habitats, *ungakoa* were the most frequently recorded invertebrate. Densities were greatest within Tavaenga Control (439.06 ± 44.47 ind./100 $m^2$) and Karanga Rā'ui (391.25 ± 163.98 ind./100 $m^2$).

### 3.1.7 *Rori Toto* (*Holothuria atra*)

Within reef habitats, the greatest densities of *rori toto* were observed within Tavaenga Rā'ui South (147.19 ± 46.26 ind./100 $m^2$) and Tavaenga Permanent Rā'ui (139.84 ± 72.46 ind./100 $m^2$). The *puna* of Tavaenga had approximately 2.6 times greater densities of *rori toto* than the *puna* of Keia (*puna: p* < 0.012, Fig. 5). *Rori toto* were not observed in ORT habitats.

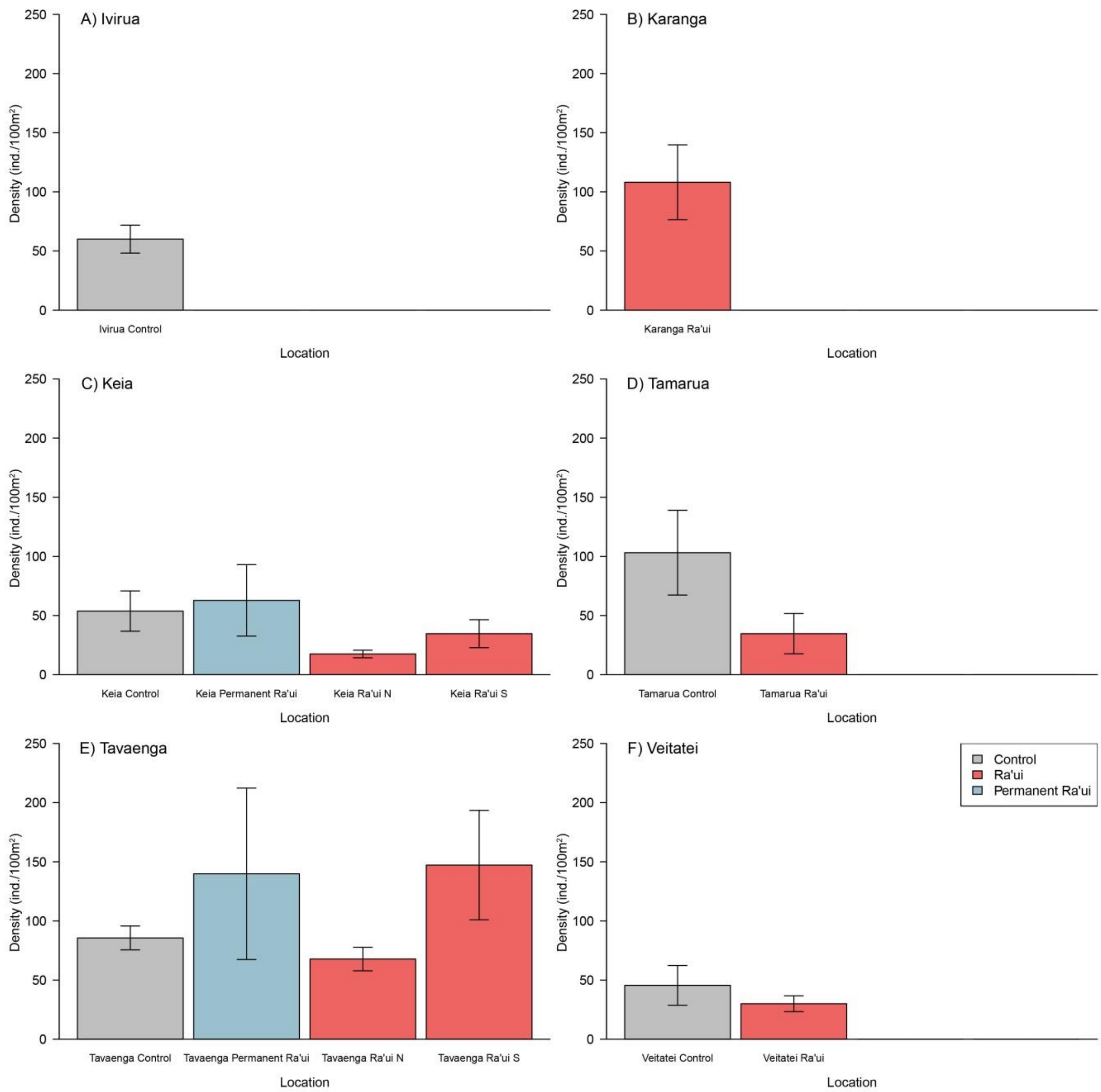


Fig. 5. Mean *rori toto* densities (± 1 S.E.) from reef survey sites.

### 3.1.8 *Rori Piripiri* (*Holothuria leucospilota*)

Within reef habitats, *rori piripiri* were recorded at all sites other than Keia Rā'ui North and Tavaenga Rā'ui South. The greatest density was recorded within Tavaenga Control (18.75 ± 8.60 ind./100 m2). Densities within Tavaenga Control were significantly greater than those within Ivirua Control, Karanga Rā'ui, Keia Control, Keia Rā'ui North, Keia Rā'ui South, Tamarua Rā'ui, Tavaenga Permanent Rā'ui, Tavaenga Rā'ui South and Veitatei Control (survey site: $p < 0.001$, Fig. 6). *Rori piripiri* were not observed in any ORT habitats.

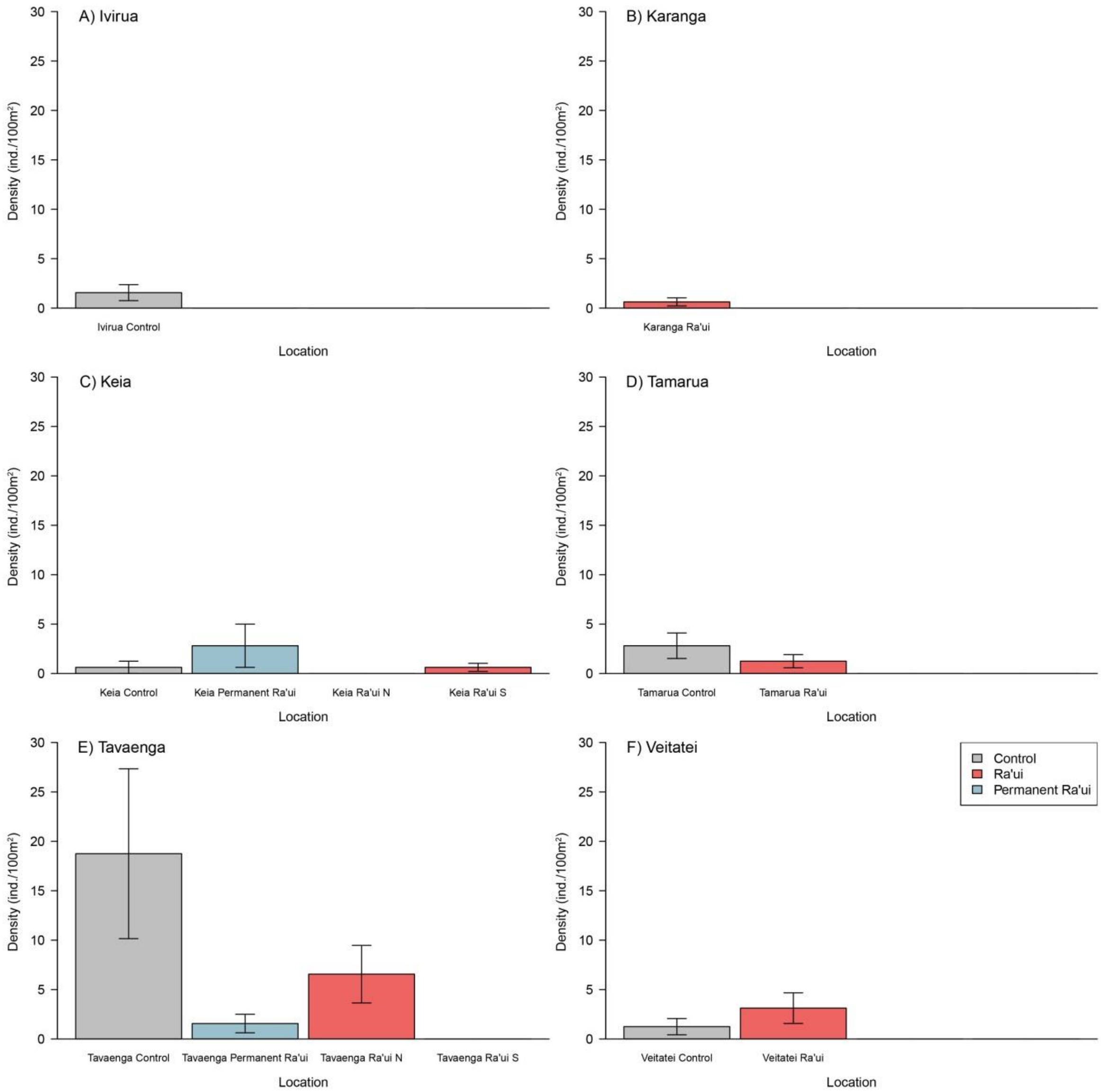


Fig. 6. Mean *rori piripiri* densities (± 1 S.E.) from reef survey sites.

