The Yaqara Bay Biodiversity Inventory Project

Report For The 2003 And 2005 Field Seasons

Yaqara Bay, Viti Levu, Fiji Islands

By Stephen G. Dunbar

R. Rick Ware, Darolyn Striley and Leslie Harris

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Written by:	Stephen G. Dunbar
Edited by:	Rick Ware, Darolyn Striley, April Sjoboen, Leslie Harris
Design and layout:	Stephen G. Dunbar
Cover photo by:	Stephen G. Dunbar
Contact us:	The Yaqara Bay Biodiversity Inventory Project Stephen G. Dunbar, Director Department of Earth and Biological Sciences Loma Linda University, Loma Linda, California 92350 USA
	Phone: (909) 558-1000, 48903 Fax: (909) 558-0259 E-mail: <u>sdunbar@univ.llu.edu</u> Website: <u>http://resweb.llu.edu/sdunbar/fiji/fiji_main.html</u>



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Figure 1. A: Map of the north coast of the main island of Viti Levu, Fiji with emphasis on Yaqara Bay study area. Inset shows the country of Fiji and the relationship of Viti Levu to the other islands of the group. **B**: Detailed view of the study area of Yaqara Bay. The map also shows the zones and sites of Artificial Reef Matrix Structures (ARMS) deployment and general collection throughout the bay.

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 - **Y BB:** Art Anker
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- **EE GG:** Stephen G. Dunbar

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Executive Summary

Initial inventory work began in Yaqara Bay from August 14 – September 2, 2003. Yaqara Bay is located on the north-central coast of the main island of Viti Levu in the Fiji Islands and is situated within the Yaqara *tikina*, approximately 35 km to the east of the town of Ba. The Yaqara River and Waisai Creek flow directly into the study site, while the Drauniivi and Korolulu Creeks empty into the larger bay area from about 4.6 km and 7.3 km, respectively to the east. Approximately 6.5 km to the west, the Nasivi River empties into the bay at the westernmost edge of the study area.

Yaqara Bay is part of a classic, shallow bay and lagoonal system with an outer barrier reef system that contains several moderately deep (~35 m) channels leading from the bay into the open waters of the Bligh Water Strait. The shallow, inner bay has a depth range of approximately 1 - 7 m and has been severely impacted by sedimentary runoff from adjacent terrestrial sources which were deforested some 50 - 60 years ago for conversion into pastoral grazing land. In its current state, almost the entire catchment area is heavily grazed and burned yearly, enhancing conditions for soil erosion and degradation (Watling, 2001). As a result, the inner bay area has low levels of visibility and high levels of silt cover over much of the shallow reef flats. Despite the wide distribution of silt throughout the bay, some patchy areas of seagrasses do occur in regions of the bay which have high water clarity and are very shallow (~1 - 2 m).

Coral communities (although not the direct focus of this study) within the study area fell into two categories; those within the inner bay and those of the outer reefal zones. Many surfaces of corals within the inner bay were covered with either a filamentous algae/microbial mat assemblage, or a layer of fine, easily resuspended silt, or both. Some sections of the inner bay tended to have very patchy areas of coral reefs which seemed to be dominated by small, and often 'top-cropped' *Porites* species. Coral communities of the outer reefal areas appeared to suffer much less coverage by silt, with the outer reference sites being virtually free of sediment buildup.

Corals dominating these areas appeared to be the *Acropora*, the *Seriatopora* and the *Lobophyllia*. Another notable difference between the inner bay and outer reefal areas was the presence and size of *Diploastrea* colonies observed in the outer reefs. In outer reefs and some inner reef areas, coral growth was noted to be quite rapid around the perimeters of Artificial Reef Matrix Structures (ARMS) (Zimmerman & Martin, 2004) for some *Acropora* species over 16 months.

Preliminary work consisted of a general survey of habitat types throughout Yaqara Bay. Between August 14 – September 2, 2003 sites were selected in which settlement substrates would be placed and collections done. A few initial collections were made by hand to determine the most efficient and viable methods to be used in subsequent collection efforts. Study sites were initially selected by estimating areas that had a high diversity of substrates and habitats from maps and charts. From these, zones exemplifying various habitat types were viewed by boat and further selected. Within each zone, sites were selected in which ARMS would be placed. In all, 4 zones were selected throughout the bay. Within each zone, 3 sites were selected within 5-20 m of each other. Three replicate ARMS were placed at each site. In addition to the 4 zones selected, 2 reference sites were also selected that were determined to lie outside of the influence of Yaqara River sedimentation. In all, a total of 40 ARMS were positioned throughout the bay. All sites chosen were no deeper than 27 m below the surface of the water so that the placement of ARMS focused on the 4 - 27 m depth zone. Zones in which ARMS were situated covered some 74 km² of bay area between Nacilau Point on the eastern perimeter and Cokora Reef on the west. In addition, a very preliminary collection of invertebrates was made during the 2003 expedition in and around some areas in which ARMS were placed. This general collection was done by hand sampling a range of habitats within the bay area, from rocky shores to sandy-bottom substrates at 25 m depths. This series of sampling resulted in a collection of approximately 140 specimens from 9 taxa.

During the January 19 – February 7, 2005 expedition, retrieval of 8 ARMS took place along with the sampling of rocky shores, mangrove stands, mud flats, coral reefs, silt-covered sand bottoms and seagrass beds resulting in a total collection of 1087 specimen lots (from sorted materials – not including ARMS filters and scrubby pads) from 15 taxa.

The main threats to the biodiversity of Yaqara Bay have been identified as the sedimentation runoff from terrestrial sources and destructive fishing practices. Sedimentation is identified as the principal local threat. Inshore areas of the bay have been so heavily impacted by sedimentation that there are large areas in which no coral or seagrass communities exist. In some sediment-impacted areas where coral communities are able to survive, these communities appear to be dominated by species which are extremely tolerant of low light and low visibility conditions. While there appears to be no pressure from commercial fishing efforts and there is relatively low local fishing pressure on the Yaqara Bay region, some local fishers are employing methods of subsistence fishing which are not only unsustainable, but are extremely destructive to coral reefs in this system. The main practice impacting local reefs (and to an unknown extent, the invertebrate communities) is the use of explosive substances. To the extent to which the use of explosives are understood to accelerate the deterioration of coral reefs wherever the practice is used, this issue is one which will require careful monitoring and management in the region.

