REPORT

Coral reef biodiversity community-based assessment and conservation planning in the Marshall Islands: Baseline surveys, capacity building and natural protection and management of coral reefs of the atoll of Rongelap.

Silvia Pinca, Maria Beger, Editors

Authors:
Silvia Pinca – Ecological Section, Management Recommendations
Maria Beger – Fish Diversity, Management Recommendations
Eric Peterson – Management Recommendations
Zoe Richards – Coral Diversity
Emma Reeves – Management Recommendations

NRAS[1] TEAM AND CMI[2]

[1] **NATURAL RESOURCES ASSESSMENT SURVEYS (NRAS) TEAM**:

Silvia Pinca PhD, Project Leader, milviapin@yahoo.com

Maria Beger, Project Co-Leader, mbeger@zen.uq.edu.au

Daniel Barshis, danbarshis@yahoo.com

Benjiamin Dominici, bendomo@hotmail.com

Robert Fournier, thewildlensman@aol.com

Sacha Jellinek, sacha_jellinek@hotmail.com

Ingolf Kuehrt, Ingolf.Kuehrt@agadobe.de

Craig Masburger, musburge@hawaii.edu

Berry Muller, sped_07@yahoo.com

Anna Mc Murray, annahayes99@hotmail.com

Eric Peterson, e.peterson@uq.edu.au

Emma Reeves, reevesemma@yahoo.com

Zoe Richards, zoer@mtq.qld.gov.au

Melba White, babbubz@yahoo.com

[2] **COLLEGE OF THE MARSHALL ISLANDS**
Marine Science Program
P.O. Box 1258
Majuro, MH 96960


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Abstract

The project was undertaken to assess the reef health, status, fisheries potential, conservation value and biodiversity of two atolls in the Marshall Islands: Rongelap and Bikini. The data produced represent a first comprehensive reference of reef status at national and international level and are used to recommend national marine conservation plans for Rongelap and Bikini. This report focuses on Rongelap Atoll. There is much interest from the local Government for the management of marine resources and the plans to re-inhabit the islands are imminent. The work carried out on the expedition in Rongelap was for the Rongelap Atoll Local Government (RALGov) to assess their marine resources, on which to base new eco-tourism and sport diving and fishing ventures.

The project was also successful in training local people to practices of reef assessment and monitoring techniques for establishing marine protected areas (MPAs). The trained people have the skills, knowledge and interest necessary to continue this work in the future. The project is also promoting reef conservation among the population through newspaper and journal articles and presentations.

During this project, a multidisciplinary team of scientists and trained volunteers carried out surveys on the coral reef ecosystem. The surveys included several levels of detail, ranging from species level biodiversity surveys to volunteer-based reef status surveys. The team assessed for each site (a) the species diversity for fishes and corals, (b) quantitative ecological information including abundance and biomass of fishes, coral cover and substratum, and algae cover and diversity, and (c) community-level reef status information collected by the Reef Check method. In addition, the team set up and conducted a detailed survey of two permanent transects for future monitoring.

The project team surveyed 12 sites around Rongelap Island from shore and a further 2 sites on other islands west of Rongelap Island. The results show that this area could be divided into 5 biogeographical zones, encompassing lagoon sites, outer reef sites and passes. The outer reef zone showed the highest coral cover and species richness. A high proportion of food fishes was also found in these zones, although a different suite of fish species was abundant and large inside the lagoon. High fish biomass, high percentages of coral cover and a total species number of 361 fishes and 170 corals indicated that the reefs around Rongelap Island are outstandingly pristine and healthy. Considering the small size of the area surveyed, it is exemplary that the reef supported more than two thirds of all fishes known from the Marshall Islands.

This report gives recommendations and scientific background to support the establishment of new MPAs and community-based management practices. Once these MPAs are approved, they will represent the first example of coral reef conservation in the RMI. This work has also been the first example of collaborative monitoring between the government, individuals and local NGOs and represented the first effort towards the participation into a regional network of research, monitoring and management of reefs and their resources.

Acknowledgements

There are different agencies and people that we wish to thank for permitting this work to be accomplished. Without their help and support this research could not have been possible:

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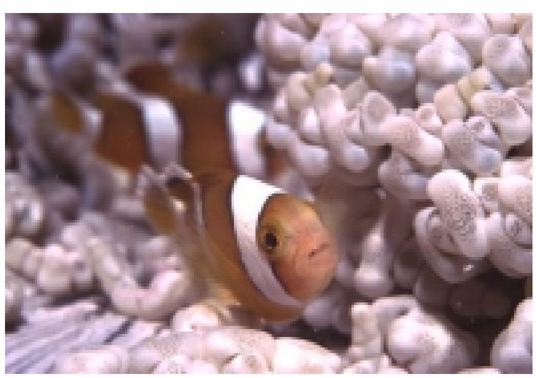