### 3.1.9 *Rori Puakatoro* (*Actinopyga mauritiana*)

Within reef habitats, *rori puakatoro* were observed at all sites. Significant differences in densities between sites did not exist.

### 3.1.10 *Āvake* (*Tripneustes gratilla*)

Across all sites, *āvake* were observed in Tavaenga Control (n = 4), within the RBT habitat, only.

### 3.1.11 *Vana* (*Echinothrix diadema*)

Within reef habitats, *vana* were observed in all sites except Tamarua Control. Significant differences in *vana* densities between sites were detected (survey site*:* $p < 0.001$) where densities in Keia Rā'ui North were generally greater than densities in Keia Control, Keia Rā'ui South, Tamarua Control, Tavaenga Rā'ui South and Veitatei Rā'ui (Fig. 7). Within ORT habitats, *vana* were observed in all sites with the exception of Keia Permanent Rā'ui and Tamarua Rā'ui (Fig. 8). Across all sites, *Vana* densities were approximately five times greater over the reef in ORT habitats, compared to within the reef RBT and RFT habitats (mean density approximately 83.0 ind./100 $m^2$ and 15.8 ind./100 $m^2$ respectively).

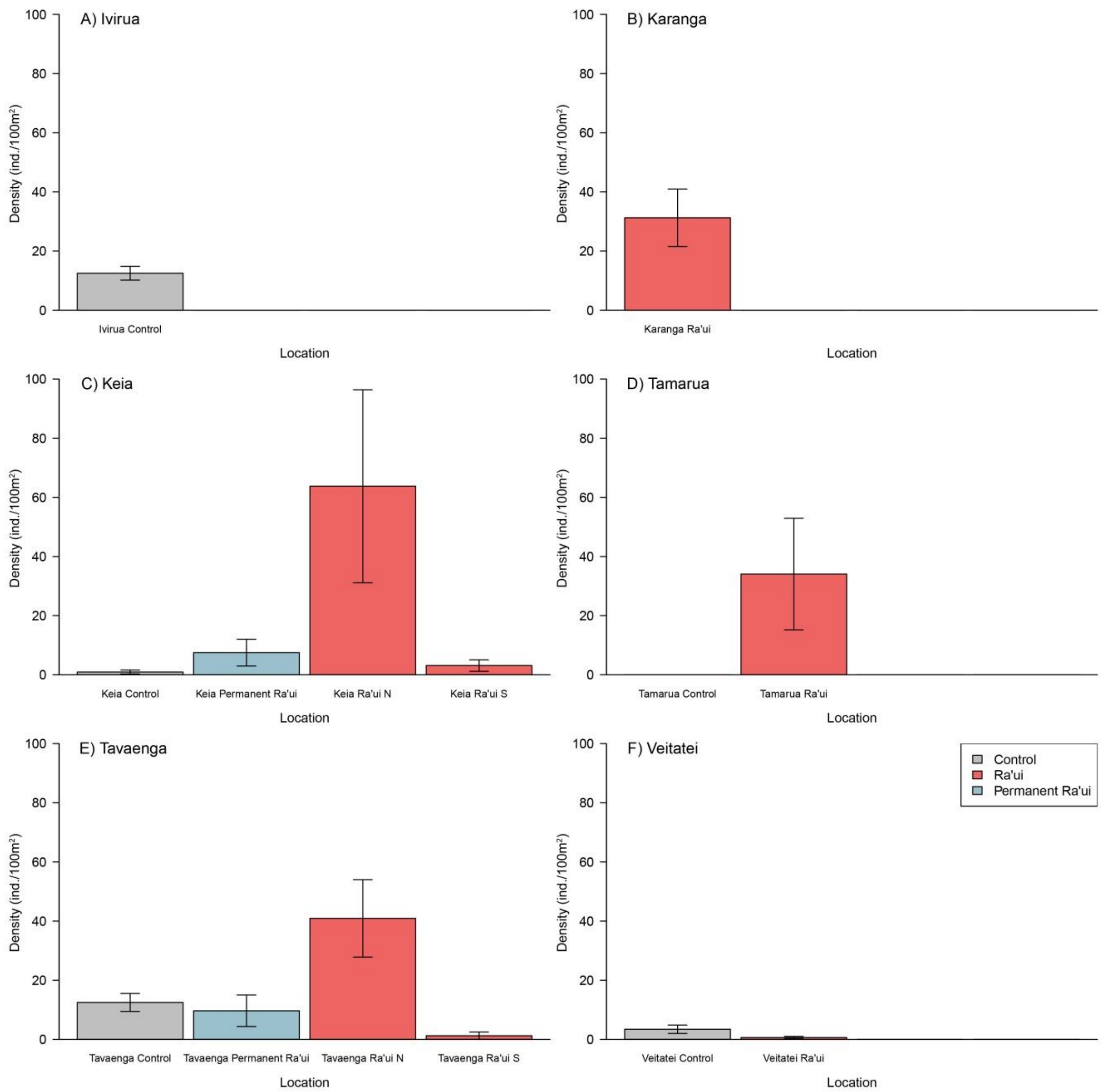


Fig. 7. Mean *vana* densities (± 1 S.E.) from reef survey sites.