The alteration of foreshore due to impending development is another issue which will require the careful development of a management framework in order to ensure the sustainable use of marine resources throughout Yaqara Bay. This should focus on the potential for a community-based Marine Protected Area with large no-take sectors within the local area *qoliqolis*, the establishment of an ecosystem-wide monitoring system and the on-going collection of biological information throughout the bay.

This document constitutes a mid-point progress report. Research and analyses are continuing.

Introduction

 \mathbf{As} part of his message on The International Day for Biological Diversity, 2004, the Secretary-General of the United Nations underscored the importance of placing the highest priority on guaranteeing "the health and effective functioning of the earth's support systems – on land, in the seas and in the air" and on the promotion of "global awareness of the value of biodiversity..." (UN Secretary-General, 2004). Measuring biodiversity and understanding its role in ecosystem function is vital since human impacts are continually altering biodiversity (Ray, 1991). The threat of extinction for many species lead the National Science Board (1989) to conclude that the loss of biodiversity is "a global crisis requiring international solutions." As well, Ray & Grassle (1991) argue that the loss of biodiversity is a problem deserving of the utmost public attention and scientific interest. However, studies of marine ecology, biogeography, conservation, toxicology, bioprospecting, biochemistry and environmental monitoring cannot be effectively undertaken where there is a significant lack of information regarding resident species (Hewitt, 2002; Bottger-Schnack et al., 2004). In turn, information regarding resident species cannot be gathered without inventory surveys. Thus, our understanding of 'biodiversity' itself is inextricably linked with species inventories and collections.

The Yaqara Bay Biodiversity Inventory Project (YBBIP), anchored by strong national and international partnerships, continues to inventory the crustacean, echinoderm, polychaete and, to a limited extent, molluscan marine cryptofauna of Yaqara Bay, Fiji. A planned inventory of macrofaunal invertebrate species designed to be comprehensive and collaborative is essential as a primary source for local policy and cooperation, future research and education. Programs in need of this inventory include environmental studies, ecological monitoring, understanding distributions, curriculum development and the training of Fisheries personnel. Furthermore, recent surveys in Australia and elsewhere indicate that the detection of invasive species in tropical systems has been constrained by taxonomic limitations (Hewitt, 2002), thus underscoring the importance of inventory surveys such as that reported here.

No areas of the marine environment of Fiji, even along the northern coast of the most populous island, Viti Levu, have as yet been inventoried for the cryptic, macrofaunal invertebrates (cryptofauna) occurring in shallow waters. As a result, little is currently known regarding rates of endemism in Fiji for most groups of invertebrates in this and neighboring regions and there is great difficulty in identifying important sites or areas from the biogeographic standpoint (Whippy-Morris and Pratt, 1998; WWF, 2003). Our work in the area provides the first planned inventory of macro-invertebrates, despite the recognition by many scientists of the ecological significance of the Indo-Pacific region (Gee and Warwick, 1996), particularly Fiji's reef biodiversity (Zann et al., 1997; South and Skelton, 2000). Yaqara Bay is of particular and urgent interest for several reasons.

Firstly, it is an important site for indigenous fishing (Anderson and Mees, 1999). The research site lies within two local area *qoliqolis*; those of Tavua and Rakiraki. It is possible that without a strategic management plan, upcoming coastal development may result in reduced biomass of lower trophic organisms on which fish stocks depend, increasing subsistence fishing pressure on Yaqara Bay resources.

Secondly, Yaqara Bay lies within an area of very high habitat diversity. This area has recently been recognized by the World Wide Fund for Nature (WWF) Fiji Island Marine Ecoregion (FIME) workshop (December, 2003) and the National Geographic Society (November, 2004) as being a biodiversity "hotspot" of potentially global importance and therefore in vital need of assessment.

Thirdly, this study is precisely the kind of information that Gray (1997) argues is needed, particularly from tropical coasts of the Southern hemisphere. No study in this region to date has attempted to inventory the biodiversity and identify the invertebrate cryptofauna from adjacent habitats and microhabitats of any coastal area on Viti Levu. The YBBIP is in the process of collecting this kind of information which can contribute to decisions for management and future study.

Lastly, the 2,100 hectares adjacent to the bay have been scheduled for city-scale residential and commercial development by the Yaqara Group Limited (YGL). In keeping with commercially acceptable environmental standards, YGL has expressed keen interest in an inventory of the biodiversity of Yaqara Bay both prior and subsequent to development for potential consideration in establishing a Marine Protected Area (MPA) at this site. However, further consideration of this objective is dependent on a detailed biodiversity study of Yaqara Bay. By initiating this study early in the development process, it is anticipated that construction will proceed within a framework that is sensitive to the need to sustain biodiversity and ecosystem stability.

Methods

Initial work between August 14 – September 2, 2003 consisted mainly of site selection for the placement of Artificial Reef Matrix Structures (ARMS) and a very preliminary collection of invertebrate samples from areas within the vicinity of some ARMS. ARMS sites were chosen to represent as many ecosystems as possible within the bay. Once chosen, the GPS position of each site was recorded (WGS 84, horizontal datum).

