WCS-Fiji Marine Biological Monitoring Handbook

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Introduction

This handbook describes the marine biological monitoring techniques that the Wildlife Conservation Society (WCS) Fiji Country Program is currently using to monitor reef resources inside traditional Fijian fishing grounds (*qoliqoli*) where networks of marine protected areas (MPAs) have been established. The protocols have built on existing methodologies and have evolved over time to meet the needs of the WCS-Fiji program. In this section, we describe the rationale behind the monitoring approaches and how they have been optimized to fit our staffing capability and cost constraints. As the goals of the Fijian MPA networks surveyed are primarily to increase stock of food fish, we concentrate on methods for surveying relevant coral reef fish communities. We then describe several methods to collect benthic data which we predominantly use to exclude differences in reef fish communities specifically related to habitat. These data also provide valuable baseline information which could be used to monitor recovery in the event of large-scale disturbance to the reef systems. Lastly, we describe new monitoring protocols based on resilience assessments designed by IUCN and partners to identify reef areas likely to resist and/or recovery from climate-based disturbance (Obura & Grimsditch 2009).

Coral Reef Fish Monitoring

Fish survey methods

Coral reef fish populations exhibit high natural variability which makes it challenging to detect changes in population size or density that are related to management measures (McClanahan et al. 2007). Variation can be caused by natural factors associated with: diurnal and tidal movements (Thompson and Mapstone 2002); population processes such as reproduction, recruitment and mortality (Williams 1983; Hixon and Carr 1997); habitat complexity and habitat utilization preferences (Friedlander and Parrish 1998; Friedlander et al. 2003); speed of fish movement and difficulty of detecting cryptic species (Green and Alevizon 1989; Willis 2001). Variation may be further introduced in fish size and abundance estimates by varying abilities and swimming speeds of observers or the presence of divers in the vicinity, particularly where fishing pressure is high (Fowler 1987; Lincoln Smith 1988; Samoilys and Carlos 2000; Gotanda et al. 2009).

Underwater visual census (UVC) monitoring has become a mainstay of programs assessing the effects of protected areas on reef fish population recovery. Several types of UVC monitoring are most commonly utilized, including belt transects and stationary point counts (Saimolys and Carlos 2000). Samoilys and Carlos (2000) found few significant differences between the methods, but noted that the data obtained by either were characterised by "high variability, low precision and low power". For belt transects, they recommend a size of 50 m x 5 m, replicated at least 10 times, with low swimming speeds (33 m^2 min^{-1}).

To reduce variability in fish estimates, several authors have recommended limiting the number of species surveyed (Williams 1986; Lincoln Smith 1989). In addition, different taxa can be surveyed on multiple passes of the same transect and within the same tidal regime with good (> 7 m) visibility (McClanahan and Kaunda-Arara 1996; McClanahan 2008). However, the number of sites and transects utilized (and passes along transects) will ultimately require a trade-off between obtaining enough statistical power to detect differences among factors influencing reef fish population density and size and practical constraints of time, money, staff capacity and feasibility

(Bros and Cowell 1987, Samoilys and Carlos 2000). WCS-Fiji has chosen to limit the fish counted to targeted food fish families and families with important ecological functions (see Belt transects for Fish Size and Abundance) that are easily recognizable (e.g. Chaetodontidae). Given the large number of MPAs requiring monitoring in each qoliqoli where WCS-Fiji presently works, the monitoring teams limit their surveys to 1 pass per transect in order to be able to cover more sites per monitoring period.

Optimal experimental designs for assessing differences in fish populations related to management can be assessed through a priori power analyses. However, power analysis calculations are typically not robust when using non-normally distributed data (Zar 1999), such as most fish survey data. New developments in statistics and statistical software have addressed this issue: permutational analysis of variance (PERMANOVA) allows for the calculation of pseudo-F ratios on the basis of any distance measure from non-parametric data for balanced, multi-factorial ANOVA designs (Anderson 2001). WCS-Fiji has modified our experimental design over time through an adaptive process when new information has become available to reduce variability in the data and increase the power to detect differences related to the factors of the survey design.

WCS-Fiji monitoring designs of fish abundance and size in 2007-2008 included three factors: management (open, closed), exposure (forereef, backreef), and depth (top, shallow, deep). In general, two forereef and two backreef sites were surveyed within each management treatment, with 5 replicate transects nested within depth categories and depth nested within sites. In late 2008, exploratory data analysis revealed high variability in fish abundance and biomass recorded from backreef sites which made it difficult to detect differences related to management effects from data collected between October 2005 and October 2008, even when data were pooled across exposure gradients (forereef, backreef). A power analysis using PERMANOVA+ within PRIMER software (Anderson et al. 2008) indicated that changing the sampling design to increased sample size of *forereef-only* sites would improve the ability to detect differences related to management (Appendix 1). Therefore, monitoring was conducted in 2009 on forereefs only to improve our power to detect differences related to protection.

Further power analyses conducted in 2010 show that changing the number of transects surveyed has minimal effect on our ability to detect differences related to management, but would greatly change costs (Appendix 2). However, the power to detect difference related to management is improved by nesting sites within depth categories using the same sampling effort (# of transects). The 2010 monitoring design will be modified based on these results so that depth categories are surveyed at different sites instead of evaluating multiple depths at each site.

Data cleaning and biomass calculation

Observer bias is investigated by assessing the mean number of fish species counted per transect by each observer. Fish biomass is calculated from size class estimates of length (L) and existing published values from Fishbase (Froese and Pauly 2009) used in the standard length-weight (L-W) expression $W = aL^b$, with *a* and *b* parameter values preferentially selected from sites closest to Fiji (e.g. New Caledonia). If no L-W parameters is available for the species, the factors for the species with the most similar morphology in the same genus are used (Jennings and Polunin 1996). If a suitable similar species cannot be determined, averages for the genera are used. As many of the L-W conversions require fork length (FL), a length-length (L-L) conversion factor can be obtained from Fishbase where necessary to convert from total length (TL) recorded during the surveys to FL before biomass estimation.

Coral Reef Benthic Habitat Monitoring

There are many reasons to survey coral reef benthic communities. Many studies are done to understand ecological drivers of natural differences in community structure. Population processes such as recruitment, competition, predation and mortality fluctuate naturally in response to environmental conditions and levels of disturbance (Connell et al. 1997; Connell et al. 2004) and can produce very different benthic communities that support different fish assemblages.

Other types of monitoring are done to observe direct and indirect shifts in benthic community composition related to major disturbance, which may include: tropical storms, floods, overfishing, coral bleaching or combined response of several of the above categories. Overfishing of reef grazers in particular may lead to shifts from coral to algal dominance following large disturbances resulting in mass coral mortality (e.g. bleaching, tropical cyclones; Hughes 1994). Management through no-take protected areas can result in differential changes to benthic cover (McClahanan et al. 2002), in particular by promoting recovery of reef grazers who promote reef resilience by limiting algal cover (Mumby et al. 2006; Green et al. 2009).

There has been much debate over the preferred methods for monitoring benthic habitats, with many management agencies using point intercept transects (PIT), line intercept transects (LIT) or photo/video transects. PIT is easy to learn and implement and has been a recommended tool of Reef Check, though it is not good for picking up rare species on the reef and gives no indication of coral colony sizes (Hill and Wilkinson 2004). LIT, recommended by the Global Coral Reef Monitoring Network (GCRMN), gives additional information on coral colony size, which may indicate disturbance frequency (Meesters et al. 1996), but the size estimates are only accurate if the line passes over the entire width of the colony (S. Jupiter, pers. obs.) and may be time consuming to implement (Hill and Wilkinson 2004). When combined with photoquadrats across fixed, permanent transects, however, it can provide reliable estimates of benthic cover, coral diversity and change over time.

As with the methods for monitoring reef fish populations, the WCS-Fiji protocols for monitoring benthic habitats have evolved over time with additional staff training. Initially, all surveys were conducted using PIT where modified GCRMN life forms of benthic cover were measured at 0.5 m intervals along the same replicate 50 m transects used for counting fish. In order to add an additional layer of information to be able to assess differential response to and recovery from disturbance, observers began recording coral genera in 2007 in addition to life form. In 2008, WCS-Fiji also established permanent transects for period monitoring using LIT plus photoquadrats which are analysed for benthic cover using Coral Point Count with Excel extension (CPCe) software (Kohler and Gill 2006).

Because reef topography and complexity has been shown to be a major driver of fish assemblages across several spatial scales (Wilson et al. 2007; Purkis et al. 2008; Pittman et al. 2009), WCS-Fiji began measuring rugosity of the 10 m replicate LITs in 2008 using a fine chain. Beginning in 2009, along PIT transects, WCS-Fiji additionally started giving a complexity score to each 0.25 m^2 surrounding every 0.5 m point where: 1 = minimal relief; 2 = some vertical relief (e.g. boulder corals); 3 = high vertical relief (e.g. branching corals, reef crevices). These complexity measures have been adapted in 2010 to give a broader range at both the micro- and macro-scale. For resilience assessment surveys in 2010, WCS-Fiji will evaluate micro-complexity at within each 0,25 m^2 surrounding each 0.5 m point on a five point scale where: 1 = totally flat (e.g. sand); 2 = rubble/small patches of vertical relief; 3 = mounding structures; 4 = submassive or coarse branching structure; and 5 = complex branching structure with crevices in the reef. Every five meters, the observer will additionally measure macro-complexity on a 5 point scale while looking forward at the entire reef structure where: 1 = no vertical relief; 2 = low, widespread relief; 3 = moderate relief; 4 = complex vertical relief; and 5 = complex vertical relief with fissues, caves and/or overhangs.