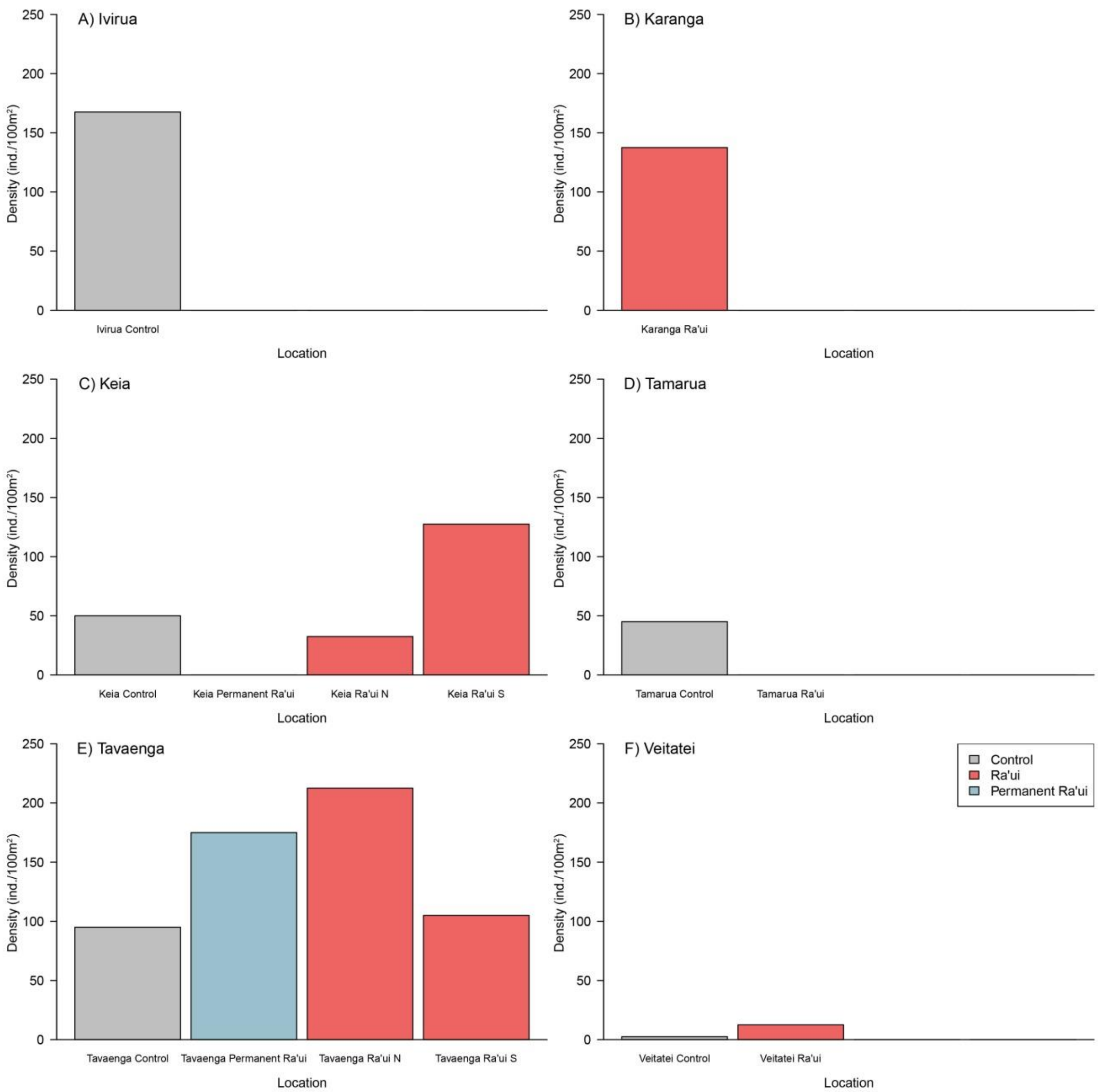


Fig. 8. Mean *vana* densities from ORT habitats.

### 3.1.12 *'Atuke* (*Heterocentrotus mammillatus*)

Within reef habitats, *'atuke* were recorded only within the control sites of Ivirua, Keia, Tamarua and Veitatei (Fig. 9). Significant differences in species density were not detected between survey site or *puna*.

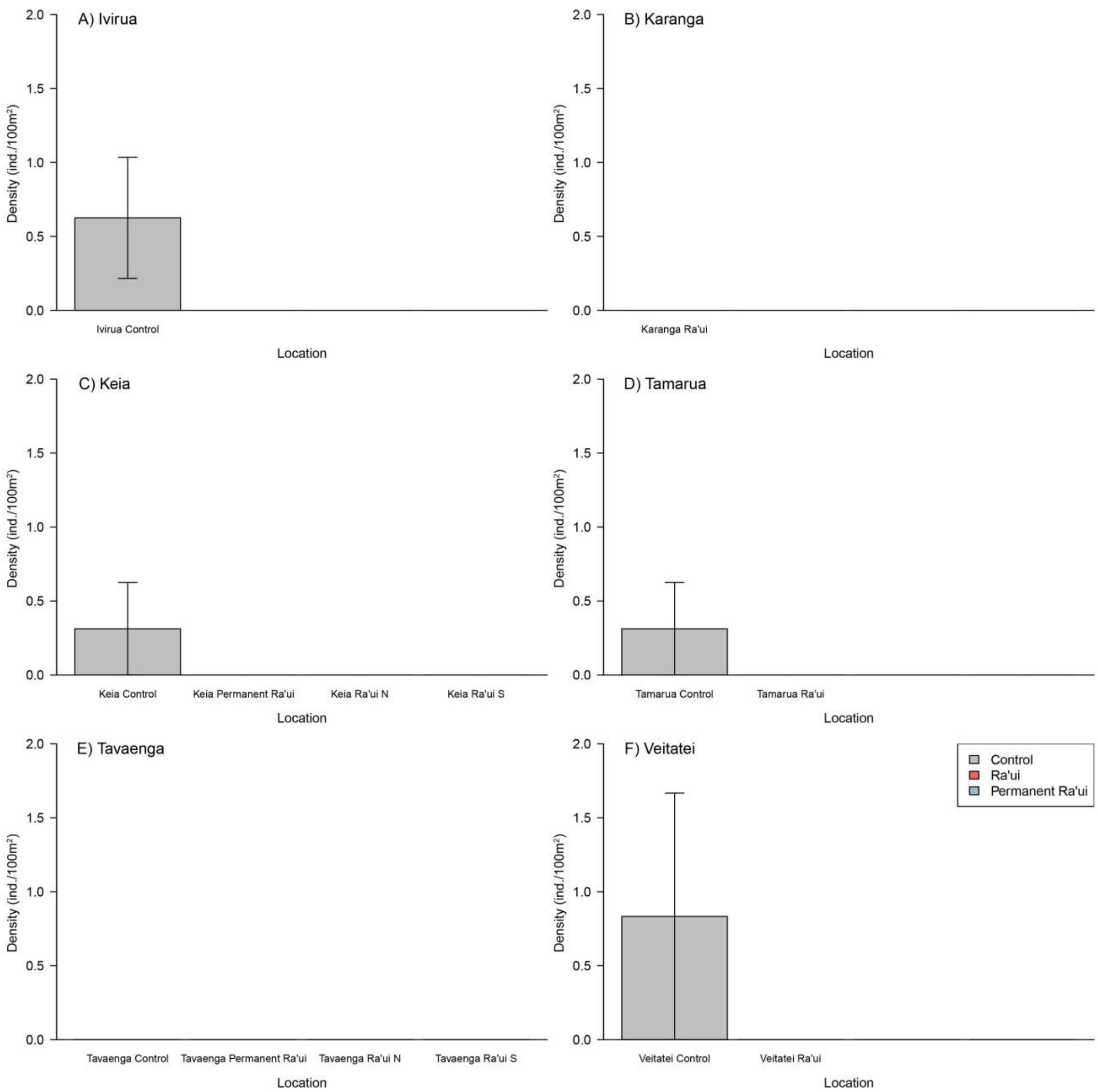


Fig. 9. Mean ‘*atuke* densities (± 1 S.E.) from reef survey sites.

### 3.1.13 *Mapi’i* (*Scutellastra flexuosa*)

*Mapi’i* were only observed within the reef habitats of Keia Control, Tamarua Control, Veitatei Control and Veitatei Rā’ui. Significant differences in species densities between sites or *puna* were not detected.

### 3.1.14 *Karikao* (*Astralium rhodostomum*)

Within reef habitats, *karikao* were observed in the Ivirua Control, Keia Control, Tamarua Control, Veitatei Control and Veitatei Rā'ui (Fig. 10). Within the ORT habitat, *karikao* were only observed in the Tamarua Rā'ui and Veitatei Rā'ui. Significant differences in species densities between sites or *puna* were not detected.