Photo by Robert Fournier

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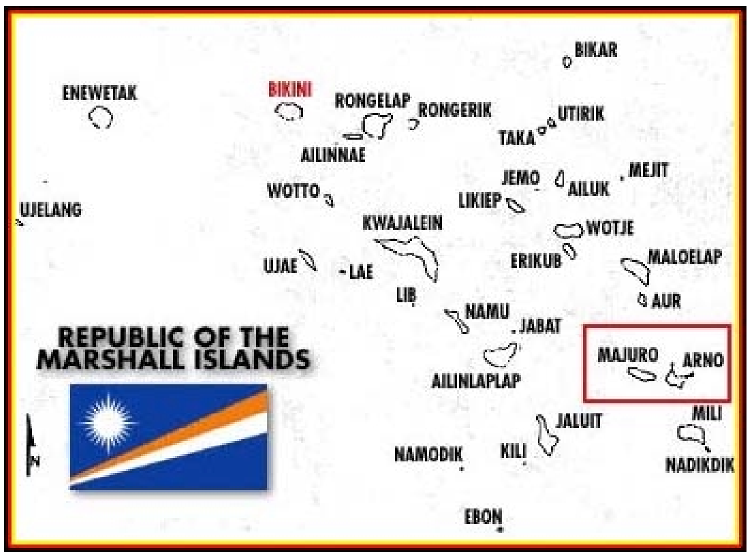
1. Introduction

The Republic of the Marshall Islands (RMI, 168 00 E, 9 00 N) encompasses 29 atolls and 5 islands (Figure 1). The atolls of the RMI encompass over 1,200 low coral limestone and sand islands, with the highest point of approximately 10 m above sea level (CIA, 2001). RMI comprises more than one-tenth of the world's atolls (Micronesia, 2002) and ranks eleventh globally regarding coral reef area (Spalding et al., 2001). With the exception of the two north-western atolls, Enewetak and Ujelang, the Marshall Islands are arranged in two island chains running roughly NNW to SSE: the western Ralik Chain and the eastern Ratak Chain. Both the atoll of Rongelap and the atoll of Bikini are in the Ralik chain.

Figure 1. Map of the Republic of the Marshall Islands (Micronesia, 2002).



The RMI has an unusual history due to the nuclear weapons testing by the USA. The tests were conducted for sixty-seven nuclear bombs between the years of 1947 and 1962 on the atolls of Bikini and Enewetok, with many more atolls affected (CIA, 2001, Niedenthal 2001, Micronesia, 2002).

1.1 Marine resources and management

The RMI is a country with very diverse and unique natural resources (Fosberg, 1990) which are very nearly totally marine (RMIBiodiversityProject, 2000), The Marshall Islands have an ancient tradition of sustainable use of marine resources controlled by social rules (Weissler, 2001). The natural environment has been well tendered with these customary practices. However, these values have been lost to modern life styles acquired through the presence of western immigrants and, more recently, investors from Western and Asian countries. As a consequence, the natural resources are being depleted and degraded (Weissler, 2001). Sedimentation, pollution from big oil stocking tankers and foreign fishing vessels, dredging, and overexploitation of the marine biological resources for the live fish industry and corals for aquarium trade, and extraction for local use (clams and turtles) are a list of many threats to coral reefs and the coastal environment. Problems of over-fishing are becoming increasingly evident to fishermen in the outer islands, as in Likiep and Jaluit (SP, pers. comm.). Moreover, population numbers are increasing rapidly (1.5 % annual rate of increase), amplifying the threats to reefs with waste and sewage disposal. The fisheries management has changed dramatically over the years. In the past it was managed by traditional means, directed by chiefs in the form of 'Mo' areas. 'Mo's' or taboo areas were set apart as reserves for harvesting food, while conserving a food resource, as a way of living in harmony with the environment (RMIBiodiversityProject, 2000). This tradition has been lost but recently local people started asking the support of the national agencies – such as the Environmental Protection Agency and the Marshall Islands Marine Resource Authority – in order to regulate harvesting of resources in their atolls through re-introduction of the traditional fishing restriction zones. The Marshallese people believe the reactivation of a 'mo' would ensure natural resources not to be depleted while at the same time would create a necessary sanctuary to safe guard areas for future generations (RMIBiodiversityProject, 2000).

Also, at a central government level there is increasing interest in sustainable use and restoration of depleted resources. A "Biodiversity Strategy and Action Plan" was issued in 2000 by the Marshall Islands to plan for the conservation of RMI biodiversity and for the sustainable use of its biological resources through (a) activation of conservation sites, (b) education and capacity building for local people to gain the knowledge and skills for conservation of the natural resources; and (c) research to gain a better understanding of the marine ecosystems. Similarly, the recently issued document "Strategic Development Plan, Vision 2018" (RMI, 2001) is based on the recommendations made by the Second National Economic and Social Summit held in March and April of 2001, and states a strong need for natural — especially marine — conservation clearly. The document specifically indicates the need to establish marine reserves to enhance (a) fisheries, (b) tourism, and (c) local awareness. RMI is also party to the international environmental agreements on Biodiversity, Climate Change, Desertification, Law of the Sea, Ozone layer protection and Ship pollution and has also signed but not yet ratified to Climate Change-Kyoto Protocol (CIA, 2001). As part of the RMI's obligations to the international environmental agreements, Acts have been drawn up to govern the law. Some of these Acts are summarized in Table 1.

Table 1. RMI legal instruments relevant to the marine environment, stating their outcome and objectives.