ARMS Construction and Deployment in 2003

ARMS were developed on the property of the Yaqara Pastoral Company by first constructing a wooden frame into which premixed cement was poured (Figure 2). Each individual ARMS consisted of a series of three cement blocks. The dimensions of the base block were 32.5 cm long by 25.4 cm wide by 7.6 cm deep. The dimensions of the second and third level blocks were 30.5 cm long by 22.9 cm wide by 5.1 cm deep (Figure 3). During construction, the second and third level blocks were temporarily embedded with both 2.54 cm and 5.08 cm PVC tubing placed on the upper-facing surface while the cement was still wet. After drying, these pipes were removed leaving dome-shaped tunnels that intruded the block part way (Figure 3 and 4). A rectangle layer of rubber fiber material was laid on the uppermost block to attract the settlement of small, interstitial fauna and this entire assemblage was then tied together using both plastic zip ties and nylon rope to stabilize the structure. Four to five dish scrubber pads were randomly attached by zip ties onto the secured structure so that they protruded from the surface of the matrix blocks. The final stage was the assembly of the rubble basket into which the matrix block structure would be placed. This was done by connecting 2.54 cm diameter PVC pipe together into a 0.13 m² frame to which black plastic mesh was 'sown' with zip ties (see Fig. 5).



Figure 2. Production of the ARMS begins with pouring a concrete mix into wooden frames. Inserted onto the cement are various lengths of PVC pipe. The slabs are then left to dry and harden.



Figure 3. After drying, slabs are removed from the frames and arranged according to order of use. Note the 'tunnels' produced as a result of inserted PVC pipes.



Figure 4. Slabs are assembled into stacks with the largest slab forming the base. Two 'tunnel' slabs are added atop the base. Each stack stands approximately 30 cm high.



Figure 5. Once the fiber pad and dish scrubbies have been added to the structure, the assembly is placed within the rubble basket made of plastic mesh and PVC pipe.

Once assembled, ARMS were transported by tractor to the shore on a flatbed trailer. From there, the structures were loaded onto our research vessel and transported to the sites at which they were deployed. To deploy the structures, a diver was first sent down to the seafloor with the rubble basket. The rubble basket was set in place and partially filled with coral rubble from within 1-2 m surrounding the deployed basket. At the surface, the crew secured a rope around the ARMS unit so that it could be lowered into position with the assistance of two divers. Once in place, the guide rope was removed and the base of the ARMS was littered with additional coral rubble. At each site, three ARMS replicates were placed within 5 - 20 m of each other, either on the same isobath, or at different depths along a slope. For each site an additional base block was constructed with a iron reinforcement bar eye embedded into the block. A rope and buoy were secured to this 'anchor block' so that visual relocation of the site could be accomplished when conditions permitted, in addition to relocating the buoy by GPS. Once all 40 ARMS were in place, they were left to colonize for 16 months. Table 1 provides details on the latitude, longitude and depth of each station in which ARMS were deployed.

Preliminary Collections 2003

Preliminary collections in 2003 consisted of only a few samples of macrofauna collected over approximately three days by using dip nets, diver-operated PVC corers that sampled a surface area of 0.01 m^2 and a volume of 1 liter of sediment and by hand. Samples were mainly collected from areas of high sedimentation within Zone 1, Zone 2, Zone 3 and from Reference Sites 1 and 2. These samples were processed in the makeshift laboratory at the Yaqara Pastoral Company and shipped back to the Natural History Museum of Los Angeles County, where they are currently housed.

Table 1. The names, geographical locations and depths of study sites used for general collection of invertebrate
fauna as well as placement and recovery of Artificial Reef Matrix Structures (ARMS) within Yaqara Bay.
Established August, 2003. First recovery and general collections done January 19 – February 7, 2005. *=
relocated/final position; **= stations from which ARMS were recovered in 2005.

Zone	Station	Latitude (S)	Longitude (E)	Depth (m)
1	1**	17°23.4'	177°54.5'	5.20
1	2**	17°23.3'	177°54.5'	9.14
1	3	17°23.4'	177°54.6'	12.80
2	1	17°22.7'	177°57.4'	4.90
2	2	17°23.7'	177°57.6'	10.36
2	3	17°23.4'	177°57.5'	3.96
2	3*	17°23.4'	177°57.5'	7.92
3	1**	17°22.4'	177°59.8'	6.10
3	2**	17°22.4'	177°59.7'	6.10
3	3	17°22.5'	177°58.7'	7.01
3	3	17°22.5'	177°59.6'	13.11
4	1	17°19.3'	177°57.2'	4.57
4	2**	17°19.3'	177°57.2'	9.14
4	2	17°19.3'	177°57.2'	15.85
Ref 1	1	17°21.8'	178°01.1'	9.45
Ref 1	2	17°21.8'	178°01.1'	12.50
			I	1

Table 1. Continued

Zone	Station	Latitude (S)	Longitude (E)	Depth (m)	
Ref 2	1*	17°18.6'	177°59.7'	14.33	
Ref 2	2	17°18.6'	177°59.7	9.14	
Sea grass Beds		17°23.5'	177°58.2'	1.50	

ARMS Retrieval and Collections in 2005

In January 2005, researchers returned to Yaqara Bay and were, once again, joined by Fiji Ministry of Fisheries and Forests officers to facilitate the first major collection of invertebrates from the study sites established in August of 2003 and nearby surrounding areas. The recovery of ARMS and collection of organisms occurred over the three weeks of January 19 – February 7 and was accomplished by a team of over 14 people plus support staff from the villages of Yaqara, Drauniivi, Togovere and Rabulu.

Recovery of each ARMS followed the same basic protocol. The site area was located by GPS. A diver was sent in to locate the site buoy and the ARMS to be recovered. A pop buoy was then released to mark the exact location of the ARMS. Once divers had completed a series of photographs and video clips of the undisturbed ARMS and the immediate vicinity along 20 m, north-south and east-west transects, additional divers were sent down to recover the structure and rubble basket. In all, eight ARMS were recovered during the 2005 expedition. Once collections from these ARMS had been completed, these structures were re-assembled and re-deployed at the sites from which they had been taken.