For data analysis to date, percent cover of lifeforms have been combined into 7 functional strata: unconsolidated substrate (US: rubble, sand, silt); reef matrix (RM: dead coral, reef pavement, crustose coralline algae, coralline algae); macroalgae (MA: all fleshy macroalgae > 2 cm, including cyanobacteria); live hard coral (LC: all hard coral classes including *Millepora* and *Tubipora*); other soft substrate (OT: including soft corals, sponges, ascidians, anemones); turf algae (TA: ≤ 2 cm height on reef pavement)p; and upright coralline algae (UC: e.g. *Halimeda* spp). This information is combined with fish biomass and abundance data to evaluate whether benthic cover and complexity influences fish assemblages. Only studies that take into account multiple stressors across spatial and temporal scales and their potential synergistic reactions will be able to tease apart the main factors structuring current day reef community composition (e.g. Done et al. 2007) and be able to assess whether management measures have influence over other factors.

Monitoring for Reef Resilience

An important job of reef managers is to maintain coral reef ecosystems in a desired "healthy" state. While the definitions of coral reef health will vary based on location and context, in general, the desired state includes: moderate to high hard coral cover in a range of colony sizes and species; low macroalgal cover; and abundant fish populations across all trophic and functional groups. A reef that can maintain these qualities over time is considered stable.

Ecosystem stability is often described by measuring several components, which may include: the rate of return to a previous steady state after perturbation (resilience); the capacity to absorb perturbations without change (resistance); the amount of perturbation tolerated before switching to an alternate state (robustness); and the length of time a system remains in one state (persistence) (Pimm 1984; Vogt et al. 1997; McCann 2000). Stability depends partly on the length of intervals between disturbance relative to recovery rates, and on the spatial extent of disturbances relative to the spatial extent of the effective dispersal range (Turner et al. 1993). For example, on coral reefs, coral populations may be able to recover more rapidly from local disturbances, such as dynamite fishing, than widespread disturbances, such as mass coral bleaching, that may kill off all of the seed populations. Stability also reflects history: the degree to which an ecosystem can respond to and recover from disturbance is constrained by how natural selection and disturbance frequency and intensity has influenced the component species in the past (Holling 1973; Jupiter et al. 2008).

A reef that is impacted from chronic disturbance is going to be less likely to recover quickly from a large, acute and therefore is less *resilient*. For example, nutrient accumulation has been implicated in reduced ecosystem resilience, leading to catastrophic shifts to alternate states on coral reefs from coral to fleshy macroalgal dominance (Nystrom et al. 2000). So what can managers do to improve reef resilience? Walker's (1995) concept of ecosystem conservation emphasizes the importance of first determining which processes are critical for maintaining ecosystem function and persistence, and then protecting the groups of functionally redundant species carrying out these ecosystem processes. In this model, priority should be given to important functional groups with the fewest number of species (Walker 1995). On coral reefs, herbivorous fishes have been recognized to have critical ecological functions in terms of maintaining clean space on which new reef recruits of reef-building corals and coralline algae can settle (Green et al. 2009). Therefore, in selecting areas to set aside as MPAs, it is important to ensure that there are abundant populations of herbivores, with multiple species in each functional group.

WCS-Fiji has adapted the protocols of Obura and Grimsditch (2009) to identify areas across complex reef systems that are likely to be the most resilient to disturbance from climate-based threats (e.g. bleaching, run-off, storms). In addition to categorizing the herbivores from the 50 m x 5 m transects into herbivore functional groups, this manual describes methods to assess: coral population structure, in order to evaluate likelihood of resisting new disturbance as different genera have different susceptibilities to bleaching and sediment tolerances (Stafford-Smith and Ormond 1992; Marshall and Baird 2000); coral recruitment, in order to assess the likelihood of recovering from disturbance; algal cover, which measured in conjunction with herbivore populations will give an indication of grazing capacity; site flushing, which may reduce the likelihood of temperature stress; and site shading, which can reduce stress from both temperature and ultraviolet radiation.

Handbook Format

In the following section, the specific protocols used by the WCS-Fiji program are described for carrying out transects for fish sureys, PIT and LIT for benthic cover surveys, coral population structure and recruitment and algal abundance. Datasheets in support of the surveys are found in Appendix 3. LIT datasheets are the same as the PIT datasheets with the exception that the distance field is blank and filled in by observers. The complete list of known fish found in Fiji for each of the WCS-Fiji target families is in Appendix 4. The list has been compiled through confirmed sightings by local experts (A. Jenkins, H. Sykes) and compared with museum collections. The complete list of known scleractinian coral genera is found in Appendix 5, based on compilation of Fiji records by Lovell and McLardy (2008).

Belt Transects for Fish Size and Abundance

Scientific Questions

- **Are food fish bigger and more abundant inside protected areas?**
- **What are the natural differences in food fish size and abundance due to habitat?**
- **Are there different types of fish communities inside protected areas? (i.e. Has fishing altered fish community structure?)**
- **What are the natural differences in fish communities due to habitat?**

Protocol

1. Diver will descend to required depth (shallow: 5-8 m; deep: 12-15 m) and randomly select a section of reef to begin surveying. At high tide, diver will descend to the lower depth limit (shallow: 7-8 m; deep: 14-15 m). At low tide, diver will descend to the upper depth limit (shallow: 5-6 m; deep: 12-13 m)

2. Diver will wait 3 minutes for fish to settle

3. While waiting, diver will use a compass to note the direction of reef slope and will estimate the depth of the reef base on the following scale: 0 - 5 m; >5 - 10 m; >10 - 20 m; >20 - 40 m; >40 m.

4. Diver will attach end of transect tape to appropriate substrate (**not live coral**) and ensure that it is firmly attached

5. Diver will record: Site name, Recorder Name, Transect #, Depth Class (Deep/Shallow), Date, Water Temperature, Tide, Start Time, and Actual Depth (m)

6. Diver will swim forward, releasing transect tape behind him/her, and record all fish sighted within a 5 m cube of the transect (2.5 m to each side of the tape and 5 m perpendicular to tape, **Figure 1**). Transects should follow a depth contour on the reef, attempting to stay on reef substrate as much as possible.

7. All species of fish are to be recorded from the following families:

Acanthuridae (Surgeonfish)
Balistidae (Triggerfish)
Caesionidae (Fusiliers)
Carangidae (Jacks and Trevallies)
Chaetodonotidae (Butterflyfish)
Ephippidae (Spadefish aka Batfish)
Haemulidae (Sweetlips)
Kyphosidae (Chubs and Rudderfish)
Labridae (Wrasses)
Lethrinidae (Emperors)
Lutjanidae (Snappers)
Mullidae (Goatfish)
Nemipteridae (Breams)
Pomacanthidae (Angelfish)
Priacathidae (Bigeyes)
Scaridae (Parrotfish)
Serranidae (Groupers minus Athias**)**
Siganidae (Rabbitfish)
Scombridae (Mackerel & Tuna)
Sphyraenidae (Barracuda)
Sharks (all families)

Refer to the WCS updated Fish list for Fiji for most current records of fish within the above groups expected to be found in Fiji (Appendix 4)

8. Fish are to be recorded to Genus and species where possible and to genus only if there is uncertainty. Refer to the Fiji Fish List (Appendix 4) for all fish found in Fiji for each family.

9. If the species is not known, record the genera followed by U/I #1, U/I #2, etc., and record notes about appearance at bottom of page.

10. Size of fish are to be recorded in the following classes (to nearest cm): 2-5, 6-10, 11-15, 16-20, 21-25, 26-30, 31-35, 36-40, and >40. For fish >40 cm, note the # of large fish in the box on the data sheet and the size of **each** of the fish in the last column on the right.

11. Diver should maintain a slow, even pace. Transects should take **at least 20 minutes**!

12. Only **3 transects maximum** should be completed on **one tank** of compressed air

13. Diver should leave at least **5 m** of space between each transect

14. At the end of the final transect, diver will wind up the tapes and return to the boat

15. For each site, **five x 50 m** transects should be completed for each depth category (e.g. deep, shallow) for monitoring sites. **three x 50 m** transects may be completed if carrying out resilience assessments or gathering information to relate to habitat maps with higher spatial coverage of the qoliqoli.