Act	Outcome	Objectives
National Environmental Protection Act, 1984	Established the RMI Environment Protection Authority (EPA) as an independent statutory authority.	-regulating individual and communal activities to ensure maintenance of safe, healthy and aesthetically pleasing surroundings. -prevent env. Degradation. -monitoring of human impacts on natural resources. -preserving historical, cultural and natural aspects of the nation's heritage.
Coast Conservation Act, 1988	Calls for planning, monitoring and controlling the	-survey the resources and uses of the coastal zone.

	development of the coastal zone. The Act also directs RMI EPA and provides for the establishment of an EIA program	-prepare a coastal zone management plan to regulate and control development activities in the CZ. -develop and implement plans for coastal resource conservation.
Marshall Islands Marine Resource Authority Act (MIMRA), 1988	Established MIMRA to coordinate and regulate the exploration, exploitation and management of biological and physical resources.	-prohibiting destructive fishing techniques such as the use of dynamite or chemicals. -define standards for fishing equipment. -prohibits foreign fishing vessels from fishing within the EEZ without appropriate licensing
Marine Resources (Trochus) Act, 1983	Regulates the harvesting of *Trochus*.	- establish a licensing and permitting system and define a harvest season.
Marine Resource Act, TTPI Code	Originates from preceding Trust Territory Code.	-prohibits the killing of turtles on land and the collection of eggs -sets minimum ocean-capture size limits and establishes seasonal capture quotas. -limits for the harvesting of cultivated sponges and black-lip pearl oysters.
Endangered Species Act, TTPI Code, 1975	Protects certain Sp. Deemed to be endangered. The endangered sp. List of the Trust Territory was adopted.	-prohibits harvesting, possessing, selling or exporting any threatened or endangered plant or animal sp.
Marshall Islands Marine Resource Authority Act (MIMRA), 1997	Long-term conservation and sustainable use of fishery resources	Fisheries conservation, management and development.

Source: (adapted and summarized from Crawford, 1993).

Highlighted in the table is the MIMRA Act of 1997; it is under this Act MIMRA is enabled to take measures for the management of fish in the fishery waters based on the precautionary principle. The 1997 Act enables MIMRA to have open and closed fishing seasons, restrictions on fish size and equipment used. MIMRA can protect nesting and breeding areas, while most importantly they can declare any specified area as a protected area and establish reserve areas. The authority can take measures for management and development of fisheries within the internal waters and inside 5 miles of the baseline from which the territorial sea of any atoll is measured. A local government council may take measures for the management and development of local fisheries to the same limits in accordance with the MIMRA Act, 1997, including the establishment of marine protected areas with approval from the authority. The local government of Rongelap Atoll (RALGov) is empowered by the MIMRA 1997 Act to establish marine protected areas (MPAs). The establishment of MPAs is therefore a local government objective and a national government priority.

1. 2 Background

The target locations for the study were the two atolls of Rongelap and Bikini, located in the far North of the western Ralik Chain. Rongelap Atoll, 125 miles south-east of Bikini, has been un-inhabited for 5 decades. The population has been forced to abandon their island following the explosion of the H-bomb 'Bravo' whose fall-out hit Rongelap in 1954 (Micronesia, 2002). An unexpected change in wind direction at the time of the blast left Rongelap in the path of deadly clouds of radioactive ash. The US claimed that Rongelap was safe and took no responsibility for any relocation of the people from the atoll at the time. It was later proven by a US Congressional Committee that there had been warnings of a change in wind direction the day before the test, and also warnings that if the testing went ahead Rongelap would be affected. The US eventually had to accept responsibility and in 1995 the US established a trust fund for the Rongelapese people. Part of this US established trust fund is being spent on infrastructure on the islands of Rongelap Atoll as a precursor to re-inhabitation.

Figure 2. Aerial photograph of Rongelap atoll.

Since 1954 the inhabitants have been moving in exile from atoll to atoll in search of a temporary home. The people of Rongelap were moved to Mejatto, an island on Kwajalein Atoll, in 1985 by Greenpeace, while the US still claimed the island was safe. Since 1985 Rongelap Atoll has been uninhabited, the reefs and lagoons un-fished, until 1998, when the resettlement program was put into effect with Phase 1 of the repatriation. Rongelapese are preparing to once again inhabit their native islands and are at present working for a reestablishment of a community.

Rongelap local government (RALGOV) has formally requested the assistance of the College of the Marshall Islands (CMI) Marine Science (MSP) team to undertake the study in order to collect baseline information on the status of reef of the island that is soon to host about seven hundred new inhabitants. As consequence of the historical events, Rongelap has effectively been protected from exploitation for over 50 years. On a global scale, it might be one of the few untouched reefs remaining. However, the government and the people themselves need to organize a plan for the attentive exploitation of the natural resources that will take place when the imminent relocation starts. The baseline assessment and the relative recommendations will help in such a task.

Moreover, the proximity of Bikini and Rongelap could lead to an expansion of the existing tourist operation on Bikini. Divers and sport fishermen could visit the two atolls and practice different activities. Such an opportunity could become advantageous for both atolls and could be used for employment and development prospects for the relocating inhabitants on both atolls.

2. Methods

This project entailed three phases, leading to a local institutionalization of a marine conservation program in the long term. Phase one: training and education of local volunteer monitors. Phase two: field work: surveys in the two atolls, with participation of both specialists and local volunteers. Phase three: data processing, results issuing and preparation of recommendations for guidance rules for the establishment of MPAs in RMI.

Phase 1. The first, educational, phase took place during the two weeks preceding the field work. Marshallese students and volunteers were trained in marine resource assessment methods, identification of marine organisms and data management. The following activities took place in Majuro atoll:

- Classroom teaching of students in species identification and survey design,
- Practical training in survey operations
- Practical teaching in diving-for-science procedures, safety and dive planning
- Information of the public about the project and the marine environment through newspaper articles

The second part of the education/awareness phase goes on in Majuro as after-field activity, through participation to conferences, presentations, newspaper articles and lectures. This phase is valuable in order to inform the Marshallese public — young students, fishermen and regional governments — about the importance of coral reef ecosystems and their conservation.