Collection of animals was divided into two main categories; general collections and ARMS collections. General collections were accomplished by a number of standard techniques including hand collecting, slurp guns, yabbie pumps, dip nets and diver-operated corers. These methods were employed on seagrass beds, mudflats, subtidal sand and silt bottoms, rocky shores, around mangrove stands and among coral reefs. ARMS collections were made by processing the structure on the shore. This required cutting apart the rope and zip ties that held the unit together. These materials, along with the dish scrubby pads, were immediately preserved in alcohol as bulk samples and left with the Fiji Ministry of Fisheries and Forests (Lami Office) for later sorting. Once the top surface of the ARMS was photographed, any animals that could be detected were removed and placed in vials containing seawater to be kept alive. Algal mats and encrusting sponges were also scrapped off and preserved in alcohol. The uppermost block of the ARMS was folded back to reveal both the underside of the first block and topside of the second block. These surfaces were photographed, animals removed and scrapings preserved as before. This process was repeated again until all visible animals had been collected from the entire structure and the blocks had been scraped clean of obvious epibionts.

Specimens were transported to the laboratory at the Yaqara Pastoral Company, where they were placed in containers with aerated seawater. As many representatives as possible were photographed live, catalogued and preserved. Preliminary identifications were made using field guides by Allen and Steene (1994), Allen and Steene (2000) Colin and Arneson (1995), Tudge (1995), Madrigal (1999) and by taxonomists that were present, so that a cumulative list of invertebrate species was begun over the duration of the expedition. All specimens were then packaged for transport back to the Natural History Museum of Los Angeles County, where the collection is currently housed.

Education Outreach in 2003 *SWEEP*

Initial talks with Mr. Brian Hamilton, Director of the Primary Education program at Fulton College began. The benefits of the program to practicing teachers who were upgrading from certificates to degrees were discussed, as well as the benefits to teachers in training. A proposal of the Shallow Water Ecological Education Program (SWEEP) program was provided to Mr. Hamilton at that time for review and feedback. Electronic communications continued throughout 2003 and 2004. Final drafts of program proposals were submitted by YBBIP to Mr. Hamilton and efforts to coordinate logistics for potential SWEEP students were made.

Local Schools

During the 2003 expedition, Drauniivi Public School was contacted and informed of the YBBIP in order to establish links between the project and the school. Arrangements were made both for students to visit the researchers on site, and also for some of the researchers to make a formal video presentation to the students at the end of the expedition.

Local Communities

Through the enthusiastic efforts of Mr. Sele Tagivuni, CEO of the Yaqara Pastoral Company, local communities were immediately made aware of the project as it began. This was mainly done through the *sevusevu* (or "blessings") meetings. At these gatherings, village chiefs, elders and community leaders received information regarding the proposed project and the importance of their support for the research work that was to ensue.

National Media

The national public media were invited to cover the research activities of the YBBIP. Both newspaper and television media were contacted.

Education Outreach in 2005

Education outreach in 2005 consisted of three main programs, as well as several formal and informal meetings with community leaders, school groups and the national media. These were the training workshop, the SWEEP and the "These Are My Oceans" (TAMO) programs.

Training Workshop

Prior to the the 2005 YBBIP research expedition in Fiji, three team members proceeded to the capital city of Suva in order to conduct a workshop on basic sampling and identification of marine invertebrates. The workshop was arranged by Dr. Stephen Dunbar, hosted by the Fiji Ministry of Fisheries and Forests (Lami) and facilitated by Ms. Leslie Harris and Ms. Daorlyn Striley, both of the Natural History Museum of Los Angeles County, California.

SWEEP

The Shallow Water Ecological Education Program (SWEEP), under the direction of Ms. Teri Faught was designed to provide practicing teachers and students in Education a unique opportunity to spend five days of intensive study in the field with working marine researchers.

The course included introductions to concepts of marine science and marine ecology, lectures by marine specialists, exposure to fieldwork during the collection events of the YBBIP and information on how to keep and use small marine animals to facilitate student learning and practical studies in the classroom setting.

TAMO

Another outreach program facilitated by the YBBIP is the "These Are My Oceans" (TAMO) educational kit. The TAMO kit was designed to introduce primary school-aged students to basic marine ecology and principals of marine conservation and stewardship. The main component of the TAMO kit is the TAMO booklet, which contains coloring pages, games, stories and activities that can be done at school or at home. The booklet is meant to be used in conjunction with the science curriculum of the primary schools and as an aid for teachers in the teaching of marine science concepts. The kit will also contain posters, stickers and a CD with underwater footage and the story of the YBBIP project. If funding is available, a YBBIP Team Member t-shirt may also be included in the kit.

Local Schools

During the 2005 season, local schools were again contacted to encourage them to arrange times with the YBBIP when they might tour the research site, meet team members and learn about the project.

Local Communities

Contact with local village communities was made on both a formal and informal basis. Formal contact was again facilitated by Mr. Sele Tagivuni, while informal contacts were facilitated by team members/Fisheries Officers, Babitu Rarawa, Serugali Ledua and William Saledrau.

Results

General Bay Structure

Yaqara Bay houses a complex of marine habitats. We identified 8 major habitat types. These are: rocky shores, mud flats, mangrove forests, subtidal sand flats, seagrass beds, intermittent patch reefs, shallow reef flats and barrier reef walls. Much of the inner bay is shallow (less than 3 m), with extensive areas at the mouths of both the Yaqara River and Waisei Creek heavily impacted by sedimentation. Shallow areas within the bay that are not directly affected by sedimentation continue to maintain high visibility and sustain small, vibrant patch reefs.

Some 5 km offshore, the shallow reef flats of the bay appear to be in good health. There were no visible signs of coral bleaching, despite consistent sea surface temperatures (SST) of 29.4 \pm 2.0°C over the duration of the expedition. Some of the uppermost corals of these reef flats have undergone dieback due to regular exposure during low tide cycles.

Beyond the reef flat, the barrier wall slopes down to a depth of about 23 m and terminates in the sand flats that stretch northward and into the Bligh Water Straits. In the immediate area of Yaqara Bay, this wall is broken through by at least three prominent channels. These are the Manava Passage to the west, the Natobu Drauivi Passage slightly east of Manava Passage and the Nukurauvula Passage to the east (see Figure 1B).

Coral Communities

Although direct data collection on coral communities was not within the scope of this project, some general observations are included here. Information reported here are the results of casual observations during general invertebrate collections done by dive team members.