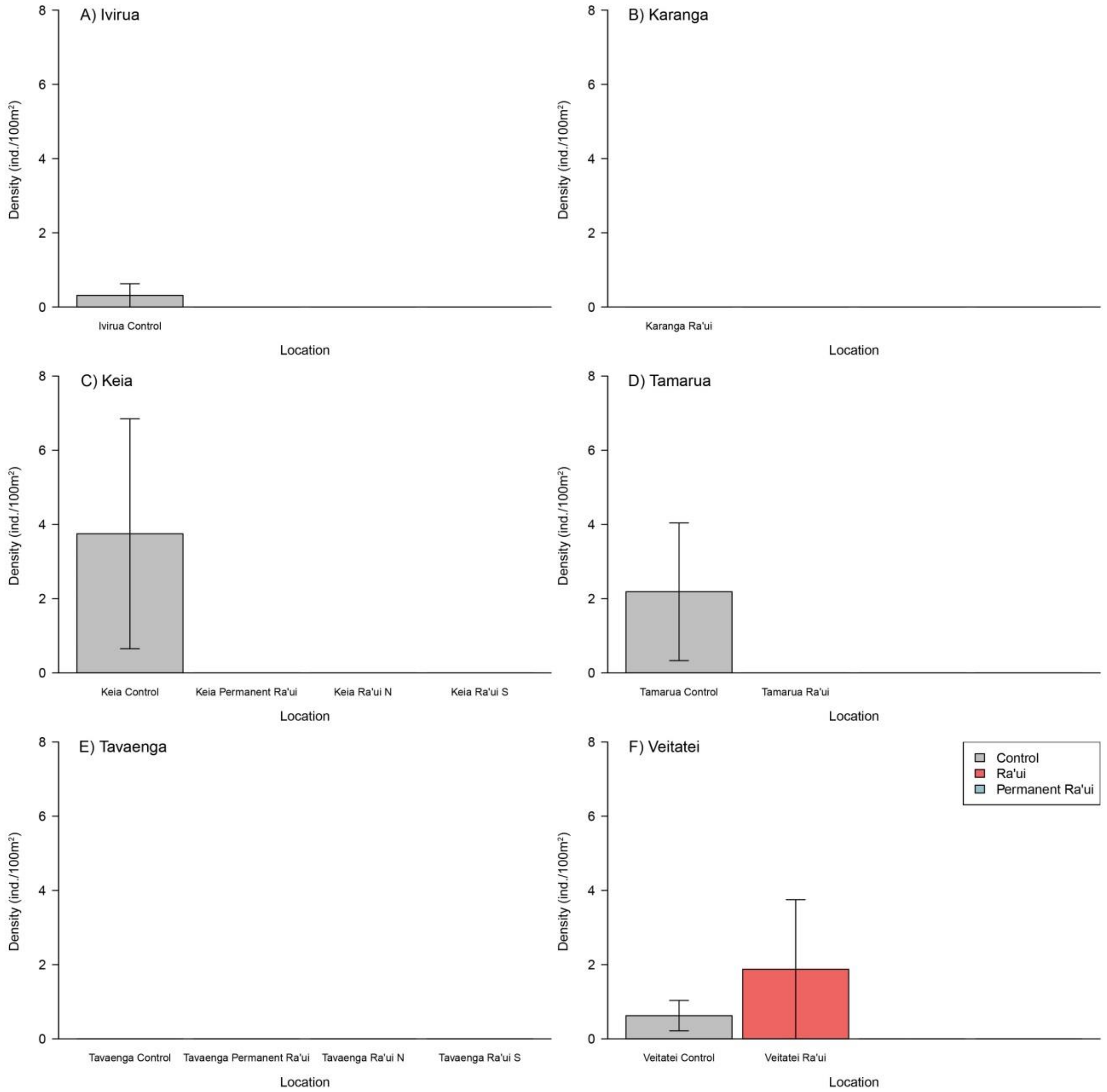


Fig. 10. Mean *karikao* densities (± 1 S.E.) from reef survey sites.

### 3.1.15 *Mangeongeo* (*Drupa morum*)

Within reef habitats, *mangeongeo* densities were greatest in Keia Control, Tavaenga Permanent Rā'ui and Veitatei Rā'ui. *Mangeongeo* were also observed in Keia Rā'ui South, Tavaenga Control, Tavaenga Rā'ui South and Veitatei Control (Fig. 11). *Mangeongeo* were not observed within any site of the ORT habitat. Significant differences in species densities between sites or *puna* were not detected.

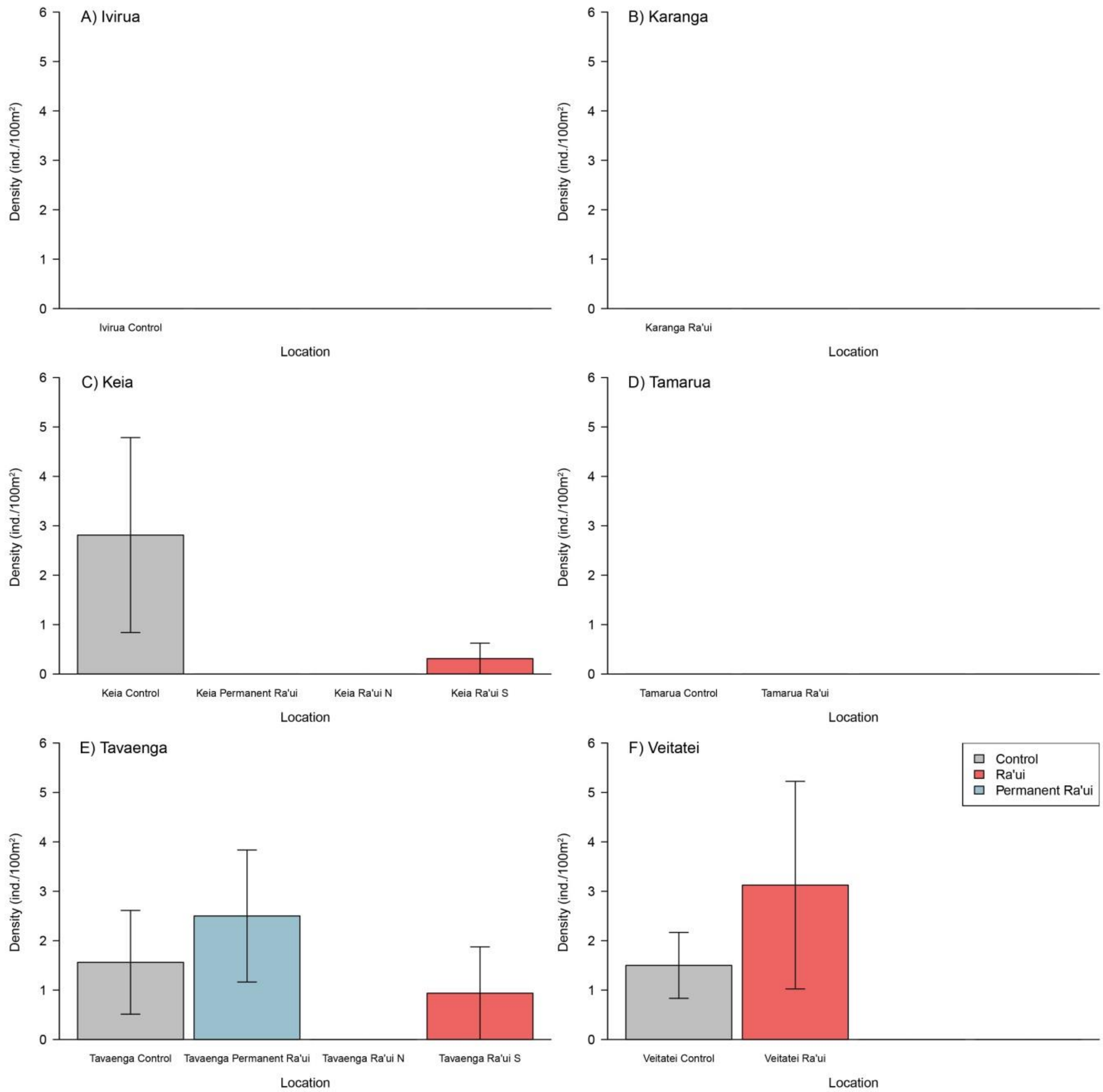


Fig. 11. Mean *mangeongeo* densities (± 1 S.E.) from reef survey sites.

### 3.1.16 *Popoto* (*Conus* spp.)

Within reef habitats, *popoto* were observed in the Karanga Rā'ui, Keia Control, Keia Permanent Rā'ui, Tamarua Rā'ui, Tavaenga Control, Tavaenga Permanent Rā'ui, Tavaenga Rā'ui South, Veitatei Control and Veitatei Rā'ui (Fig. 12). Within the ORT habitat, *popoto* were observed in the Ivirua Control, Tamarua Control and Veitatei Control. Significant differences in species densities between sites or *puna* were not detected.