Phase 2. This was the survey part of the project to check on the status of marine resources in line with the local government's requirements and wishes. This reef assessment phase was conducted by experts and previously and newly trained local students. The *training-by-doing* aspect of this phase was done conforming to the need expressed by the government to train Marshallese people to the assessment of local marine biodiversity. The program collected three levels of data with varying quality, reliability and utility: A. Biodiversity Information, B. Reef Status data and Monitoring baseline, C. Community and volunteer data (Table 3). The field work involved several stages of survey activities. The external specialists and assistants entered the project at this point.

Detailed survey of target sites. The following survey techniques were applied at the identified target sites:

- Coral and fish biodiversity: presence/absence and semi-qualitative abundance in timed swims (two fish experts)
- Algae diversity and abundance: points records for algal coverage with algae quadrats (25 x 25 cm, 4 replicate per transect, 4 x 3 replicates per site)
- Line intercept transects for substrate, coral and algae: percent cover on a 50 m line (3 replicates per site, three different depths) and reef health transects: counts of *Acanthaster planci* (coral eating crown-of-thorn starfish), dead and bleached coral
- Line transects for invertebrates: counts of target species of invertebrates on a 50 m x 5 m corridor (3 replicates per site, three different depths)
- Line transects for fish (size and abundance): fish counts and size estimation of commercially and ecologically important species, on a 50 x 5 m corridor m (3 replicates per site, three different depths)
- Reef Check: global volunteer reef health assessment scheme (www.reefcheck.org)
- Permanent transect installation for repetitive monitoring programs and long time data acquisition, such as coral recruitment, effects of re-location, fishing and diving activities, and climatic effects such as coral bleaching.

The survey methods were based on standard methodologies used in coral reef science (English et al., 1997, for ecological and monitoring surveys, Werner and Allen, 1998, for biodiversity assessments, Pinca, 2001, for the previous study in RMI), and Reef Check for the community monitoring (www.reefcheck.org). Surveys were depth stratified at deep (18 m), medium (12 m) and shallow (5 m) depth. Very shallow areas or lagoons were assessed only for coral and fish biodiversity. Data were entered *in situ* and analysed in Majuro. For substrate categories, coral life forms and target genera and species for: corals fish, seaweeds, invertebrates, see Appendix I.

Phase 3. Data processing, results issuing and preparation of recommendations took place in Majuro, Australia, and the UK, between September and November 2002. Each scientist participated to the elaboration and preparation of the report. The results are being published as well as used to prepare recommendations for the location and managing design for new MPAs in the two atolls. Public presentations, lectures, articles and displays are being held in the town of Majuro and will be presented at international conferences. The first conference to be attended by Silvia Pinca will be the Second International Tropical Marine Ecosystems Management Symposium (ITMEMS2) in Manila between March 25th-29th 2003. A special session in Micronesia coral reef management will be held by Dr. Pinca.

2.1 Site selection

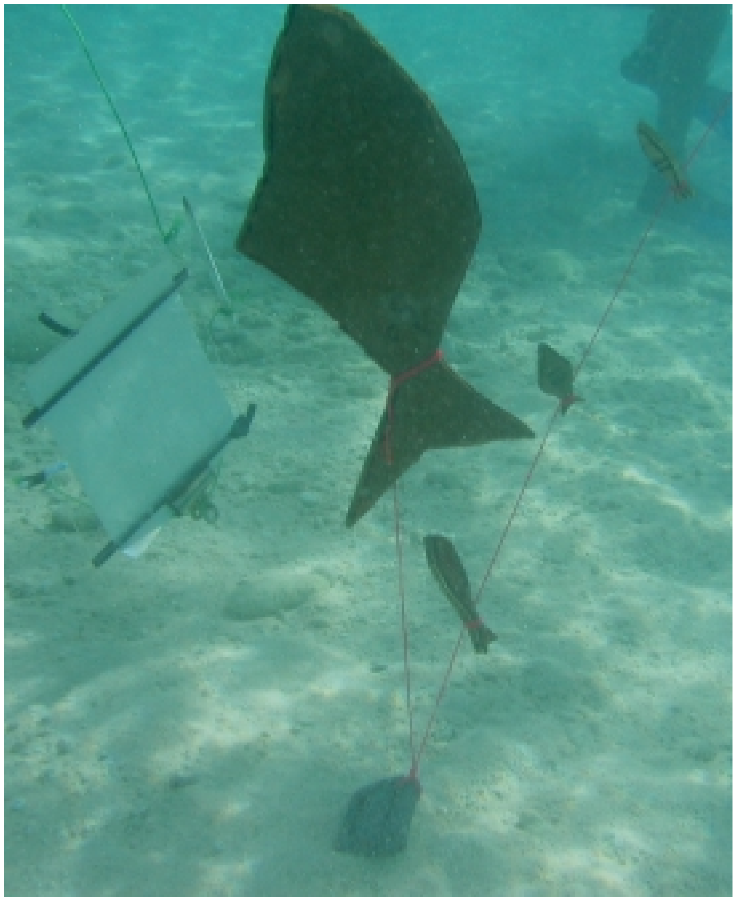
For logistical reasons, the sites in Rongelap Atoll were limited to the main island of Rongelap-Rongelap (Rongelap main island) and to two sites at the south side of the atoll: on the ocean side of the islands of Arubaru and Eniroruuri. On Rongelap-Rongelap balance was given to sites located on the lagoon and the ocean side.