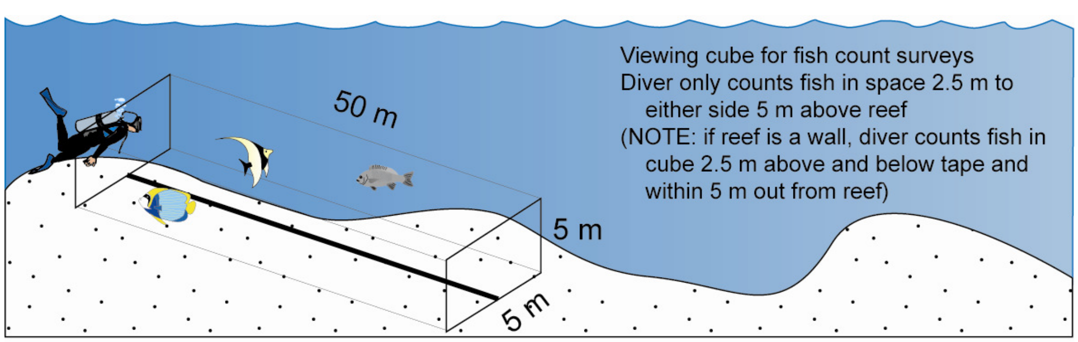


Figure 1. Schematic of diver counting fish within 5 m x 5 m cube along reef.

Point Intercept Transects for Benthic Cover

Scientific Questions

- **Are there significant differences in benthic cover between sites and habitats within sites that may influence fish and invertebrate abundance?**
- **Are there any significant differences in benthic cover that could be related to indirect effects of management?**

Protocol

1. Diver will wait 2-3 minutes after fish recorder begins laying transect tape before starting survey and after invertebrate recorder begins, starting at same point as fish survey

2. Diver will record: Site name, Recorder Name, Transect #, Depth Class (Deep/Shallow), Date, Water Temperature, Tide, Start Time, and Actual Depth (m)

3. Starting at the 0.5 m mark on the transect tape, diver will record benthic substrate directly below the tape (at each 0.5 m) to the modified GCRMN category listed below:

Abbreviation	Category Description	Abbreviation	Category Description
RC	Rock (non-carbonate)	**CM**	Coral massive
RB	Rubble	**CS**	Coral submassive
SD	Sand (<0.5 cm)	**CC**	Coral corymbose
SI	Silt (very fine)	**SC**	Soft coral
DA	Dead coral with fleshy algae	**CMR**	Coral mushroom
CCA	Crustose coralline algae	**SP**	Sponge
ACB	*Acropora* branching	**ZO**	Zooanthid
ACD	*Acropora* digitate	**OT**	Other biota
ACT	*Acropora* table	**AA**	Algal assemblage
ACS	*Acropora* submassive	**CA**	Coralline algae (w/ structure)
ACE	*Acropora* encrusting	**HA**	*Halimeda*
ACC	*Acropora* corymbose	**MA**	Macroalgae
CB	Coral branching	**TA**	Turf algae
CE	Coral encrusting	**MC**	Microbial
CF	Coral foliose		

4. For **OT** category, diver should note what the other biota is (e.g. black coral, anemone)

5. In the column labelled complexity, diver should record the general reef micro-complexity with a ½ m^2 around the point on the tape as either: 1 = totally flat (e.g. sand); 2 = rubble/small patches of vertical relief; 3 = mounding structures; 4 = submassive or coarse branching structure; and 5 = complex branching structure with crevices in the reef.

6. In the live/dead category, the diver should record whether the entire coral colony is: L - live; E: bioeroded; B1: partially bleached; B2: white; B3: bleached and partly dead. If the

0.5 m mark on the tape falls over dead or partially dead coral, the llifeform will be DA or DCA, however where possible note the Genera.

7. For live hard corals, macroalgae and soft corals, diver will record the genus (if known), in addition to GCRMN life form. See Appendix 5 for all genera of reef-building corals likely to be found in Fiji.

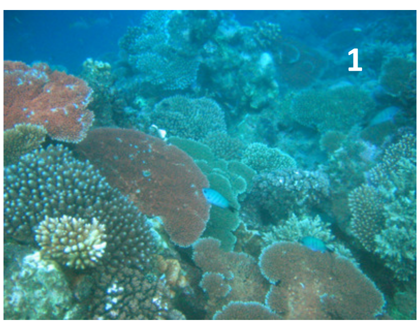
8. Every 5 m, diver will record macro-complexity by looking forward at the reef and evaluating on a 5 point scale where: 1 = no vertical relief; 2 = low, widespread relief; 3 = moderate relief; 4 = complex vertical relief; and 5 = complex vertical relief with fissues, caves and/or overhangs.

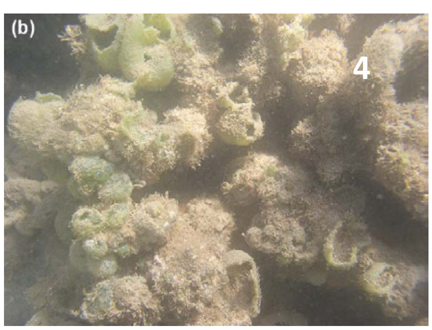
9. Every 12.5 m (or in each quarter of the transect), diver will evaluate sediment type (based on reference collections in the field) and sediment thickness (**see photos below**).

10. Diver should maintain a slow, even pace. Transects should take **at least 20 minutes**!

11. Only **3 transects maximum** should be completed on **one tank** of compressed air

12. For each site, **five x 50 m** transects should be completed for each depth category (e.g. deep, shallow). The requirements for sampling at each depth category will vary by site and weather conditions. **three x 50 m** transects may be completed if carrying out resilience coverage of the qoliqoli.





Line Intercept Transects for Benthic Cover

Scientific Questions

- **Are there significant differences in coral community composition between sites and habitats within sites that may influence fish and invertebrate abundance?**
- **How do the coral communities reflect environmental conditions and potential prior histories of disturbance?**
- **Are the current coral communities resilient to disturbance?** *(NOTE: multiple years of monitoring along the SAME transects are required to answer this question)*

Protocol

1. **Four x 10 m PERMANENT** transects will be established along shallow (6 m) reef foreslopes *where coral is present*. Divers should leave **5 m** of space between each transect

2. Diver will attach end of transect tape to appropriate substrate (**not live coral**) and ensure that it is firmly attached. Diver will pull the tape **taut** to 10 m

3. **[Initial set-up of transects only]** Diver will cable tie **TWO** permanent marker floats at the start and **ONE** float at the end of the 10 m. Diver will add additional cable ties along the transect as visual markers to relocate the site during future monitoring events

4. A chain to measure rugosity will be attached to the beginning of the transect and carefully laid over the coral until the 10 m mark. The chain will be marked at every metre. The diver will put his/her hand over the part of the chain which falls on the 10 m mark, and measure the distance from the last metre mark along the transect tape. The total rugosity measurement will equal the total number of metre marks on the chain plus the additional distance from the last mark.

5. Diver will record: Site name, Recorder Name, Transect #, Rugosity, Date, Water Temperature, Tide, Start Time, Actual Depth (m)

6. Diver will record GCRMN categories (see Point Intercept methods section for table) to the nearest **1 cm** along the transect

7. For **OT** category, diver should note what the other biota is (e.g. black coral, anemone)

8. In the column labelled complexity, diver should record the general reef complexity with a ½ m^2 around the point on the tape as either: 1 – flat/rubbly (no vertical structure; 2 – mounding or submassive (medium amount of horizontal and vertical structure; or 3 – branching and complex (high horizontal and vertical structure). (**TIP:** Diver should imagine that he/she is a 5 cm damsel fish. If there would be nowhere for the fish to hide, the point should be categorized as 1. If the fish could shield itself behind a mound, but not tuck itself

into a crevice, the point should be categorized as 2. If the fish could safely hide itself from predators, the point should be categorized as 3.

9. In the live/dead category, the diver should record whether the entire coral colony is: L: live; D: dead: PD: part-dead; B: bleached; PB: part-bleached; DS: diseased. If the point is not on a coral colony, the diver should record whether the **REEF SUBSTRATE** below that point is live or dead.

10. For live hard corals, macroalgae and soft corals, diver will record the genus (if known), in addition to GCRMN life form. See list on p. 34 for all genera of reef-building corals likely to be found in Fiji.

11. Diver should draw a line in the margin linking together all records going across a single colony. For example, if there was a massive Porites with several dead patches, the diver should connect all life form categories that cover the length of the colony.

12. **Photographs** over **½ m x ½ m quadrats** will be taken over every other metre along each of the four x 10 m transects (e.g. with the edge of the quadrat positioned along metre 0, 2, 4, 6, 8 on the tape = **five total photographs per transect, Figure 2**). One diver should move the quadrats while a second diver takes the photographs, maintaining a constant height above the reef. Before each photograph, take a photo of either the metre tape or the second diver's hands showing the position along the metre tape.