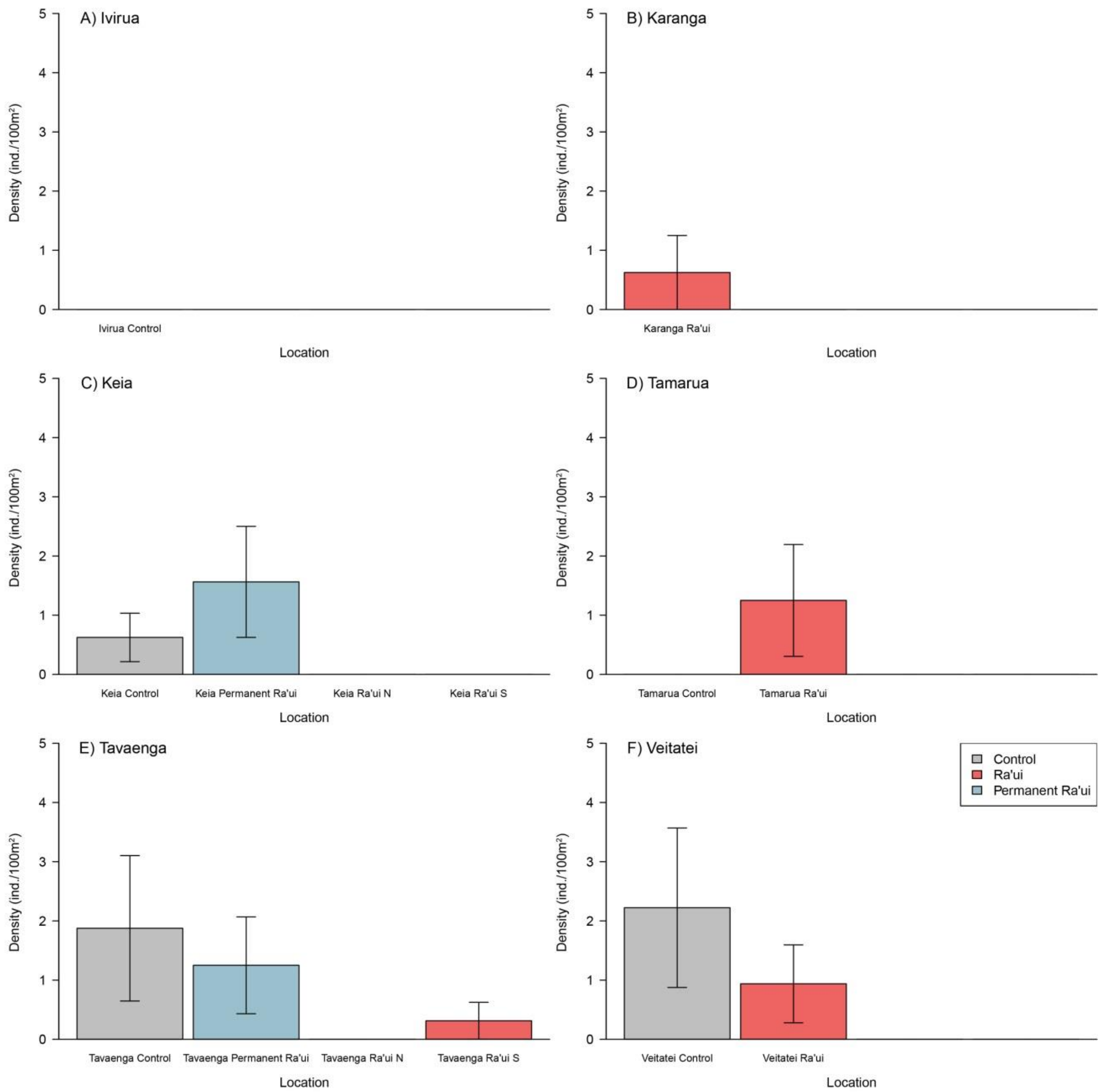


Fig. 12. Mean *popoto* densities (± 1 S.E.) from reef survey sites.

## 3.2 Finfish

A total of 5,369 finfish were observed across 14 transects, representing 95 different taxa. The most frequently observed species was the *maito* (*Ctenochaetus striatus*)*,* where a total of 1,120 individuals were recorded. Other frequently observed fish included *Chromis acares* (n = 758) and *Chromis vanderbilit* (n = 599).

### 3.2.1 Total Abundance: Finfish

Finfish numbers were highest within the survey site Tavaenga Rā'ui North with a density of 406 ind./100 $m^2$ (Fig. 13). Overall, the *au puna* of Keia and Tavaenga had the highest finfish densities (182.0 and 249.9 ind./100 $m^2$ respectively) and Veitatei, the lowest (96.0 ind./100 $m^2$).

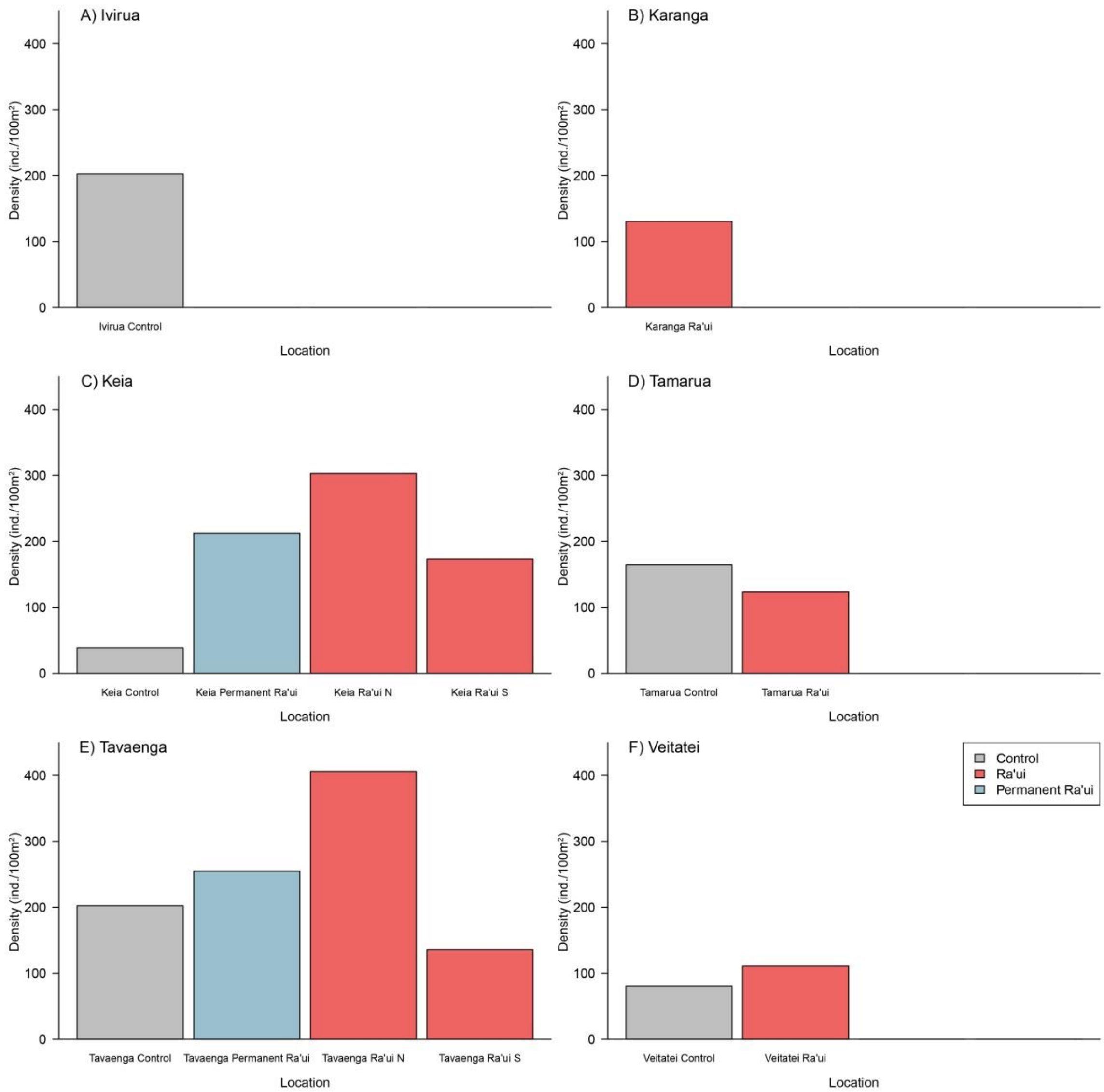


Fig. 13. Finfish abundance within ORT sites.

### 3.2.2 Total Richness: Finfish

Fish species diversity ranged from 25 species/50 $m^2$ in Keia Control to 39 species/50 $m^2$ in Keia Permanent Rā'ui (Fig. 14). Overall, species richness between *au puna* was similar.