Corals varied widely among inventory sites. Areas of the inner bay held small patches of coral communities, most often dominated by clusters of various *Acropora* species as well as some *Porites* species. In Zone 1 (see Figure 1B), some *Goniastrea* was photographed, as well as patches of possibly *Acanthastrea*. In some deeper sections of the inner bay, *Pavona* occurred in large clusters. Small patches of *Montipora* (?) also were prevalent at some sites (Zone 1, Site 1) and were sometimes seen close to small colonies of what appeared to be *Barabattoia*. *Fungia* were also often seen at these shallow depths (4 - 8 m).

On the shallow reef flats of Vedrala and Cakau Moi, branching *Acoropora* appeared to be most dominant. *Seriatopora* and *Pocillopora* also appeared to be prevalent in this zone.

The outer walls of Vedrala and Cakau Moi reefs contained apparently healthy populations of a wide variety of hermatypic corals, including *Pocillopora*, *Seriatopora*, *Acropora*, *Porites*, *Fungia*, *Platygyra*, and *Diploastrea*. The soft corals, *Sarcophyton*, *Dendronephthya*, *Sinularia* (?), *Clavularia* (?), *Tubipora* (?) were very abundant along the wall slope. On the sea floor, patches of large *Diploastrea* occurred. In at least one site (Reference 1, Site 1), *Palythoa* (?) zoanthids were recorded. *Pavona clavus* was also photographed at this location.

Invertebrates 2003

The data presented on invertebrates in this report are not directly comparable with other reports, such as that by Obura and Mangubhai (2003) from Fiji, or Obura & Stone (2002) for Phoenix Islands, Kiribati, since methodologies among studies differ. The invertebrate portion of the study at Ono Kadavu (Obura & Mangubhai, 2003) was focused on only a few widely recognizable species. Methodologies used in the Kirabati study (Obura & Stone, 2002) were more similar to those reported here, with target groups in their study also including the molluscs, echinoderms and crustaceans, and sampling for diversity done on a more random basis rather than along belt transects.

The diversity and abundance of invertebrates collected within Yaqara Bay during this preliminary phase was low. This was likely a result of the very limited collection effort made at that time. Since the purpose of the 2003 expedition was mainly to establish collections sites within Yaqara Bay and to place the ARMS, little time was allocated for collection of specimens. In addition, large echinoderms (i.e. *Linkkia, Culcita, Choriaster, Bohadschia, Holothuria, Stichopus*) and molluscs (i.e. *Tridacna*) although present, were not collected or recorded on this expedition. In any case, results from limited general collection at this time showed the highest number of morphotypes for annelids and molluscs at 42 each. Crustacean morphotypess were relatively high at 30, while collections of echinoderms resulted in only six morphotypes. The diversity of other taxa fell well below these four main groups (Figure 6).



Figure 6. The percentage of each taxa from a total of 126 specimen lots from general collections done during August, 2003. Each lot may contain from 1 - 25 individuals as representatives of the given taxa.

Invertebrates 2005

A diverse range of target invertebrate cryptofauna were collected between January 19 and February 7, 2005 throughout Yaqara Bay. It should again be noted that large invertebrates, even within the target groups, were neither collected nor recorded. These would include large specimens of the sea cucumbers, seastars, basket stars, crinoids, bivalves and gastropods. However, we did note that among large invertebrates that were present, echinoderms were the most diverse and most abundant. In particular, the seastar Linckia levigata was present throughout the shallow areas of the bay. Most often, single individuals of L. levigata were observed among small patch reefs in areas of high visibility. Three crown-of-thorns seastars, Acanthaster planci, were present along the outer reef wall area of the study site. The two individuals collected measured between 4 and 7 cm in diameter and were likely juveniles of less than a year old. The third individual, found at Reference Site 1, was much larger (only three arms visible, each approximately 15 - 20 cm long). A small number of pincushion stars, Culcita novaguineae and Choriaster granulatus, were seen among reefs in both the outer edges of the study site and among the shallow reef of Reference Site 2. The sea cucumber, Bohadschia marmorata, was infrequently found on the coral rubble bottom of outer reef Reference Site 1, as well as on the sandy bottom of the shallow bay where waters were clear. Large synaptid holothurians (Eupata and/or Synapta) were particularly abundant and visible in the shallow bay, especially among seagrass beds. These were usually noted while in transit from one site to another.

When the sum of all specimen lots (each specimen lot contains between 1 and 25 individuals representing the specific taxa) were compared (Figure 7 and Table 2), crustaceans were found to have the largest number, comprising 47 % of the total number of lots over all taxa. When the crustaceans, molluscs and polychaetes were combined, they provided 89 % of all lots collected over all taxa.

The smallest numbers of specimen lots were represented by the foramaniferans (only one lot collected), the bryozoans (one lot) and the brachiopods (one lot). These were recorded from Zone 3, Reference 2 and Zone 4, respectively.

These numbers represent total effort, irrespective of the collection method used. Further specifics on collection effort by method and by zone are provided below.



Figure 7. The percentage of each taxa from 1087 specimen lots collected irrespective of method (general or ARMS), or area of collection effort, during January, 2005. Each lot may contain from 1 - 25 individuals as representatives of the given taxa.

General Collections in 2005

General collections in 2005 were taken from as many representative substrates and environments as possible, including rocky and sandy intertidal, mud and mangrove flats, subtidal sand, mud, rock, coral and seagrass beds (see Figure 8). Samples were collected into whirl-packs and brought to the laboratory where they were kept alive until photographed and catalogued. A total of 8 days were dedicated to general collection, although general collections in the intertidal took place more often than collections by SCUBA.



Figure 8. Team members used SCUBA and snorkeling for general collections of invertebrates in subtidal areas at depths from 1 - 16 m. Samples were collected from sand, mud and rock substrates, as well as from coral reefs.

These collections resulted in the recording of 647 specimen lots from 11 taxa. The percentage of each taxa from the total lots collected by this method are presented in Figure 9.