2.2. Training

The participants in the NRAS team followed a program of training and validation appropriate to the undertaking of marine surveys. The training was organized for scientists, experienced volunteers and Marshallese students on marine science courses. The team familiarized and revised their knowledge on fish families and target fish species, coral forms and target coral species, target species of seaweeds and target invertebrate species. The target species were chosen from information on past studies done in the RMI by members of the NRAS team and published literature on the Marshall Islands (Pinca, 2001). The validation was done through a series of identification tests on the computer and in the water, combined with test surveys where buddy scuba divers recorded the same information and then the results were compared. In order to participate on the surveys, the divers had to pass the calibrated tests. Results had to be within 10% of difference between the two divers, to assure good data quality and comparability between team members.

Underwater fish size estimation was aided by a ruler with centimetres tags marked on the recording slate. To learn this size estimation underwater with the natural magnification, trails with wooden fish where prepared and suspended underwater. They had to be sized in a test (Photograph 1).

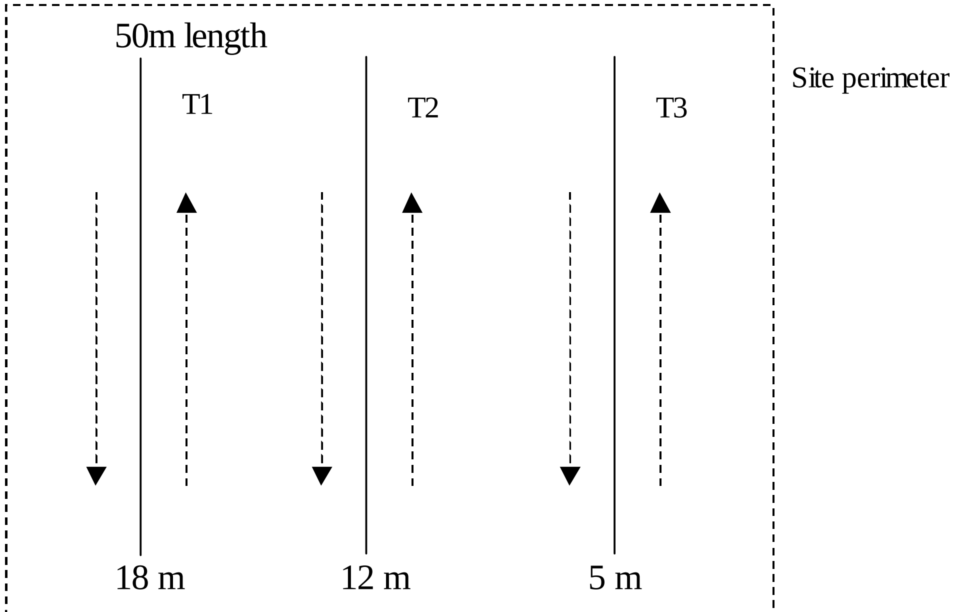
Photograph 1. Wooden fish prepared for a test on fish size estimation underwater.



2.3 Transect Surveys

The NRAS surveys included recording the fish, coral, invertebrate and seaweed data on a series of 3 transects; 2 divers were working on each of the three transects that were located at predetermined depths. The diagram in Figure 3 below shows the layout of transects at one site, with the site perimeter indicating the coverage of information gathered from one site. The transect method was chosen to represent the characteristics of the whole site, over a range of depths (between 5 to 20 m) to give a wide enough coverage on different zones on the reef (Figure 3). Each diver would swim the transect four times, accomplishing different duties at a time.

Figure 3. Layout of three transects at each survey site (Transect 1, 2, and 3 are T1, T2, and T3).



A 50 meter tape measure was laid to allow quantitative analysis and used as a marker so the same transect would be covered on return swims from one end of the transect to the other. 18 meters was the maximum depth for the deep transect, allowing enough time for the pair of scuba divers to complete the work without going in to decompression time. On each transect at each site two scuba divers were collecting the information. Each diver had two jobs, accomplished on a transect swim at a time.

"Fish" Surveyor (Diver to pass over site first):	***"Coral" surveyor:***
Records large fish	Lays the 50m tape
Records smaller fish	Records the corals or substrate every 50cm
Records 4 quadrates of seaweed target genera and percentage coverage (at the markers of 10, 20, 30, 40 m on the tape)	Records the number of target invertebrates
Helps buddy roll up the tape measure	Reels up the 50m measuring tape

2.3.1 Fish data

Fish counts were undertaken by 1 scuba diver, swimming along the 50 m length measuring tape. On the first swim, the diver recorded fish of size C class (over 20 cm in size) and on a second transect swim fish of size A (< 10 cm) and B class (6-10 cm). The fish surveyor swam along the designated depth contour recording fish while the buddy laid the tape measure behind. Fish surveyors recorded all target fish, within an estimated box of 5 meters, 2.5 m to either side of the tape, 5 m above and 5 m forwards (Figure 4). The target fish were recorded at family and species level for the fish families shown in the table in Appendix 2. The fish species recorded where estimated into three size classes: A 6-10cm, B 10-20cm, C >20cm. The meandering swimming pattern allowed to record the smaller species and the sedentary species.