13. At the end of the final transect, divers will wind up the tapes and return to the boat

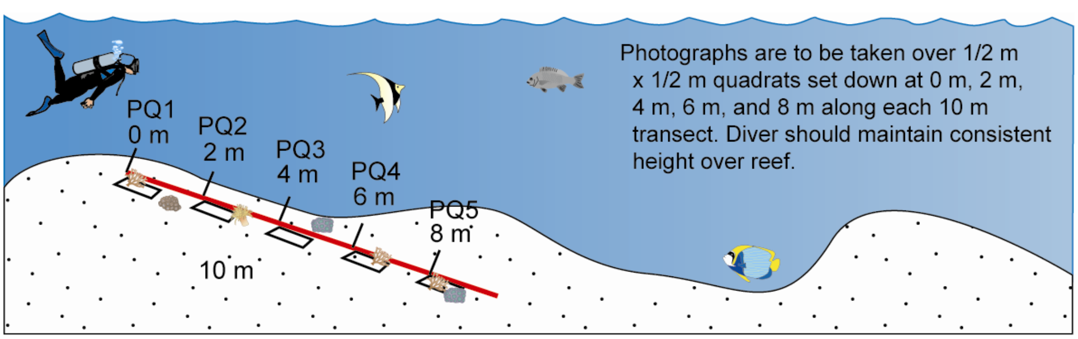


Figure 2. Schematic diagram of how quadrats should be placed along each LIT transect to take photographs from above.

Coral Population Structure

Scientific Questions

- **Do corals exhibit high likelihood of resistance to disturbance (numerous corals that can tolerate bleaching and stressful conditions)?**
- **Do corals exhibit high likelihood of resilience to disturbance? (range of size classes and dominance patterns)**

Protocol

1. Diver will lay out survey tape to 25 m across a shallow area of reef **where corals are present**

2. Using a 1 m ruler, diver will swim along a **25 m x 1 m** belt and record all corals within the following genera that are common on Fijian reefs and have different stress tolerances: Acropora; Montipora; Seriatopora; Pocillopora; Porties (massive); Porites (branching); Diploastrea; Echinopora; Favia; Favites; Goniastrea; Platygyra; Fungia; Hydnophora; Lobophyllia; Galaxea; Echinophyllia; Pavona; Pachyseris; Gardinoseris; Coscinaraea; Psammocora; and Turbinaria.

3. For each colony, diver will measure size and score within the following size classes: 11 - 20 cm; 21 - 40 cm; 41 - 80 cm; 81 - 160 cm; 161 - 320 cm; > 320 cm.

4. If the colony is healthy, diver will make a tick mark (|) in the size class box. If bleaching or bioerosion has occurred, diver will indicate with the following notations: E - bioeroded; B1 - partly bleached; B2 - white; B3 - bleached and part dead.

5. Diver will record all colonies whose centre lies **WITHIN** the transect. Large colonies with their center outside the transect must be ignored.

6. If time and air permit, diver and buddy conducting coral recruit and algal surveys will repeat measurements along a second, replicate transect, ensuring to leave enough air supply for a 10 minute swim.

7. At the end of the final transect, diver will wind up the tapes.

8. Following completion of transect, buddy pair will survey the area. For each coral genera on the list, diver will assess frequency within the community by the following scores: 1 - Dominant; 2 - Abundant; 3 - Common; 4 - Uncommon; 5 - Absent.

9. If other coral genera are present that do not appear on the list, diver will provide names and frequency ranks for those genera in the space provided at the bottom of the datasheet.

Coral Recruitment and Algal Cover

Scientific Questions

- **Is there evidence of coral recruitment, which may indicate ability to recover from disturbance?**
- **How much is the site dominated by algal cover? Is the algal cover related to the amount of herbivores on the reef?**

Protocol

1. Diver will wait for buddy to lay out 25 m transect.

2. In good visibility conditions (>25 m), the buddy pair can work from opposite ends of the transect to provide more working space. In poor visibility conditions, pair must start from same end of the transect for safety.

3. Diver will carry two quadrats: 1 m^2 and 1/2 m^2.

4. At 0 m, 5 m, 10 m, 15 m, 20 m, and 25 m, diver will place the 1 m^2 quadrat and count all coral recruits within size classes: < 3cm; 3 - 5 cm; > 5 cm - 10 cm.

5. Within the same 1 m^2 quadrat, diver will estimate the percentage cover of: turf algae (which includes both the lifeform classes TA and DA with algae < 1 cm); macroalgae (all algae > 1cm); filamentous microbes; upright coralline algae; crustose coralline algae; and all other substrates combined. The total of all scores must add up to **100%**.

6. At each sampling point (0, 5, 10, 15, 20, 25 m), diver will take a photograph record over the 1/2 m^2 quadrat.

7. If time and air permit, diver and buddy conducting coral population structure surveys will repeat measurements along a second, replicate transect, ensuring to leave enough air supply for a 10 minute swim.

8. Following completion of transect, buddy pair will survey the area. Diver will record number of COTS, *Drupella*, and urchins seen during this swim.

Reef Profile and Site Description

Scientific Questions

- **Are reefs and reef habitats protected from elevated temperatures and UV light from flushing and/or shading?**

Protocol

1. During initial descent, one diver will be nominated to draw a profile of the dive site. This can be done by the surveyor conducting PIT surveys while he/she is waiting for fish to settle and fish surveyor to begin transect.

2. Diver should make note of: site name; reef zone; date; time; tide; observer; water temperature; visibility; current; and maximum and minimum reef slope angle.

3. Back on the boat during the surface interval, all divers should have a joint discussion to assess: exposure of monitoring area at low tide; tidal currents; ponding/pooling; physical shading at noon; and canopy shading. Description of ranked characteristics from 1 - 5 are listed for each factor below.

REEF PROFILE AND SITE DESCRIPTION 2010					WCS
Site Name:				**Reef Zone:**	
Data recorded by:		**Date:**		**Water Temp** (^{o}C):	
Tide: (Rising / Full/ Falling/ Low)		**Time** Start/End:	/	**Depth** (m):	
Visibility (m):		**Current** None/ Weak/ Moderate/ Strong:		**Reef Slope Angle**	
Exposure of monitoring area at low tide (local knowledge)	**5:** fully exposed	**4:** partially exposed	**3:** barely submerged	**2:** submerged > 2 m	**1:** deep > 10 m
Tidal currents (local knowledge)	**1:** too strong to swim against	**2:** if swam fast could move foreward	**3:** moderate	**4:** slow current	**5:** not noticeable
Ponding/Pooling	**1:** well-flushed by strong currents near channels	**2:** well-flushed by currents	3: moderate opportunity for flushing	**4:** small amount water movement	**5:** enclosed shallow water body
Physical Shading at Noon	**1:** overhangs, vertical wall	**2:** crevices, caves, macrostructure	**3**: shallow slope angled away from sun	**2:** shallow slope angled towards sun	**1:** flat, shallow
Canopy Shading	**1:** very large numbers of tabulate and shade-providing corals	**2:** very large numbers of tabulate and shade-providing corals	**3**: medium numbers of tabulate and shade-provding corals +/or macroalgae providing shade to small colonies	**4:** low coral cover and macroalgal cover	**5:** no cover cover or macroalgal canopy

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Appendix 1. Power analysis to assess limitations of including exposure as a factor

Table 1. Critical F-statistics needed to conclude significant differences at p < 0.05 level for experimental design of Kubulau 2007 and 2008 surveys where (a) exposure, site and depth are considered as separate factors; and (b) sites are pooled across exposure categories.

Factor	Levels	Nesting	Fixed/ Random	Numerator	Denominator	Critical F-statistic
(a) Exposure, Site and Depth as factors						
Status	2 (open, closed)		fixed	1	4	12.2
Exposure	2 (back-, forereef)		fixed	1	4	12.2
Site	2	status x exposure	random	4	96	2.93
Depth	3 (top, shallow, deep)	status x exposure x site	fixed	2	8	6.06
N	5					
Sample size	120					
(b) Site and Depth as factors						
Status	2 (open/closed)		fixed	1	6	8.81
Site	4	status	random	6	96	2.55
Depth	3 (top, shallow, deep)	status x site	fixed	2	12	5.1
N	5					
Sample size	120					

Table 2. Critical F-statistics needed to conclude significant differences at p < 0.05 level for experimental design of Kubulau 2009 surveys for (a) Namena MPA with 5 closed sites and 5 open sites surveyed; and (b) Namuri and Nasue MPAs with 4 closed sites and 4 open sites each surveyed.

Factor	Levels	Nesting	Fixed/ Random	Numerator	Denominator	Critical F-statistic
(a) Namena MPA (n = 10 sites total)						
Status	2 (open, closed)		fixed	1	8	7.57
Site	5	status	random	8	80	2.35
Depth	2	status & site	fixed	1	8	7.57
N	5					
Sample size	100					
(b) Namuri/Nasue MPA (n = 8 sites total)						
Status	2 (open, closed)		fixed	1	6	8.81
Site	4	status	random	6	64	2.63
Depth	2	status & site	fixed	1	6	8.81
N	5					
Sample size	80					

Power analysis of experimental design showed a reduction in critical F-statistic values when sites are pooled across exposure (Table 1a,b) and when higher replicates of forereef only sites are surveyed (Table 2a,b). The main improvements were an expected increase of power to detect an effect of status (crit F reduced from 12.2 to 7.57), which was the main question addressed by the original experimental design.

Based on the results of the above sets of analyses, a decision was made to survey forereef sites only in Kubulau in April-May 2009 and to increase the number of sites surveyed in closed and open areas to improve the statistical power to detect differences related to management and depth. Results from pre-2009 are reported from forereef sites only in the body text.