Crustaceans made up the majority of specimen lots gathered by general collecting, totaling 55 % of the total number of lots collected by this method. The molluscs and polychaetes comprised 19 % and 16 %, respectively, of all lots collected in this way. Of the remaining 10 % of specimen lots, the smallest number were collected from the cnidarians and the nemerteans (each 0.46 %), the insects (0.31 %) and the ascidians (0.15 %). Numbers of individuals collected may, however, reflect the fact that collections were aimed at target taxa.

Several taxa were absent from material that were sampled by general collections, including the echiurans, foramaniferans, bryozoans, and brachiopods.



Figure 9. The percentages of each taxa collected by general collecting methods during the 2005 season.

ARMS Collections 2005

The diversity and abundance of invertebrates collected from ARMS retrieved was lower than expected. Despite the time submerged (August, 2003 – January, 2005), the degree of fouling and inhabitation by invertebrates was low (see Figures 10, 11 & 12). ARMS were colonized by sessile fauna such as macroalgae, encrusting sponges, hydrozoans and stony corals, yet colonization by motile, cryptic invertebrates was low. The total number of lots collected by this method was 440.

In Figure 13, it can be seen that the most prominent organisms collected from ARMS were crustaceans, which made up 35 % of all specimen lots collected in this way. Molluscs and polychaetes were also prominent taxa making up 28 % and 25 %, respectively, of all specimen lots collected from ARMS. Five taxa constituted the lowest numbers of specimen lots collected by this means. These were the Foramanifera, the Nemertea, the Platyhelminthes, the Bryozoa and the Branchipoda, each making up 0.23 % of the total number of lots.

Although 440 lots were collected from ARMS, this number accounted for only 40 % of the total 1087 over the 2005 collection effort.



Figure 10. Two views. Zone 1, Station 1, Replicate 1 is shown. **A:** The ARMS in its original, undisturbed position underwater. Settlement and growth seen on the structure are a result of 16 months of submersion. **B:** Replicate 1 after retrieval with the topmost layer lifted off. Few macro-invertebrates have colonized the substrate.



Figure 11. Zone 3, Station 2, Replicate 1. **A:** The undisturbed ARMS underwater. **B:** The same ARMS immediately after retrieval and transport to the shore. Once in position for processing, the zip ties and rope are cut and the structure is disassembled one level at a time. Arrows indicate the same point on both views.



Figure 12. Zone 4, Station 2, Replicate 1. **A:** During 16 months of submersion the ARMS has acted as a settlement substrate for several macroalgae, encrusting sponges and hard corals. **B:** Despite moderate algal growth, few macro-invertebrates have colonized the substrate.



Figure 13. A comparison of the percentage of specimen lots collected from ARMS in 2005 for each taxa.

Comparisons of ARMS and General Collections

When collection methods were compared between general and ARMS, results showed that more specimen lots were collected by general collection methods than from ARMS. While the number of specimen lots is higher from general collections, it must be emphasized that the number of specimen lots is not synonymous with the number of actual specimens collected, since each lot may have multiple specimens within it.

It can be seen from Table 2 that 60 % of all specimen lots collected during the 2005 expedition were gathered by means of general collection methods, while the remaining 40 % were collected from ARMS. The most numerous specimen lots collected by both methods were consistent between methods, with Crustacea > Mollusca > Polychaeta. Echinodermata were the next most numerous specimen lots in both collection methods. These numbers reflect the target taxa of the project and may also reflect the efforts of specialist field taxonomists participating in the expedition.

	Number of S	Number of Specimen Lots Collected			
Таха	ARMS	General Collections			
Crustacea	156	356			
Mollusca	123	121			
Polychaeta	109	101			
Echinodermata	29	27			
Sipuncula	10	8			
Echiura	3	0			
Osteichthyes	3	17			
Ascidacea	2	1			
Foramanifera	1	0			
Nemertea	1	3			
Platyhelmenthes	1	8			
Bryozoa	1	0			
Brachiopoda	1	0			
Cnidaria	0	3			
Insecta	0	2			
Total	440	647			

Table 2. A comparison of the number of specimen lots collected by both general collections and from ARMS settlement structures.

Comparisons of Zones

In Table 3, the comparison of specimen lots among zones is shown. These results demonstrate that general collecting in non-designated areas yielded the greatest number of specimens over all, with a total of 52 % of all specimen lots collected coming from these areas. This was likely due to the intensity of collection in the non-designated intertidal, sandy subtidal and seagrass bed areas. There is little doubt that ease of access by snorkeling and wading, and the number of collectors able to assist in collections throughout these areas influenced the number of specimen lots in this category.

The next two zones with the greatest number of specimen lots were Zone 1 and Zone 3, with 15 % and 14 %, respectively, of the total specimen lots over all taxa. Reference 2 had only 9 % of the lots over all taxa with Reference 1, Zone 4 and Zone 2 making up the remaining 10 % of specimen lots.

	Number of Specimen Lots Collected							
Таха	Z1	Z2	Z3	Z4	R1	R2	Ε	Total
Crustacea	58	1	60	13	18	38	324	512
Mollusca	61	2	23	10	16	22	110	244
Polychaeta	30	2	57	10	18	25	68	210
Echinodermata	12	1	6	5	1	5	26	56
Sipuncula	3	1	3	0	0	3	8	18
Echiura	2	0	0	1	0	0	0	3
Osteichthyes	2	0	2	0	0	0	16	20
Ascidacea	0	0	1	1	0	0	1	3
Foramanifera	0	0	1	0	0	0	0	1
Nemertea	0	0	0	0	1	0	3	4
Platyhelmenthes	0	0	0	0	0	1	8	9
Bryozoa	0	0	0	0	0	1	0	1
Brachiopoda	0	0	0	1	0	0	0	1
Cnidaria	0	0	0	0	0	0	3	3
Insecta	0	0	0	0	0	0	2	2
Total	168	7	153	41	54	95	569	1087

Table 3. A comparison of the number of specimen lots among zones irrespective of collection method.Z=Zone, R=Reference, E=Elsewhere (non-designated area)

Education and Community Outreach in 2003

SWEEP

Ms. Teri Faught was brought on board to head up the development of the SWEEP. Planning and development continued throughout 2004.