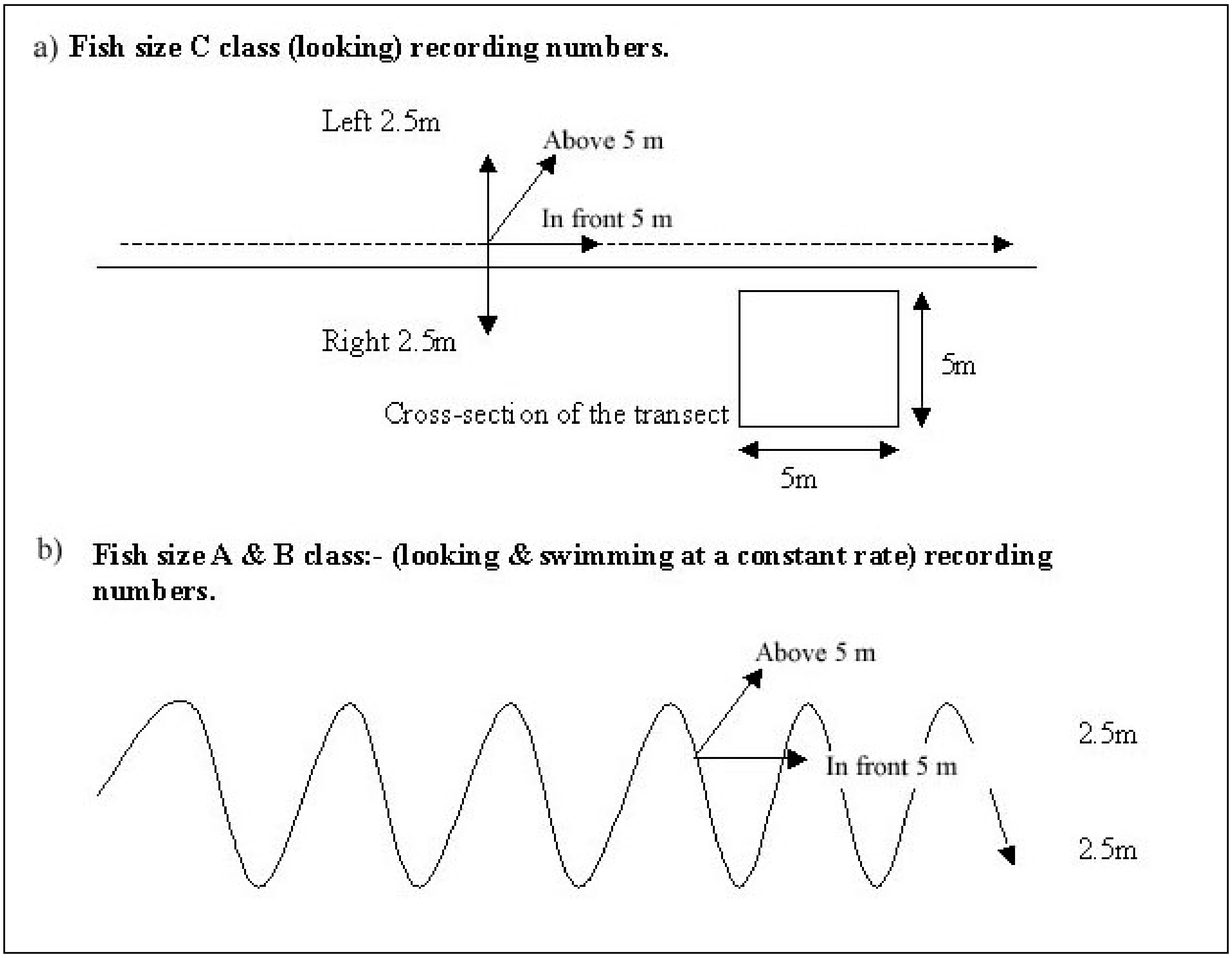
The fish size classes allow the minimum average fish biomass to be calculated, according to the formula:

$$W=a*L^b$$

Where W is weight in grams, *L* the Length in cm, and *a* and *b* are coefficients.

The biomass data could also be used as a baseline for future monitoring programs. Fish individuals which were 'observed twice' on a transect i.e. fish, which crossed in front of the diver once and shortly afterwards a similar fish (or the exactly same fish) was encountered again, were counted as separate individuals unless the observer saw them turning around and hence could be sure it is the same fish.

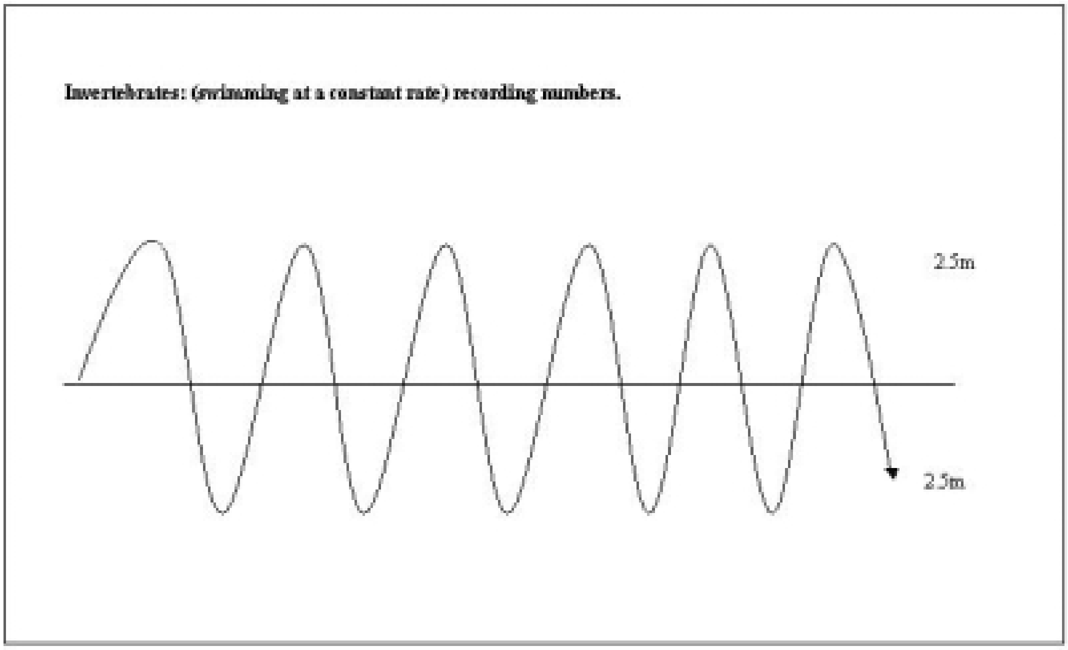
Figure 4. Patterns of swimming and observation radius for (a) large fishes and (b) small fishes.