Appendix 2. Power analysis to assess cost-effectiveness of experimental design

Factor	Levels	Nesting	Fixed/ Random	Numerator	Denominator	Critical F-statistic*
(a) Site and Depth as factors: Site=5 & transects=5						
Status	2 (open/closed)		fixed	1	8	7.57
Site	5	status	random	8	80	2.35
Depth	2 (shallow, deep)	status x site	fixed	10	80	2.21
N	5					
Sample size	100					
(b) Site and Depth as factors: Site=5 & transects=3						
Status	2 (open/closed)		fixed	1	8	7.57
Site	5	status	random	8	40	2.53
Depth	2 (shallow, deep)	status x site	fixed	10	40	2.39
N	3					
Sample size	60					
(c) Site and Depth as factors: Site=5 & transects=7						
Status	2 (open/closed)		fixed	1	8	7.57
Site	5	status	random	8	120	2.30
Depth	2 (shallow, deep)	status x site	fixed	10	120	2.16
N	7					
Sample size	140					
(d) Site and Depth as factors: Site=3 & transects=5						
Status	2 (open/closed)		fixed	1	4	12.2
Site	3	status	random	4	48	3.05
Depth	2 (shallow, deep)	status x site	fixed	6	48	2.67
N	5					
Sample size	60					
(e) Site and Depth as factors: Site=7 & transects=5						
Status	2 (open/closed)		fixed	1	12	6.55
Site	7	status	random	12	112	2.08
Depth	2 (shallow, deep)	status x site	fixed	14	112	2.00
N	5					
Sample size	140					
(f) Depth and Site as factors: site nested within depth						
Status	2 (open/closed)		fixed	1	16	6.12
Depth	2 (shallow, deep)	status	fixed	1	16	6.12
Site	5	depth x site	random	16	80	1.97
N	5					
Sample size	100					

* Critical F-statistic for α = 0.05

Rough survey cost estimates based on fixed daily costs for fieldwork and total number of sites can be calculated from the power design table above with the following equation:

$$SC = N / TPD * CPD + TC$$

SC: Survey costs; N: sample size (total number of transects); TPD: transects per day (can vary depending on the number of teams and boats doing the surveys); CPD: cost per day (total daily costs for the whole survey team); TC: Travel cost (total costs for the survey team to get to the study area and back).

Increasing the number of transects done per depth at each site only results in a small increase in power to detect differences related to protection while dramatically increasing costs. Increasing the number of sites surveyed with two depths surveyed at each site will improve power, however will also increase costs. Meanwhile, nesting sites within depth categories (5 transects per site at 5 sites per depth category (x2)) results in the most improved power to detect management differences without increasing costs or manpower over current sampling design (5 transects per depth, 2 depths per site (x5)).

Appendix 3. Datasheets

FISH ABUNDANCE AND SIZE To Genera / Species SIDE 1 WCS 2010

Five 50 x 5 m transects per site. Each transect should take at least 20 minutes to survey.

Site Name:		**Transect number:**		**Deep/Shallow:**	
Data recorded by:		**Date:**		**Water Temp** (^{o}C):	
Tide: (Rising / Full/ Falling/ Low)		**Time** Start/End:	/	**Depth** (m):	

Record fish to Genera level as minimum, Species where confident. Count all seen, in size classes.
Where species unknown record Genera “U/I # 1”, “U/I # 2” etc., record identifying characteristics in notes by number.

Compass Direction Reef Slope:		**Depth of Reef Base:**	___: 0 - 5 m ___: 5 - 10 m ___: 10 - 20 m ___: 20 - 40 m ___: >40 m

#	Genus	Species	2 - 5 cm	6 - 10 cm	11 - 15 cm	16 - 20 cm	21 - 25 cm	26 - 30 cm	31 - 35 cm	36 - 40 cm	>40 cm	Size if >40
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
24												
24												
25												

BENTHIC COVER PIT LIFEFORM To Family / Genus SIDE 1 WCS 2010					
Site Name:		Transect number:		Deep/Shallow:	
Data recorded by:		Date:		Water Temp (°C):	
Tide: (Rising / Full/ Falling/ Low)		Time Start/End:	/	Depth (m):	

Life-Form Categories	RC Rock (non-carbonate)	RB Rubble (0.5 – 15cm)	SD Sand (<0.5cm)	SI Silt (Very fine)	DA Dead Coral w/ Fleshy Algae	CCA Crustose Coralline Algae
ACB Acropora branching	ACD Acropora digitate	ACT Acropora table	ACS Acropora submassive	ACE Acropora encrusting		
CB Coral branching	CE Coral encrusting	CF Coral foliose	CM Coral massive	CS Coral submassive	SC Soft coral	
CMR Coral mushroom	ACC Acropora corymbose	CC Coral corymbose	SP Sponge	ZO Zooanthids	OT Other biota	
MC Microbial	AA Algal Assemblage	CA Coralline algae	HA Halimeda	MA Macroalgae	TA Turf algae	
Micro-Complexity	1: totally flat (e.g. sand)	2: rubble/small patches (min relief)	3: mounding (medium structure)	4: Submassive or coarse branching	5: branching, complex and crevices	
Live/Dead	L: live	E: bioeroded	B1: partially bleached	B2: white	B3: bleached and partly dead	
Macrocomplexity	1: no vertical relief	2: low, widespread relief	3: moderate relief	4: complex vertical relief	5: fissures, caves, overhangs	

0.5m – 12.5m						13.0m – 25.0m					
PIT (m)	Life Form	Micro Com-plex	Live/ Dead	Macro Complex	Genus	PIT (m)	Life Form	Micro Com-plexity	Live/ Dead	Macro Complex	Genus
0.5						13.0					
1.0						13.5					
1.5						14.0					
2.0						14.5					
2.5						15.0					
3.0						15.5					
3.5						16.0					
4.0						16.5					
4.5						17.0					
5.0						17.5					
5.5						18.0					
6.0						18.5					
6.5						19.0					
7.0						19.5					
7.5						20.0					
8.0						20.5					
8.5						21.0					
9.0						21.5					
9.5						22.0					
10.0						22.5					
10.5						23.0					
11.0						23.5					
11.5						24.0					
12.0						24.5					
12.5						25.0					
Sed Thickness			Sed Texture			Sed Thickness				Sed Texture	

CORAL POPULATION STRUCTURE SIDE 1 WCS 2010							
Site Name:		Transect number:		Deep/Shallow:			
Data recorded by:		Date:		Water Temp (°C):			
Tide: (Rising / Full/ Falling/ Low)		Time Start/End:	/	Depth (m):			
Dominance	1: Dominant	2: Abundant	3: Common	4: Uncommon	5: Absent		
Large Corals	Size Class (| - live; E - bioeroded; B1 - partly bleached; B2 - white; B3 - bleached & part dead)						
Genus	11 - 20 cm	21 - 40 cm	41 - 80 cm	81 - 160 cm	161 - 320 cm	>320 cm	Dom
Acropora (Acroporidae)							
Montipora (Acroporidae)							
Seriatopora (Pocilloporidae)							
Pocillopora (Pocilloporidae)							
Porites (massive) (Poritidae)							
Porites (branching) (Poritidae)							
Diploastrea (Faviidae)							
Echinopora (Faviidae)							
Favia (Faviidae)							
Favites (Faviidae)							
Goniastrea (Faviidae)							
Platygyra (Faviidae)							
Fungia (Fungiidae)							
Hydnophora (Merulinidae)							
Lobophyllia (Mussidae)							
Galaxea (Oculinidae)							
Echinophyllia (Pectinidae)							
Pavona (Agariciidae)							
Pachyseris (Agariciidae)							
Gardinoseris (Agariciidae)							
Coscinaraea (Siderastreidae)							
Psammacora (Siderastreidae)							
Turbinaria (Dendrophyllidae)							
Other Genera Dominance Scores:							

CORAL RECRUITS AND ALGAL COVER SIDE 1 WCS 2010						
Site Name:		Transect number:		Deep/Shallow:		
Data recorded by:		Date:		Water Temp (°C):		
Tide: (Rising / Full/ Falling/ Low)		Time Start/End:	/	Depth (m):		
Measures	Quadrat					
Coral	0 m	5 m	10 m	15 m	20 m	25 m
# Coral recruits < 3 cm						
# Coral recruits 3 - 5 cm						
# Coral recruits > 5 - 10 cm						
Photo						
Algae	0 m	5 m	10 m	15 m	20 m	25 m
% Turf Algae (< 1 cm) TA + DA						
% Macroalgae (> 1 cm) MA						
% Microbial (MC)						
% Upright coralline algae (CA)						
% Crustose coralline algae (CCA)						
% Other (all other lifeforms)						

Along entire area:

COTS

urchins

Drupella

Other Notes

Appendix 4. Fiji Fish List for Targeted Families

Family	Genus	Species	CommonName
Acanthuridae	Acanthurus	albipectoralis	Whitefin Surgeonfish
Acanthuridae	Acanthurus	auranticavus	Orange Socket Surgeonfish
Acanthuridae	Acanthurus	bariene	Roundspot Surgeonfish
Acanthuridae	Acanthurus	blochii	Ringtail Surgeonfish
Acanthuridae	Acanthurus	dussumieri	Eyestripe Surgenfish
Acanthuridae	Acanthurus	fowleri	Blackspine/Fowlers Surgeonfish
Acanthuridae	Acanthurus	grammoptilus	Fined-lined Surgeonfish
Acanthuridae	Acanthurus	guttatus	Whitespotted Surgeonfish
Acanthuridae	Acanthurus	leucopareius	Whitebar Surgeonfish
Acanthuridae	Acanthurus	lineatus	Striped Surgeonfish
Acanthuridae	Acanthurus	maculiceps	White-freckeld Surgeonfish
Acanthuridae	Acanthurus	mata	Yellowmask Surgeonfish
Acanthuridae	Acanthurus	nigricans	Whitecheek Surgeonfish
Acanthuridae	Acanthurus	nigricauda	Epaulette Surgeonfish
Acanthuridae	Acanthurus	nigrofuscus	Brown Surgeonfish
Acanthuridae	Acanthurus	nigroris	Bluelined Surgeonfish
Acanthuridae	Acanthurus	nubilus	Dark Surgeonfish
Acanthuridae	Acanthurus	olivaceus	Orangeband Surgenofish
Acanthuridae	Acanthurus	pyroferus	Mimic Surgeonfish
Acanthuridae	Acanthurus	sp.	Unknown Species Surgeonfish
Acanthuridae	Acanthurus	thompsoni	Whitetail Surgeonfish
Acanthuridae	Acanthurus	triostegus	Convict Tang
Acanthuridae	Acanthurus	xanthopterus	Yellowfin Surgeonfish
Acanthuridae	Ctenochaetus	binotatus	Twospot Surgeonfish
Acanthuridae	Ctenochaetus	cyanocheilus	Bluelipped Bristletooth
Acanthuridae	Ctenochaetus	sp.	Unknown Ctenochaetus species
Acanthuridae	Ctenochaetus	striatus	Lined Bristletooth
Acanthuridae	Ctenochaetus	tominiensis	Tomini Surgeonfish
Acanthuridae	Naso	annulatus	Whitemargin Unicornfish
Acanthuridae	Naso	brachycentron	Humpback Unicornfish
Acanthuridae	Naso	brevirostris	Spotted Unicornfish
Acanthuridae	Naso	caesius	Gray Unicornfish
Acanthuridae	Naso	hexacanthus	Sleek Unicornfish
Acanthuridae	Naso	lituratus	Orangespine Unicornfish
Acanthuridae	Naso	lopezi	Slender Unicornfish
Acanthuridae	Naso	minor	Blackspine Unicornfish
Acanthuridae	Naso	sp.	Unknown Naso species
Acanthuridae	Naso	thynnoides	Barred Unicornfish
Acanthuridae	Naso	tonganus	Humpnose Unicornfish
Acanthuridae	Naso	unicornis	Bluespine Unicornfish
Acanthuridae	Naso	vlamingii	Bignose Unicronfish
Acanthuridae	Paracanthurus	hepatus	Palette Surgeonfish
Acanthuridae	Zebrasoma	flavescens	Yellow Tang
Acanthuridae	Zebrasoma	scopas	Brushtail Tang
Acanthuridae	Zebrasoma	sp.	Unknown Zebrasoma species
Acanthuridae	Zebrasoma	veliferum	Pacific Sailfin Tnag
Balistidae	Balistapus	sp.	Unknown Balistapus species
Balistidae	Balistapus	undulatus	Orange-lined triggerfish
Balistidae	Balistoides	conspicillum	Clown Triggerfish
Balistidae	Balistoides	sp.	Unknown triggerfish

Balistidae	Balistoides	viridescens	Titan Triggerfish
Balistidae	Canthidermis	maculatus	Spotted oceanic triggerfish
Balistidae	Canthidermis	sp.	Unknown Canthidermis species
Balistidae	Melichthys	niger	Indian Triggerfish
Balistidae	Melichthys	sp.	Unknown Melichthys species
Balistidae	Melichthys	vidua	Pinktail Triggerfish
Balistidae	Odonus	niger	Redtooth Triggerfish
Balistidae	Pseudobalistes	flavimarginatus	Yellow margin Triggerfish
Balistidae	Pseudobalistes	fuscus	Yellow-spotted triggerfish
Balistidae	Pseudobalistes	sp.	Unknown Pseudobalistes species
Balistidae	Rhinecanthus	aculeatus	Picasso Triggerfish
Balistidae	Rhinecanthus	rectangulus	Wedge-tail Triggerfish
Balistidae	Rhinecanthus	sp.	Unknown Rhinecanthus species
Balistidae	Sufflamen	bursa	Scythe Triggerfish
Balistidae	Sufflamen	chrysopterum	Flagtail Triggerfish
Balistidae	Sufflamen	fraenatum	Bridled Triggerfish
Balistidae	Sufflamen	sp.	Unknown Sufflamen species
Caesionidae	Caesio	caerulaurea	Blue and gold fusilier
Caesionidae	Caesio	lunaris	Lunar Fusilier
Caesionidae	Caesio	sp.	Unknown Caesio species
Caesionidae	Caesio	teres	Yellow and blueback Fusilier
Caesionidae	Gymnocaesio	gymnoptera	Slender fusilier
Caesionidae	Pterocaesio	lativittata	Wide-band Fusilier
Caesionidae	Pterocaesio	marri	Twinstripe Fusilier
Caesionidae	Pterocaesio	pisang	Ruddy Fusilier
Caesionidae	Pterocaesio	sp.	Unknown Pterocaesio species
Caesionidae	Pterocaesio	tile	Bluestreak Fusilier
Caesionidae	Pterocaesio	trilineata	Threestripe Fusilier
Carangidae	Alectis	ciliaris	African Pompano
Carangidae	Alectis	sp.	Unknown Alectis species
Carangidae	Atule	mate	Yellowtail Scad
Carangidae	Atule	sp.	Unknown Atule species
Carangidae	Carangoides	bajad	Orangespotted trevally
Carangidae	Carangoides	caeruleopinnatus	Coastal trevally
Carangidae	Carangoides	chrysophrys	Longnose trevally
Carangidae	Carangoides	dinema	Shadow Trevally
Carangidae	Carangoides	ferdau	Blue Trevally
Carangidae	Carangoides	fulvoguttatus	Gold-spotted Trevally
Carangidae	Carangoides	gymnostethus	Bludger Trevally
Carangidae	Carangoides	oblongus	Coachwhip Trevally
Carangidae	Carangoides	orthogrammus	Yellow-spotted Trevally
Carangidae	Carangoides	plagiotaenia	Barcheek Trevally
Carangidae	Carangoides	sp.	Unknown Carangoides species
Carangidae	Caranx	ignobilis	Giant Trevally
Carangidae	Caranx	melampygus	Bluefin Trevally
Carangidae	Caranx	papuensis	Brassy Trevally
Carangidae	Caranx	sexfasciatus	Bigeye Trevally
Carangidae	Caranx	sp.	Unknown Caranx species
Carangidae	Caranx	tille	Tille Trevvally
Carangidae	Decapterus	kurroides	Redtail Scad
Carangidae	Decapterus	macarellus	Mackerel Scad
Carangidae	Decapterus	russelli	Russell's Mackerel Scad
Carangidae	Decapterus	sp.	Unknown Decapterus species
Carangidae	Elagatis	bipinnulata	Rainbow Runner