Local Schools

On the afternoon of Thursday, August 28, some 41 students from Class 5 and 6 arrived at the YBBIP field site to tour the temporary research facility on the grounds of the Yaqara Pastoral Company. Students were first shown how ARMS were constructed and assembled (Figure 14). Several single cement blocks were freshly made so that each individual could etch his/her name into a block. Next, students were taken to a video/live animal station, at which they watched a five minute presentation of underwater video taken by team members of YBBIP work in Yaqara Bay. An assembly of live invertebrates were present for students to discuss and experience. From this station, groups were ushered into the makeshift laboratory where they were able to view invertebrates from the bay through a dissecting microscope, as well as view photographs of animals from the preliminary collections made within the bay (see Figure 15).

At Drauniivi Public School on September 1, Dr. Stephen Dunbar and Mr. Rick Ware presented underwater video and still photographs of the initial work carried out by the YBBIP to the same students who had earlier toured the field site. The video featured the underwater placement of the single cement blocks which the students had signed. The video and subsequent presentation on the importance of marine environments and the conservation of such ecosystems was positively received by both students and teachers. A gift from the class was received by the presenters. Dunbar and Ware extended an invitation to the class to return to the study site on the next expedition.



Figure 14. Drauniivi Public School students assist Rick Ware in building some cement slabs for ARMS.



Figure 15. Leslie Harris uses photographs of recently collected animals to describes some of the features of invertebrates from Yaqara Bay.

Local Communities

Three *savusavu* gatherings were attended by the YBBIP team during August, 2003. Two meetings were held with the Drauniivi Village elders and one with the Togovere Village elders. An additional meeting was granted by the *Roko Tui ni Ba* (Governor of Ba Province), at which the objectives, accomplishments to date and future plans of the YBBIP were presented. Full, 'in-principle' support was given by the *Roko Tui* to continue the project in the Yaqara Bay region.

National Media

Contact with the national media resulted in one story printed in the national newspaper, The Fiji Times, dated Thursday, August 28, 2003.

Education and Community Outreach in 2005 *SWEEP*

The initial launch of the SWEEP took place with three students from Fulton College. They were: Ms. Asenaca Ciridaudau, Mr. Tupou Vakaloloma and Mr. Misaele Toutou. The number of students was lower than expected. This appears to be due to the lack of advertising done on the campus of Fulton College for the program. Despite efforts to publicize the program, communications in Fiji regarding the SWEEP were minimal so that teachers and students in the Primary Education Program were not sufficiently made aware of the opportunity.

The initial SWEEP required that students attending the program pay their own way to the research site at Yaqara and that they also pay a tuition of F\$50.00 per student. These funds were used to pay for their room and board over the duration of the course. Funding is being sought to alleviate the need for local SWEEP students to pay this tuition.

Nevertheless, the students who did attend the SWEEP were enthusiastically engaged in coursework on the main groups of marine animals and basic marine ecology. Students were also enlisted to assist researchers during processing of ARMS in the field, as well as in the laboratory. Furthermore, instruction was provided on the keeping of small marine invertebrates in the classroom and how to facilitate practical learning through interaction with marine organisms. Students spoke highly of the program and were only disappointed that their fellow students at Fulton were unable to take advantage of the program. Currently, ways are being discussed to improve advertising of and enrollment in the SWEEP for the next field season.

TAMO

A first draft of the Booklet was presented to teachers at the Drauniivi Public School for their feedback. Teachers were encouraged to review the Booklet and provide their critiques, needs, and concerns. The first draft was enthusiastically received and the positive reviews are now under consideration for enhancing the utility and effectiveness of the Booklet. A final draft is planned for teachers and the Ministry of Education to review in October of 2005.

Local Schools

In 2005, the Drauniivi Public School and the Rabulu Indian School visited the study site. Five interpretive stations were set up where groups of students had opportunities to learn both about the YBBIP and about general principals of marine conservation and protection. YBBIP team members facilitated groups throughout the day, fielding questions, showing underwater video, demonstrating SCUBA, connecting students with live marine animals and hosting them in the laboratory facility (Figure 16).



Figure 16: A: Teri Faught teaches Drauniivi Public School students about diving; **B**: Students experience marine invertebrates under the direction of Dot Norris; **C**: Students enthralled with underwater video from Yaqara Bay.

Local Communities

During the 2005 season, the team met with chiefs and elders of Drauniivi Village on February 1 and Togovere Village on February 2. These meetings consisted of bilateral extensions of goodwill and continued collaboration toward the goals of the YBBIP. An invitation to attend another *savusavu* meeting was extended to the research team by the village of Rabulu. However, it was not possible to attend this meeting due to scheduling.

In addition to local village meetings, the team was honored to meet with the French Ambassador to Fiji, His Excellency Eugene Berg and his wife, along with the Minister of Fisheries and Forests, the Honorable Konusi Yabaki, the Chairman of the Yaqara Pastoral Company, Mr. Nemani Buresova and the Minister for Public Enterprise and Public Reform, the Honorable Jonetani Galuinadi during a formal presentation on the grounds of the Company on January 27. The entourage toured the YBBIP laboratory facility and heard presentations by Dr. Stephen Dunbar and Ms. Leslie Harris on the research.

National Media

The national media was alerted well in advance of the 2005 expedition, as well as upon arrival of the research team. This year the research was featured in newspaper articles in the Fiji Times on January 18 and February 1. The project was also prominently featured on the evening news of the national television station, Fiji One, on both January 23 and February 4.

Photo Gallery of Organisms

The following three pages provide a brief gallery of live-color photographs of a small fraction of the organisms collected, photographed and catalogued during the 2003 and 2005 field seasons.



Figure 17. Typical marine invertebrates found among the different habitats of Yaqara Bay. A: the subtidal hermit crab, *Calcinus pulcher*; B: a common mangrove hermit crab, *Clibanarius longitarsus*; C: *Diogenes serenei*; D: *Alpheus obesomanus*; E: *Alpheus acutofem*; F: *Alpheus rapax*; G: *Carupa tenuipes*; H: *Coralliocaris graminea*, associated with *Acropora* coral; I: a subtidal brachyuran crab.