2.3.2 Invertebrate data collection

The invertebrate data were collected by one scuba diver meandering across the 50 m measuring tape looking to a distance of 2.5 m either side of the tape (Figure 5), counting the target species (listed in Appendix 3). The purpose of criss-crossing the transect was to record the smaller species and the sedentary species.

Figure 5. Patterns of swimming and observation radius for target invertebrates.



2.3.3 Benthic Line Intercept Transect (LIT)

LITs were carried out according to AIMS-ASEAN methodology with minor adjustments. Recorders noted all features at two levels, AIMS-ASEAM life-forms and target coral genera or species (see Appendix 1). The coral data was collected by a diver, swimming along the length of the 50 m measuring tape and recording the substrate below the tape at every 50 cm.

2.3.4 Seaweed data collection

A quadrat of 25 cm x 25 cm dimension was placed next to the transect at the 10 m, 20 m, 30 m, and 40 m marks. Density or percentage coverage was estimated inside the quadrats and averaged for each depth. Target genera and larger groups were identified (Appendix 4). Samples of seaweeds were taken for preservation (pressing of dry samples) and cataloguing at the library of the College of the Marshall Islands.

2.4.1 Fish Diversity

Fish species richness was assessed by Maria Beger, using timed swims for 60 to 90 minutes at each survey site. All sites were sampled at least once; two sites had multiple samples. Underwater observations were recorded onto a plastic sheet on a slate. The most commonly seen species were pre-printed on the recording sheet and ticked when seen, other species were noted separately on the same sheet. Fish species were only recorded when their identification was absolutely positive. A small percentage of fishes could not be identified to species level because of constraints in visibility, cryptic behavior and too great a distance from the observer. To supplement the visual census, on some occasions samples were obtained by capturing the fish using the ichthyocide clove oil, which stuns small fish. This technique was used for smaller or cryptic fishes that are difficult to visually identify *in situ*. Underwater photos also aided with identification in a few cases.

All fish species were given a semi-quantitative rating, following the DAFOR scale (Table 2). These ratings were given considering their relative abundance, i.e. fish species that usually occur in large aggregations were rated at the higher end of the scale.

Table 2. Semi-quantitative abundance rating for coral reef fishes.

Rating	Abundance
0	None
1	Rare, 1 individual seen
2	Occasional, 2 to 6 individuals seen
3	Frequent, 7 to 50 individuals seen
4	Abundant, 30 to 200 individuals seen
5	Dominant, more than 200 individuals AND they form a major part of the overall fish biomass

The timed swim method involved a rapid descent to 25 to 30 m, with the deepest dive being 52 m on one occasion. Then the observer ascended slowly, swimming in a meandering fashion, and spent a considerable time of the dive in the surge zone. The observer included all major habitat types present at the site in the survey. Biological and topographical habitat types were also recorded semi-quantitatively (for Habitat types see Appendix 9).

The data were analyzed using multivariate clustering to demonstrate zonation of fish communities on Rongelap atoll and, in more detail, of Rongelap island. Using the Coral Fish Diversity Index (CFDI) (Allen, 2002), an estimate of total expected coral reef fish fauna was calculated. The reserve prioritization program WORLDMAP (Williams, 2000) was used to illustrate conservation priorities on Rongelap-Rongelap form the point of view of fish species diversity.

2.4.2 Coral Diversity

Corals were surveyed by Zoe Richards during 16 scuba dives to a maximum depth of 52m (average depth 30 m – exposed wall, 15 m – lagoon). Each of the 14 sites was sampled once apart from R1 and R10 at which additional dives were conducted to establish permanent monitoring transects.

Coral species richness was assessed using timed swims for 60 mins at each survey site. The timed swim method involved a direct descent to 30 m, followed by a slow ascent, swimming in a zigzag path to the shallow parts of the reef where a large proportion of time was spent surveying the reef crest. All records were based on visual identifications made underwater, except where skeletal detail was required for species determination. In the latter case, reference specimens were collected and studied at the Museum of Tropical Queensland by the Zoe Richards and Dr Carden Wallace (*Acropora*), and Dr Douglas Fenner (non-*Acropora*). Voucher specimens have been deposited in the Museum of Tropical Queensland (Townsville, Australia) and are available for viewing upon request. References for species identifications were Wallace, 1999; Veron, 2000; Hoeksema and Best, 1991; Wells, 1954; Nemenzo, 1976.