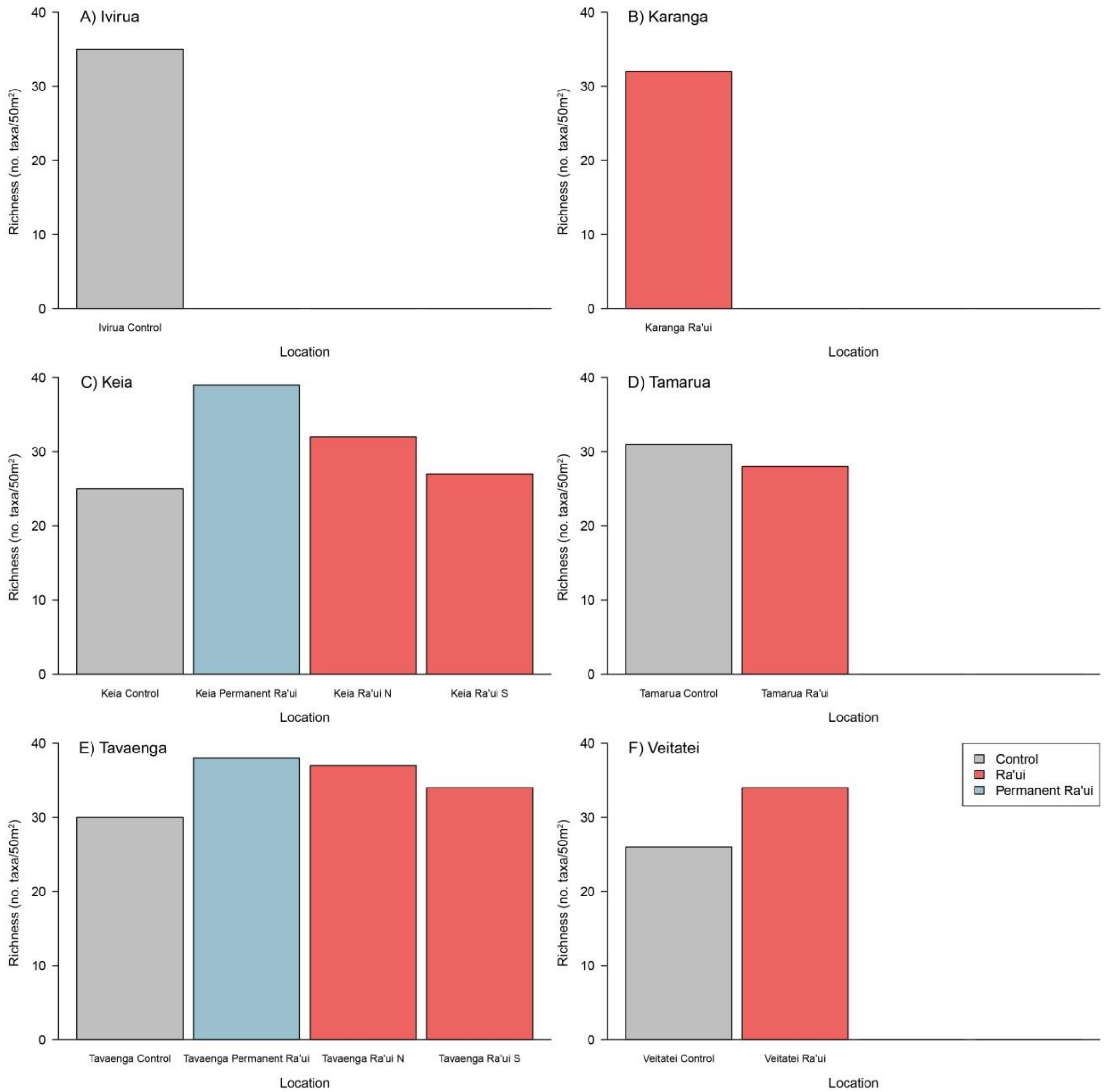


Fig. 14. Finfish richness within ORT sites.

### 3.2.3 Finfish of special interest

Finfish densities across survey sites for several species of interest are presented in Table 1. *'Iku-toto* (*Acanthurus achilles*) were observed only within the Keia Control (n = 3) and Tamarua Control (n = 5) survey sites. The only *pipi* (*Kyphosus* spp.) observed was a single animal within Veitatei Rā'ui. *Mū* (*Monotaxis grandoculis*) were only observed within Tavaenga Permanent Rā'ui (n = 2), Tavaenga Rā'ui South (n = 1) and Tamarua Control (n = 1).

*Ume* (*Naso unicornis*) were only observed within the Karanga Rā'ui (n = 2), Keia Control (n = 2) and Tavaenga Permanent Rā'ui (n = 6). *Maemae* and/or *Morava* (*Siganus* spp.) were only observed within the Ivirua Control (n = 1) and Veitatei Control (n = 1). *Tiovi* (*Acanthurus triostegus*) were observed only within Keia Rā'ui North (n = 80). *Umeume* (*Naso lituratus*) were observed at all sites with the exception of Keia Control. The *puna* of Tavaenga and Keia had the highest overall densities. *Pakati* and *u'u* (Scaridae) were observed in all sites except Tavaenga Rā'ui North and Tavaenga Rā'ui South. *Katoti* (*Centrotype loricula*) were observed at all sites with the exception of Ivirua Control.

Fish taxa of interest which were unobserved on transect included *urua* (*Caranx ignobilis*), *maratea* (*Cheilinus undulatus*), *vete* and *takua* (*Mulloidichthys* spp.) and *mango*/*papera* (Carcharhinidae).

Table 1. Density of special interest finfish species (ind./100 m$^2$) observed on transect in Mangaia, March 2018.

| Maori Name | *'Iku-toto* | *Pipi* | *Mū* | *Ume* | *Maemae & Morava* | *Tiovi* | *Umeume* | *Pakati & U'u* | *Katoti* | *Urua* | *Maratea* | *Vete & Takua* | *Mango/Papera* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scientific Name | *Acanthurus achilles* | *Kyphosus spp.* | *Monotaxis grandoculis* | *Naso unicornis* | *Siganus spp.* | *Acanthurus triostegus* | *Naso Lituratus* | *Scaridae* | *Centropyge loricula* | *Caranx ignobilis* | *Cheilinus undulatus* | *Mulloidichthys spp.* | *Carcharhinidae* |
| <u>Ivirua</u> | | | | | | | | | | | | | |
| Ivirua Control | X | X | X | X | 0.5 | X | 1.5 | 2 | X | X | X | X | X |
| <u>Karanga</u> | | | | | | | | | | | | | |
| Karanga Rā'ui | X | X | X | 1 | X | X | 0.5 | 2 | 4.5 | X | X | X | X |
| <u>Keia</u> | | | | | | | | | | | | | |
| Keia Control | 1.5 | X | X | 1 | X | X | X | 2 | 0.5 | X | X | X | X |
| Keia Permanent Rā'ui | X | X | X | X | X | X | 7.5 | 1 | 17.5 | X | X | X | X |
| Keia Rā'ui North | X | X | X | X | X | 40 | 11 | 2 | 9 | X | X | X | X |
| Keia Rā'ui South | X | X | X | X | X | X | 9 | 1.5 | 11 | X | X | X | X |
| <u>Tamarua</u> | | | | | | | | | | | | | |
| Tamarua Control | 2.5 | X | 0.5 | X | X | X | 3 | 1.5 | 3 | X | X | X | X |
| Tamarua Rā'ui | X | X | X | X | X | X | 1 | 1 | 0.5 | X | X | X | X |
| <u>Tavaenga</u> | | | | | | | | | | | | | |
| Tavaenga Control | X | X | X | X | X | X | 7.5 | 1.5 | 4 | X | X | X | X |
| Tavaenga Permanent Rā'ui | X | X | 1 | 3 | X | X | 3 | 1.5 | 7.5 | X | X | X | X |
| Tavaenga Rā'ui North | X | X | X | X | X | X | 5 | X | 7.5 | X | X | X | X |
| Tavaenga Rā'ui South | X | X | 0.5 | X | X | X | 6 | X | 4 | X | X | X | X |
| <u>Veitatei</u> | | | | | | | | | | | | | |
| Veitatei Control | X | X | X | X | 0.5 | X | 3 | 1.5 | 0.5 | X | X | X | X |
| Veitatei Rā'ui | X | 0.5 | X | X | X | X | 3 | 1.5 | 1.5 | X | X | X | X |

### 3.3 Keia Rā’ui harvest: *paua*

With the opening of the Keia Rā’ui, *paua* (*Tridacna* spp.) species density declined from 29.69 ± 9.18 ind./100 $m^2$ before harvest to 12.50 ± 4.20 ind./100 $m^2$ after harvest, but this decline was not significant ($p$ = 0.111, Fig. 15). However, differences in the distribution of *paua* sizes/lengths were detected, comparing size frequencies before and after harvest (Fig. 16). Average *paua* length decreased significantly from 141.45 ± 5.35 mm before harvest to 69.7 ± 7.89 mm after harvest ($p$ < 0.001).