Figure 17 continued. J: an large isopod; **K**: a polychaete of the genus *Prionospio*; **L**: a microscopic member of the *Sphaerodoridae*; **M**: a tiny gastropod; **N**: *Nereididae*; **O**: the polychaete, *Eunice*; **P**: the brilliantly colored *Linkia multifora*; **Q**: *Fromia*; **R**: the sand dollar, *Peronella*; **S**: a small mitre shell, possibly *Costellaria*; **T**: the nudibranch *Jorunna funebris*; **U**: a small sea hare, *Aplysia*.



Figure 17 continued. V: the nudibranch, *Pteraeolidia*; W: *Phyllidiella*; X: *Phyllidia elegans*; Y: a small brachyuran crab; Z: the snapping shrimp from the *Alpheus critus*-group; AA: an iridescent shrimp, *Jocaste*; BB: *Jocaste*; CC: a bopyrid isopod, possibly *Pseudostegias*; DD: a cluster of microscopic gastropod shells; EE: the semi-terrestrial hermit crab, *Coenobita variabilis*; FF: a coral crab of the genus *Trapezia*; GG: a striking boxer shrimp of the genus *Stenopus*.

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Publications and Presentations Resulting From This Research To Date

Fiji Time Newspaper, Thursday, August 28, 2003 Researchers focus on the small fry.

Researchers focus on the small fry.

38th European Marine Biology Symposium, September 8 – 12, 2003

Marine cryptofauna of Yaqara Bay, Fiji: finding the fauna before and after development. Poster presentation.

Today, Thursday, June 10, 2004

Natural science professor conducts study in Fiji.

Fiji Times Newspaper, Tuesday, January 18, 2005

Fiji One TV News, Sunday, January 23, 2005

Fiji Times Newspaper, Tuesday, February 1, 2005 Expert pioneers Yaqara Bay project.

Fiji One TV News, Friday, February 4, 2005

Vancouver Aquarium AquaNews, Friday, June 17, 2005 http://www.vanaqua.org/aquanews/field/index.html Bay of Plenty

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Expedition Participants

Arthur Anker, Ph.D. Collections, Photography Postdoctoral Research Fellow University of Alberta, Edmonton, Canada Phone: (780) 492-6881

Mike Boom, MFA Videography Oakland CA 94605 Phone: (510) 635-7723

Julia Brownlee, M.Sc. Construction, Collections, Dive Team PhD Candidate University of Rhode Island, Department of Natural Resources Warwick, RI 02889 Phone: (401) 743-6308

Peni Drodrolagi, B.Sc. Collections, Dive Team Officer, Fiji Ministry of Fisheries and Forests Lami, Fiji Phone: (679) 336-1122 Fax: (679) 336-1184

Stephen G. Dunbar, Ph.D. Principal Investigator, Project Director Department of Earth & Biological Sciences, Loma Linda University, Loma Linda, CA 92350 Phone: (909) 558-1000, ext. 48903 Fax: (909) 558-0259

Teri Faught, B.Ed. Education Outreach Coordinator Mountain View High School Mountain View, CA 94040 Phone: (650) 940-7442 Fax: (650) 961-6349

Leslie Harris Collections Manager, Taxonomist, Photography Collections Manager Natural History Museum of Los Angeles County, Los Angeles, CA, 90007 Phone: (213) 763-3234 Fax: (213) 749-2999 Rob Lee, B.E. Database Manager, Videographer Consultant, Robert E. Lee Highland, CA 92346 Phone: (909) 748-0825

Serugali Ledua Collections, Dive Team Officer, Fiji Ministry of Fisheries and Forests Lami, Fiji Phone: (679) 336-1122 Fax: (679) 336-1184

Lynn Morton Collections, Photography Oakland CA 94605 Phone: (510) 635-7723

Dorthy Norris, B.Sc. Collections, Dive Team, Photography Public Utilities Commission, Natural Resources Bureau San Francisco, CA 94132 Phone: (415) 242-2208 Fax: (415) 242-2285

Babitu Rarawa, B.Sc. Collections, Dive Team, Logistics, Liaison Officer, Fiji Ministry of Fisheries and Forests Lami, Fiji Phone: (679) 336-1122 Fax: (679) 336-1184

William Saladrau, B.Sc. Collections, Dive Team, Permits Research Officer, Fiji Ministry of Fisheries and Forests Lami, Fiji Phone: (679) 336-1122 Fax: (679) 336-1184

Michelle Shouse, B.Sc. Collection Processing Biologist U.S. Geological Survey & California Bay-Delta Authority, Science Program Sacramento, CA 95814 Phone: (916) 445-5511 Fax: (916) 445-7311 Darolyn Striley, B.A. Collection Processing Curatorial Assistant, Marine Biodiversity Processing Center, Natural History Museum of Los Angeles County, Los Angeles, CA 90007 Phone: (213) 763-3386 Fax: (213) 749-2999

Illiapi Tuwai, M.Sc. Collections, Logistics, Permits Executive Officer, Marine Studies Program, University of the South Pacific Suva, Fiji Phone: (679) 321-2944 Fax: (679) 330-1490

Rick Ware, M.Sc Dive Master, Safety Officer President/Senior Marine Biologist Coastal Resources Management Corona del Mar, CA 92625 Phone: (949) 412-9446 Fax: (949) 675-2970

Stephen Whitaker, B.Sc Collections, Dive Team Marine Biologist Coastal Biome Consulting San Clemente, CA 92673 Phone: (949) 291-8131 Fax: (949) 481-6509 Contribution #1 of The Marine Research Group, Department of Earth & Biological Sciences, Loma Linda University, Loma Linda, California, USA Yaqara Bay Biodiversity Inventory Report: FJ-03,-05





MINISTRY OF FISHERIES & FORESTS Fisheries Department PO Box 3165, Lami, Fiji