Coral species were given a semi-quantitative abundance rating following the DAFOR scale (0 = none; 1 = Rare, 1 colony; 2 = Occasional, 2-6 colonies; 3 = Frequent, 7 – 30 colonies; 4 = Abundant, 30 – 200 colonies; 5 = Dominant, more than 200 colonies and form a major component of the overall coral biomass). An estimate of percentage cover of coral was given for each site along with recording the three most dominant species.

Data was analyzed using multivariate clustering to demonstrate the zonation of coral communities on Rongelap atoll, and in more detail, Rongelap-Rongelap island. The reserve prioritization program WORLDMAP (Williams, 2000) was used to illustrate conservation priorities on Rongelap atoll with respect to coral species diversity.

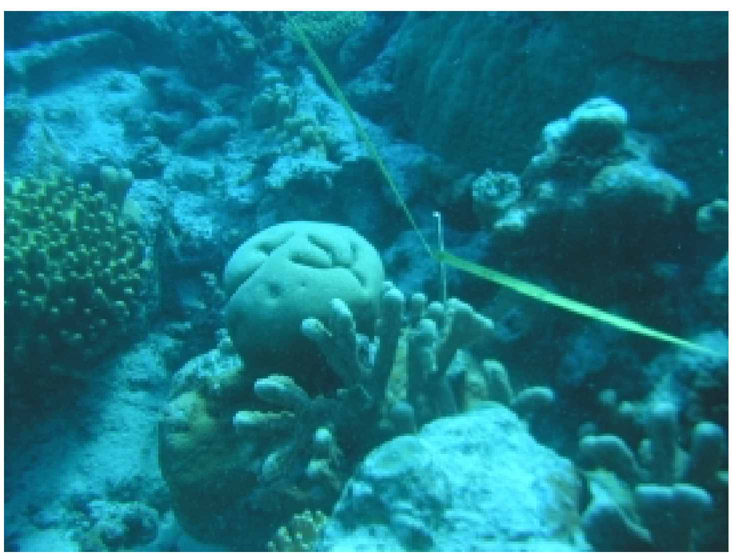
2.5 Physical information and profiles

Physical profile transect were accomplished with the all team collaborating. Three transects perpendicular to the shore were deployed. Two divers were working on each transect, using a 10 m line. One dive buddy pair worked on each of the three transects. Diver 1 (D1) for each dive buddy team was leading, holding one end of a 10 m rope to measure the length of the transect. D1 also took a depth reading every 10 m and estimated horizontal visibility. Diver 2 followed at intervals while recording substrate type and coverage (following substrate categories detailed in Appendix 1) and health of the reef for each segment. A fourth team was swimming instead parallel to the shore at 20, 15, 10 and 5 m, covering 20 m at each depth, and describing substrate and main physical features (presence of gullies, boulders etc.). Following the dive, the team completed a site assessment form entering information on GPS reading and location description.

2.6 Permanent transects

Two permanent transects (see an example in Photograph 2) were deployed for future references and monitoring. One transect was laid at 8-10 m off Jaboan point and one was laid on the wall, on the east side of Rongelap-Rongelap, at a depth of 12 m. At each site, eleven metal pins were deployed and hammered inside the bedrock, at 5 m apart between each other, along a 50 m line. Underwater epoxy was used to glue the points inside the rock.

Photograph 2: Example of a pin on permanent transect PT1.



2.7 Photographic documentation

At each site a professional photographer (Robert Fournier) was in charge of taking underwater pictures of individual fishes or corals for identification and documentation purposes, using a professional underwater camera (Nikonos 4 ®). A digital underwater camera (Olympus Camedia ® 4.1, with Ikelite ® housing) was deployed to take general pictures of habitat and individual species and to document the status of the permanent transects by S. Pinca, and in some occasion by other participants. For the first week of surveys in Rongelap, an underwater videocamera was deployed by Craig Musburger for taking videos of general habitat conditions and fish swimming behavior for later identification purposes.

2.8 Summary of methods

In summary, a variety of survey methods were applied in order to obtain a comprehensive picture of every aspect of coral reef ecology and status. To provide the reader with a quick reference of the methods used, Table 3 gives a comprehensive summary of all methods.

Table 3. A summary of all survey methodologies applied during NRAS. Levels refer to biological detail as follows: A-species level identification, B-ecological/monitoring data, and C-community-level data.

Name	Data collected	Method	Level
Coral and fish biodiversity	Record presence – absence (corals) and semi-qualitative abundance and sizes (fish) for all species	Timed swims by experts	A
Algae coverage and diversity	Point records for algal coverage and diversity at three depths	Algae 4 x 3 quadrats (25 x 25 cm)	A
Algae coverage and abundance	Line intercept transects, percent coverage at three depths	3 x 50 m line	A, B
Line intercept transects for coral and benthos	Records of distance since interception, percent cover at three depths	3 x 50 m line, life form level of identification, substrate types	B
Line transects for invertebrates	Counts of invertebrates	3 x 50 m line, 5m wide, target species identification	B
Line transects for fish (size and abundance)	Fish counts, target species, size estimation, biomass (English et al. 1997).	3 x 50 line, 5 m wide, species id, counts and length – biomass conversion	B
Reef health transects	Counts of *Acanthaster planci*, (Crown- of- thorns starfish), *Drupella sp.* (coral eating snail), dead coral and bleached coral	3 x 50 m line	B
Reef Check	Global volunteer reef health assessment scheme (www.reefcheck.org)	Low detail assessment, ideal for community participation and training.	C
Permanent transect	Installation of permanent transects for temporal monitoring	50 m long, every 5 m a pin; map substrate, corals, fish, algae	A, B