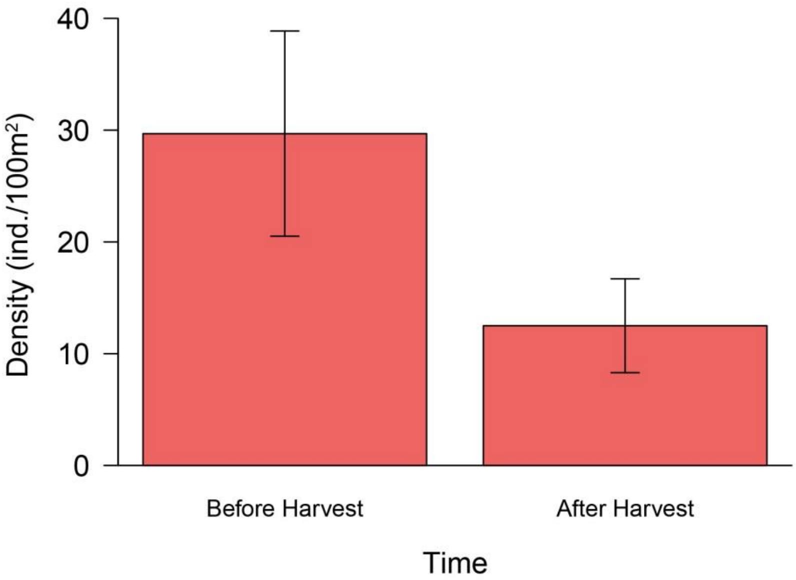


Fig. 15. Keia Rā’ui South, *Tridacna* spp. densities (± 1 S.E.) before and after *rā’ui* harvest on March 24th 2018.

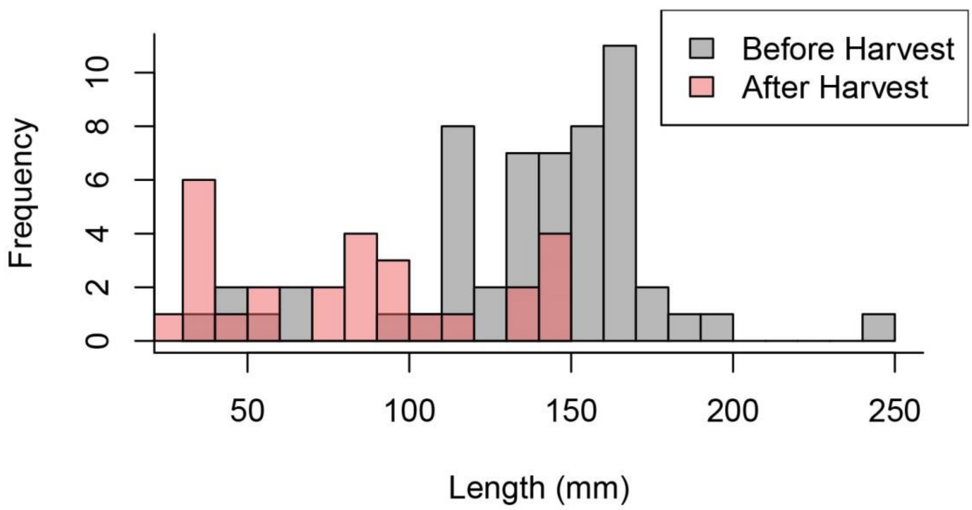


Fig. 16. Keia Rā’ui South, *Tridacna* spp. length-frequencies before and after *rā’ui* harvest.

## 3.4 Coral and Substrate

Photoquadrats were primarily composed of hard substrate (bare pavement), followed by macroalgae and crustose coralline algae (Fig. 17). Across all sites, live coral cover averaged less than 20%. Live coral cover was greatest at Tamarua Control. Hard corals were more frequently observed than soft corals. Bleached corals were rarely observed. Macroalgae, such as the calcified green alga *Halimeda spp.*, had a relatively large presence, averaging 31% coverage across all survey sites (Fig. 17).

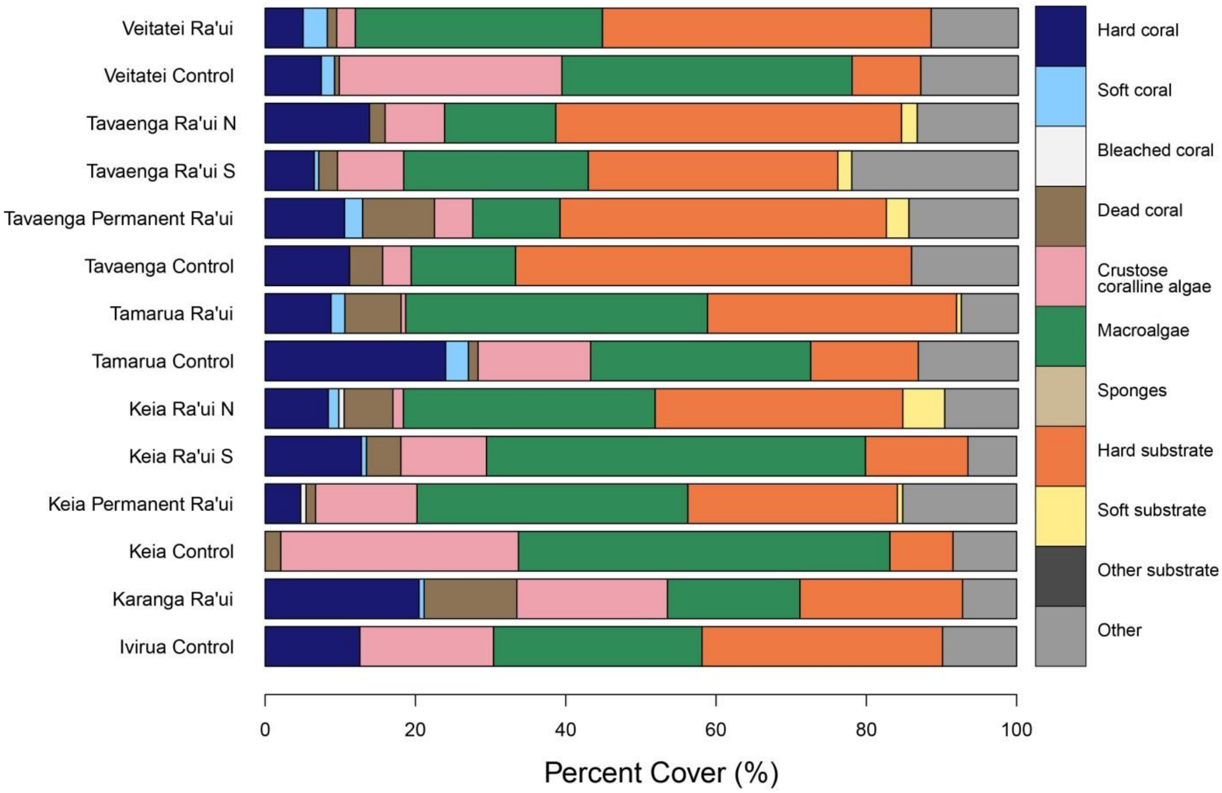


Fig. 17. Substrate type and percent cover from ORT sites.

# 4 DISCUSSION

## 4.1 Invertebrates

In Mangaia, *paua* is a valuable resource and highly sought after by fishers and local communities for consumption and sale. Our survey found an average density of *paua* in reef habitats of 7.23 ind./100 $m^2$. The lack of historic data of Mangaian reef resources prohibits long term *paua* population trend analysis (edit: Mangaia Reef Resources Baseline Assessment (2001) was located after formation of this report and unfortunately, historical comparisons were not included). However, when compared to the uninhabited island of Manuae (where *paua* densities in similar habitats averaged 290 ind./100 $m^2$, Ainley *et al.,* 2018), *paua* densities in Mangaia are low. Keia Rā'ui South, before *rā'ui* opening, had the highest *paua* densities suggesting that the *rā'ui* system of traditional fisheries management may be actively observed by fishers and contributes to effective and sustainable resource management in Mangaia.

*Ungakoa* was the most commonly observed invertebrate in Mangaia with a total of 10,860 observations made. This number is not representative of harvestable sized individuals. The majority of *ungakoa* observed were small and likely not worth the effort to harvest.

Trochus are a non-native species to the Cook Islands and introduced as a potential food and revenue resource (both using the trochus shell and meat) for island residents. Our surveys found trochus to be in extremely low numbers. Mangaian residents explained that after introduction, trochus populations were not sustained and was never a commonly observed species. This data reported in this report confirms that the trochus introduction was unsuccessful at creating a viable fishery.

*Ariri* were found in both within reef and over the reef habitats. While more common over the reef, averaging 1.96 ind./100 $m^2$, overall *ariri* numbers were low. *Ariri* are locally consumed but harvesting for this resource is reportedly sporadic and opportunistic.