Carangidae	Gnathanodon	speciosus	Golden Trevally
Carangidae	Pseudocaranx	dentex	Silver Trevally
Carangidae	Pseudocaranx	sp.	Unknown Pseudocaranx species
Carangidae	Scomberoides	lysan	Doublespotted Queenfish
Carangidae	Scomberoides	sp.	Unknown Scomberoides species
Carangidae	Scomberoides	tol	Needlescaled Queenfish
Carangidae	Selar	crumenophthalmus	Scads
Carangidae	Selar	sp.	Unknown Selar species
Carangidae	Seriola	rivoliana	Almaco Jack
Carangidae	Trachinotus	bailloni	Small spotted Dart
Carangidae	Trachinotus	blochii	Snubnose Pompano
Carangidae	Trachinotus	sp.	Unknown Trachinotus species
Carangidae	Uraspis	helovola	Whitetongue Jack
Carangidae	Uraspis	sp.	Unknown Uraspis species
Carcharhinidae	Carcharhinus	albimarginatus	Silvertip Shark
Carcharhinidae	Carcharhinus	amblyrhynchos	Gray Reef Shark
Carcharhinidae	Carcharhinus	leucas	Bull Shark
Carcharhinidae	Carcharhinus	limbatus	Blacktip Reef Shark
Carcharhinidae	Carcharhinus	melanopterus	Blacktip Reef Shark
Carcharhinidae	Carcharhinus	sp.	Unknown Carcharhinus species
Carcharhinidae	Galeocerdo	cuvier	Tiger Shark
Carcharhinidae	Negaprion	acutidens	Sicklefin lemon Shark
Carcharhinidae	Triaenodon	obesus	Whitetip Reef Shark
Chaetodontidae	Chaetodon	auriga	Threadfin Butterflyfish
Chaetodontidae	Chaetodon	baronessa	Eastern Triangular Butterflyfish
Chaetodontidae	Chaetodon	bennetti	Eclipse/Bennet's Butterflyfish
Chaetodontidae	Chaetodon	citrinellus	Speckled Butterflyfish
Chaetodontidae	Chaetodon	ephippium	Saddled Butterflyfish
Chaetodontidae	Chaetodon	flavirostris	Black Butterflyfish
Chaetodontidae	Chaetodon	kleinii	Blcklip Butterflyfish
Chaetodontidae	Chaetodon	lineolatus	Lined Butterflyfish
Chaetodontidae	Chaetodon	lunula	Raccon Butterflyfish
Chaetodontidae	Chaetodon	lunulatus	Oval Butterflyfish
Chaetodontidae	Chaetodon	melannotus	Blackback Butterflyfish
Chaetodontidae	Chaetodon	mertensii	Yellowback butterflyfish
Chaetodontidae	Chaetodon	ornatissimus	Ornate Butterflyfish
Chaetodontidae	Chaetodon	oxycephalus	Spot-nape Butterflyfish
Chaetodontidae	Chaetodon	pelewensis	Dot & Dash Butterflyfish
Chaetodontidae	Chaetodon	plebius	Blue-spot Butterflyfish
Chaetodontidae	Chaetodon	punctatofasciatus	Spot-banded Butterflyfish
Chaetodontidae	Chaetodon	quadrimaculatus	Four-spot Butterflyfish
Chaetodontidae	Chaetodon	rafflesi	Latticed Butterflyfish
Chaetodontidae	Chaetodon	reticulatus	Reticulated Butterflyfish
Chaetodontidae	Chaetodon	semeion	Dotted Butterflyfish
Chaetodontidae	Chaetodon	sp.	Unknown Chaetodon species
Chaetodontidae	Chaetodon	speculum	Mirror Butterflyfish
Chaetodontidae	Chaetodon	trifascialis	Chevroned Butterflyfish
Chaetodontidae	Chaetodon	ulietensis	Pacific Double-saddled Butterflyfish
Chaetodontidae	Chaetodon	unimaculatus	Teardrop Butterflyfish
Chaetodontidae	Chaetodon	vagabundus	Vagabond Butterflyfish
Chaetodontidae	Forcipiger	flavissimus	Longnose Butterflyfish
Chaetodontidae	Forcipiger	longirostris	Big Longnose Butterflyfish
Chaetodontidae	Forcipiger	sp.	Unknown Forcipiger species
Chaetodontidae	Hemitaurichthys	polylepis	Pyramid Butterflyfish

Chaetodontidae	Heniochus	acuminatus	Longfin Bannerfish
Chaetodontidae	Heniochus	chrysostomus	Pennant Bannerfish
Chaetodontidae	Heniochus	monoceros	Masked Bannerfish
Chaetodontidae	Heniochus	singularis	Singular Bannerfish
Chaetodontidae	Heniochus	sp.	Unknown Heniochus species
Chaetodontidae	Heniochus	varius	Humphead Bannerfish
Chaetodontidae	Parachaetodon	ocellatus	Sixspine Butterflyfish
Chanidae	Chanos	chanos	Milkfish
Ephippidae	Platax	orbicularis	Circular Spadefish
Ephippidae	Platax	sp.	Unknown Platax species
Ephippidae	Platax	teira	Teira Batfish
Haemulidae	Diagramma	pictum	Painted Sweetlips
Haemulidae	Diagramma	sp.	Unknown Diagramma species
Haemulidae	Plectorhinchus	albovittatus	Giant Sweetlips
Haemulidae	Plectorhinchus	chaetodonoides	Many-spotted Sweetlips
Haemulidae	Plectorhinchus	gibbosus	Blubberlip
Haemulidae	Plectorhinchus	picus	Dotted Sweetlips
Haemulidae	Plectorhinchus	sp.	Unknown Plectorhinchus species
Haemulidae	Plectorhinchus	vittatus	Oriental Sweetlips
Kyphosidae	Kyphosus	cinerascens	Blue Seachub
Kyphosidae	Kyphosus	sp.	Unknown Kyphosus species
Kyphosidae	Kyphosus	vaigiensis	Brassy Chub
Labridae	Anampses	caeruleopunctatus	Bluespotted Wrasse
Labridae	Anampses	geographicus	Geographic Wrasse
Labridae	Anampses	melanurus	White-spotted Wrasse
Labridae	Anampses	meleagrides	Yellowtail Wrasse
Labridae	Anampses	neoguinaicus	New Guinea Wrasse
Labridae	Anampses	sp.	Unknown Anampses species
Labridae	Anampses	twistii	Yellow-breasted Wrasse
Labridae	Bodianus	anthioides	Lyretail Hogfish
Labridae	Bodianus	axillaris	Axilspot Hogfish
Labridae	Bodianus	bimaculatus	Twospot Hogfish
Labridae	Bodianus	diana	Diana's Hogfish
Labridae	Bodianus	loxozonus	Blackfin Hogfish
Labridae	Bodianus	mesothorax	Splitlevel Hogfish
Labridae	Bodianus	sp.	Unknown Bodianus species
Labridae	Cheilinus	chlorourus	Floral Wrasse
Labridae	Cheilinus	fasciatus	Redbreast Wrasse
Labridae	Cheilinus	oxycephalus	Snooty Wrasse
Labridae	Cheilinus	sp.	Unknown Cheilinus species
Labridae	Cheilinus	trilobatus	Tripletail Wrasse
Labridae	Cheilinus	undulatus	Humphead Wrasse
Labridae	Cheilio	inermis	Cigar Wrasse
Labridae	Choerodon	cyanodus	Blue Tuskfish
Labridae	Choerodon	jordani	Blackwedge Tuskfish
Labridae	Choerodon	sp.	Unknown Choerodon species
Labridae	Cirrhilabrus	exquisitus	Exquisite Wrasse
Labridae	Cirrhilabrus	marjorie	Marjorie's Wrasse
Labridae	Cirrhilabrus	punctatus	Dotted Wrasse
Labridae	Cirrhilabrus	rubrimarginatus	Redfin Wrasse
Labridae	Cirrhilabrus	scottorum	Redtailed Wrasse
Labridae	Cirrhilabrus	sp.	Unknown Cirrhilabrus species
Labridae	Coris	aygula	Clown coris
Labridae	Coris	batuensis	Batu Coris

Labridae	Coris	dorsomacula	Spottail Coris
Labridae	Coris	gaimard	Yellowtail coris
Labridae	Coris	sp.	Unknown Coris species
Labridae	Cymolutes	praetextatus	Knife Razorfish
Labridae	Cymolutes	sp.	Unknown Cymolutes species
Labridae	Diproctacanthus	xanthurus	Yellowtail Tubelip
Labridae	Epibulus	insidiator	Slingjaw Wrasses
Labridae	Epibulus	sp.	Unknown Epibulus species
Labridae	Gomphosus	varius	Bird Wrasse
Labridae	Halichoeres	argus	Argus Wrasse
Labridae	Halichoeres	biocellatus	Red-lined Wrasse
Labridae	Halichoeres	hortulanus	Checkerboard Wrasse
Labridae	Halichoeres	margaritaceus	Pink-belly Wrasse
Labridae	Halichoeres	marginatus	Dusky Wrasse
Labridae	Halichoeres	melanurus	Tailspot Wrasse
Labridae	Halichoeres	nebulosus	Nebulous Wrasse
Labridae	Halichoeres	ornatissimus	Ornate Wrasse
Labridae	Halichoeres	prosopeion	Twotone Wrasse
Labridae	Halichoeres	scapularis	Zigzag Wrasse
Labridae	Halichoeres	sp.	Unknown Halichoeres species
Labridae	Halichoeres	trimaculatus	Threespot Wrasse
Labridae	Hemigymnus	fasciatus	Barred Thicklip
Labridae	Hemigymnus	melapterus	Blackeye Thicklip
Labridae	Hemigymnus	sp.	Unknown Hemigymnus species
Labridae	Hologymnosus	annulatus	Ring Wrasse
Labridae	Hologymnosus	doliatus	Pastel Ringwrasse
Labridae	Hologymnosus	sp.	Unknown Hologymnosus species
Labridae	Iniistius	pavo	Peacock Wrasse
Labridae	Iniistius	sp.	Unknown Iniistius species
Labridae	Labrichthys	unilineatus	Tubelip Wrasse
Labridae	Labroides	bicolor	Bicolor Cleaner Wrasse
Labridae	Labroides	dimidiatus	Bluestreak Cleaner Wrasse
Labridae	Labroides	sp.	Unknown Labroides species
Labridae	Labropsis	alleni	Allen's Tubelip
Labridae	Labropsis	australis	Micronesian Tubelip
Labridae	Labropsis	sp.	Unknown Labropsis species
Labridae	Labropsis	xanthonota	Wedge-tail Wrasse
Labridae	Macropharyngodon	meleagris	Blackspotted Wrasse
Labridae	Macropharyngodon	negrosensis	Black Wrasse
Labridae	Macropharyngodon	sp.	Unknown Macropharyngodon species
Labridae	Novaculichthys	macrolepidotus	Seagrass Wrasse
Labridae	Novaculichthys	sp.	Unknown Novaculichthys species
Labridae	Novaculichthys	taeniourus	Rockmover Wrasse
Labridae	Oxycheilinus	bimaculatus	Two-spot Wrasse
Labridae	Oxycheilinus	digrammus	Linedcheeked Wrasse
Labridae	Oxycheilinus	orientalis	Oriental Maori Wrasse
Labridae	Oxycheilinus	sp.	Unknown Oxycheilinus species
Labridae	Oxycheilinus	unifasciatus	Ringtail Maori Wrasse
Labridae	Paracheilinus	rubricaudalis	Redtail Flasherwrasse
Labridae	Paracheilinus	sp.	Unknown Paracheilinus species
Labridae	Pseudocheilinus	evanidus	Striated Wrasse
Labridae	Pseudocheilinus	hexataenia	Sixline Wrasse
Labridae	Pseudocheilinus	octotaenia	Eightstripe Wrasse
Labridae	Pseudocheilinus	sp.	Unknown Pseudocheilinus species