Of the three main species of sea cucumber (*rori toto, rori piripiri* and *rori puakatoro*), all were ubiquitous within reef habitats of all six *au puna* in Mangaia. During a harvesting event, the gonads and other desired flesh of individuals are removed *in situ*, leaving behind the unwanted remains of the sea cucumber on the reef. The ability of *rori toto* to regenerate after gonad harvest, combined with low levels of harvest, may contribute to the lack of significant differences in *rori toto* densities between *rā'ui* and areas open to unregulated harvest (Conand 1995). *Rori piripiri* densities were significantly higher within an area open to unregulated harvest (Tavaenga Control) than in some *rā'ui* areas which further suggests that harvesting and *rā'ui* management is not having a significant impact on population densities of this species. Significant differences in *rori puakatoro* densities were not found. Habitat preference is likely a greater determining factor in Mangaian sea cucumber population densities.

*Āvake* were scarce and only found within one survey site in Mangaia. *Rā'ui* harvest restrictions in Mangaia are reportedly observed by locals suggesting that within Mangaian reef habitats, *āvake* may occur naturally in low densities. Alternatively, densities may be low due to an insufficient *rā'ui* closure time which would inhibit population density recovery. Dafni (1992) found the growth rate of a subspecies of *āvake* to be highly dependent on food availability. Under prime conditions, *āvake* may achieve a maximum 60 mm growth within 150 days, although average growth within the same period was to 35 mm (Dafni 1992).

*Vana* densities in Mangaia were substantially higher than observed in recent surveys in the other Southern Group islands of Rarotonga, Aitutaki, Manuae, Takutea, Atiu and Mitiaro (Ainley et al. 2018, Kora et al. 2018, Kora et al. 2018, in preparation). In Mangaia, *vana* densities were greatest in the ORT habitat and frequently observed in large aggregations in and at the bottom of reef channels and valleys. Within transects in the ORT habitats, *vana* were found within all *puna* and in nearly all sites. Within reef habitats, *vana* were most frequently observed within *rā'ui*. Assuming that *vana* are a targeted species of interest for harvest, this suggests that *rā'ui* are effective in rebuilding and sustaining *vana* populations.

*Mapi'i, karikao, mangeongeo* and *popoto* were in low densities across all sites in Mangaia. Despite, these species being concentrated within reef habitats, significant differences in densities between sites and *au puna* were not found. While none of these species are currently harvested for their shells or meat, *Karikao* and *popoto* were reportedly eaten in the past.

## 4.2 Finfish

The low densities of *pipi* observed were likely due to their preference for reef flats and surf zones that were not targeted by the ORT finfish transects. Many *pipi* were observed off transect in the surf and on reef flats. Large shoals of *pipi* were observed (and captured by fishermen) during the opening of Keia Rā'ui South. *Pipi* are a heavily targeted and prized species in Mangaia, and are often captured with large nets. *Mū* were infrequently observed on transect, and similarly many more were observed off transect, but in depths greater than 10 m, below our ORT transects.

*Umeume* were observed within all *puna* and within all but one site, which is most exposed to wind and swell. The distribution of *umeume* records suggests that this species may have a preference for sheltered habitats and that population densities are more controlled by environmental factors than targeted fishing pressures.

*Pakati* and *u'u* were observed within all sites other than Tavaenga Rā'ui sites. Particularly, the species *Scarus forsteni* was observed in higher densities than previously observed in other southern group island surveys. Off transect, very large *Chlorurus frontalis* were observed near the surf zone.

*Maemae* and *morava* were observed only within Ivirua and Veitatei control sites. Like the *pipi,* these species are prized for food, actively targeted by fishers and were infrequently observed in our surveys likely due to their preference for shallower areas.

*Katoti* were in very high densities and observed within all *puna* and all sites other than Ivirua Control. *Katoti* are a charismatic species for SCUBA divers and underwater photographers. *Katoti* are also popular aquarium fish although prices have dropped drastically in recent years. Densities of this species in Mangaia were higher than the team had observed at other southern group islands.

## 4.3 Endangered/Sensitive Species (Sharks, Turtles and Maratea)

*Papera* (*Carcharhinus amblyrhynchos*) were not observed on transect but were frequently observed off transect during surveys. *Papera* in Mangaia are often implicated in depredation where they take already hooked or speared fish from fishers. No turtles were observed on or off transect. The cause of low turtle densities may be influenced by the rough *makatea* cliffs and lack of sandy beaches which make Mangaia unsuitable for haul out or nesting by turtles. *Maratea* (*Cheilinus undulatus*) were reported to exist in Mangaia but no observations, on or off transect, were made for this species.

### 4.4 Keia Rā'ui South Paua Harvest

Results and observations from recent surveys on other southern group islands indicate that Mangaia may have one of the only functioning *rā'ui* systems (Ainley *et al*. 2018, Kora et al. 2018, Kora et al. 2018, in preparation). This is most apparent when analysing the change in average *paua* densities and sizes, before and after the temporary lifting of the Keia Rā'ui South. Although not statistically significant, with the opening of the *rā'ui*, average *paua* densities decreased by ~50% (from 30 *paua*/100 $m^2$ to 12.5 *paua*/100 $m^2$, Fig. 15), the final density resembling those within the Keia Control. The *rā'ui* opening also indicated a statistically significant decrease in average *paua* size (approximately 50%, from 141 mm to 70 mm). The average *paua* size after harvest (70 mm) was similar to the average size in Keia Control (62 mm). The similarity of the post-harvest densities and sizes of Keia Rā'ui South, compared to the nearby Keia Control site, which is always open to unregulated harvest pressure, is interesting. We assume this was caused by the exceedingly high harvest pressure which drove *paua* densities and sizes down to the point at which catch per unit effort resembled that in the nearby Keia Control.

### 4.5 Coral and Substrate

Live coral cover averaged around 15% of the substrate, a number similar to our results from other southern group islands. However, the macroalgae cover was higher than recorded elsewhere. The majority of macroalgae was *Halimeda* spp. and found growing from the shallow reef flats to waters beyond 30 m in depth. Anecdotal reports from local Mangaian community members indicated that the water from Lake Tiriara flows through subterranean caverns and out through crevices in the outer reef slope. Assuming this is true, nutrients from land (including those used in plant cultivation) may be contributing to the growth of high densities of algae. Without historic data, identifying if these densities are natural or anthropogenically induced is difficult. Persistent and extensive macroalgae cover in reef habitats may have negative effects on overall coral health. Long term monitoring of algal densities should be performed to ensure coral health.

# 5 RECOMMENDATIONS

As previously mentioned, Mangaia is the only place in the Southern Cook Islands where our data show the *rā'ui* system of traditional management of marine resources is actively functioning and allowing species to recover between harvests. This is an accomplishment that should give the local resource managers (Mangaia Island Council and Traditional Leaders) great pride. Furthermore, the willingness to adopt new management strategies (e.g. by initiating permanent *rā'ui* sites) shows a continued drive to enhance the health and sustainability of nearshore species and ecosystems.

Outlined below are suggested recommendations that should have little immediate impact in the quantity of species harvested, but should have long term positive benefits for subsistence fishers, ecosystem resilience and biodiversity conservation in Mangaia. These recommendations may be accepted or modified to suit the need of fishers, communities and managers. We hope to meet and discuss these recommendations in person.

**Overall:**

- Ban on sale of nearshore species
- Never opening permanent *rā'ui*
- Expanding sizes of permanent *rā'ui*

***Paua*:**

Of the targeted reef species in the South Pacific, *paua* may be the most easily overharvested. Careful management of this species is imperative to its survival.

- Minimum Size Limit (e.g. 150 mm)
- Daily bag limit (e.g. 30 *paua* / person / day)
- Never harvest *paua* from over the reef

**Maratea:**

- Ban on *maratea* fishing

# 6 CITATIONS

Ainley, L., Morejohn, K. and Kora, J. 2018. Aitutaki and Manuae Reef Resources and Fore Reef Assessment, Ministry of Marine Resources. Report No. 18/?

Conand, C. 1995. Asexual reproduction by fission in *Holothuria atra*: variability of some parameters in populations from the tropical Indo-Pacific. *Oceanologica Acta* 19(3-4), pp. 209-216

Dafni, J. 1992. Growth rate of the sea urchin Tripneustes gratilla elatensis. Israel Journal of Zoology. 38, pp. 25-33

Kora, J., Ainley, L. and Morejohn, K. 2018. Mitiaro Reef Resources and Fore Reef Assessment, Ministry of Marine Resources. Report No. 18/?

Raumea, K. and Makikiriti, N. 2001. Mangaia reef resources baseline assessment. Miscellaneous Report 2001/01

Kora, J., Morejohn, K. and Ainley, L. 2018. Atiu and Takutea Reef Resources and Fore Reef Assessment. Ministry of Marine Resources. Report No. 18/? UNDER CONSTRUCTION