Labridae	Pseudocheilinus	tetrataenia	Four-Lined Wrasse
Labridae	Pseudocoris	sp.	Unknown Pseudocoris species
Labridae	Pseudocoris	yamashiroi	Redspot Wrasse
Labridae	Pseudodax	mollucanus	Chiseltooth Wrasse
Labridae	Pseudojuloides	cerasinus	Smalltail Wrasse
Labridae	Pseudojuloides	sp.	Unknown Pseudojuloides species
Labridae	Pteragogus	cryptus	Cryptic Wrasse
Labridae	Pteragogus	sp.	Unknown Pteragogus species
Labridae	Stethojulis	bandanensis	Redshoulder Wrasse
Labridae	Stethojulis	notialis	South Pacific Wrasse
Labridae	Stethojulis	sp.	Unknown Stethojulis
Labridae	Stethojulis	strigiventer	Three-line Wrasse
Labridae	Stethojulis	trilineata	Three-lined rainbow fish
Labridae	Thalassoma	amblycephalum	Two-tone Wrasse
Labridae	Thalassoma	hardwicke	Sixbar Wrasse
Labridae	Thalassoma	jansenii	Jansen's Wrasse
Labridae	Thalassoma	lunare	Crescent Wrasse
Labridae	Thalassoma	lutescens	Yellow brown Wrasse
Labridae	Thalassoma	purpureum	Surge Wrasse
Labridae	Thalassoma	quinquevittatum	Fivestripe Wrasse
Labridae	Thalassoma	sp.	Unknown Thalassoma species
Labridae	Wetmorella	albofasciata	Whitebanded Sharpnose Wrasse
Labridae	Wetmorella	nigropinnata	Sharpnose Wrasse
Labridae	Wetmorella	sp.	Unknown Wetmorella species
Lethrinidae	Gnathodentex	aureolineatus	Striped Large-eye Bream
Lethrinidae	Gnathodentex	sp.	Unknown Gnathodentex species
Lethrinidae	Gymnocranius	euanus	Japanese Large-eye Bream
Lethrinidae	Gymnocranius	grandoculis	Blue-lined large-eye Bream
Lethrinidae	Gymnocranius	microdon	Blue-spotted Large Eye Bream
Lethrinidae	Gymnocranius	sp.	Undescribed Gymnocranius species
Lethrinidae	Lethrinus	atkinsoni	Yellowtail Emperor
Lethrinidae	Lethrinus	erythracanthus	Orange-spotted Emperor
Lethrinidae	Lethrinus	erythropterus	Longfin Emperor
Lethrinidae	Lethrinus	harak	Thumbprint Emperor
Lethrinidae	Lethrinus	laticaudis	Grass emperor
Lethrinidae	Lethrinus	lentjan	Pink ear Emperor
Lethrinidae	Lethrinus	microdon	Smalltooth Emperor
Lethrinidae	Lethrinus	miniatus	Sweetlip Emperor
Lethrinidae	Lethrinus	nebulosus	Spangled Emperor
Lethrinidae	Lethrinus	obsoletus	Orange-striped Emperor
Lethrinidae	Lethrinus	olivaceus	Longface Emperor
Lethrinidae	Lethrinus	semicinctus	Black blotch Emperor
Lethrinidae	Lethrinus	sp.	Unknown Lethrinus species
Lethrinidae	Lethrinus	xanthochilus	Yellowlip Emperor
Lethrinidae	Monotaxis	grandoculis	Humpnose Bigeye Bream
Lutjanidae	Aphareus	furca	Smalltooth Jobfish
Lutjanidae	Aprion	virescens	Green Jobfish
Lutjanidae	Lutjanus	argentimaculatus	Mangrove Red Snapper
Lutjanidae	Lutjanus	biguttatus	Two-spot Snapper
Lutjanidae	Lutjanus	bohar	Red Snapper
Lutjanidae	Lutjanus	ehrenbergii	Blackspot Snapper
Lutjanidae	Lutjanus	fulviflamma	Longspot Snapper
Lutjanidae	Lutjanus	fulvus	Blacktail Snapper
Lutjanidae	Lutjanus	gibbus	Humpback Snapper

Lutjanidae	Lutjanus	kasmira	Bluestripe Snapper
Lutjanidae	Lutjanus	malabaricus	Malabar blood Snapper
Lutjanidae	Lutjanus	monostigma	Onespot Snapper
Lutjanidae	Lutjanus	quinquelineatus	Five-lined Snapper
Lutjanidae	Lutjanus	rivulatus	Blubberlip Snapper
Lutjanidae	Lutjanus	russeli	Russell's Snapper
Lutjanidae	Lutjanus	semicinctus	Black-banded Snapper
Lutjanidae	Lutjanus	sp.	Unknown Lutjanus species
Lutjanidae	Lutjanus	timorensis	Timor Snapper
Lutjanidae	Macolor	macularis	Midnight Snapper
Lutjanidae	Macolor	niger	Black Snapper
Lutjanidae	Macolor	sp.	Unknown Macolor species
Lutjanidae	Paracaesio	sordidus	Dirty odure Snapper
Lutjanidae	Paracaesio	sp.	Unknown Paracaesio species
Lutjanidae	Paracaesio	xanthura	Yellowtail Blue Snapper
Lutjanidae	Pinjalo	lewisi	Slender Pinjalo
Lutjanidae	Pinjalo	sp.	Unknown Pinjalo species
Lutjanidae	Symphorichthys	spilurus	Sailfin Snapper
Lutjanidae	Symphorus	nematophorus	Chinamanfish
Mullidae	Mulloidichthys	flavolineatus	Yellowstripe Goatfish
Mullidae	Mulloidichthys	sp.	Unknown Mulloidichthys
Mullidae	Mulloidichthys	vanicolensis	Yellowfin Goatfish
Mullidae	Parupeneus	barberinoides	Bicolor Goatfish
Mullidae	Parupeneus	barberinus	Dash-dot Goatfish
Mullidae	Parupeneus	ciliatus	Whitesaddle Goatfish
Mullidae	Parupeneus	crassilabris	Doublebar Goatfish
Mullidae	Parupeneus	cyclostomus	Golden Goatfish
Mullidae	Parupeneus	heptacanthus	Cinnabar Goatfish
Mullidae	Parupeneus	indicus	Indian Goatfish
Mullidae	Parupeneus	multifasciatus	Many Bar Goatfish
Mullidae	Parupeneus	pleurostigma	Sidespot Goatfish
Mullidae	Parupeneus	sp.	Unknown Parupeneus species
Mullidae	Upeneus	arge	Band-tail Goatfish
Mullidae	Upeneus	sp.	Unknown Upeneus species
Mullidae	Upeneus	sulphureus	Sulphur Goatfish
Mullidae	Upeneus	vittatus	Yellowstriped Goatfish
Nemipteridae	Nemipterus	sp.	Unknown Nemipterus species
Nemipteridae	Nemipterus	zysron	Slender Bream
Nemipteridae	Pentapodus	aureofasciatus	Goldstripe Bream
Nemipteridae	Pentapodus	sp.	Unknown Pentapodus species
Nemipteridae	Scolopsis	bilineatus	Two-lined Monocle Bream
Nemipteridae	Scolopsis	sp.	Unknown Scolopsis species
Nemipteridae	Scolopsis	temporalis	Bald-spot Monocle Bream
Nemipteridae	Scolopsis	trilineatus	Three-lined Monocle Bream
Pomacanthidae	Apolemichthys	sp.	Unknown Apolemichthys species
Pomacanthidae	Apolemichthys	trimaculatus	Threespot Angelfish
Pomacanthidae	Centropyge	aurantia	Golden Angelfish
Pomacanthidae	Centropyge	bicolor	Bicolor Angelfish
Pomacanthidae	Centropyge	bispinosus	Twospine Angelfish
Pomacanthidae	Centropyge	flavicauda	Whitetail Angelfish
Pomacanthidae	Centropyge	flavissima	Lemonpeel Angelfish
Pomacanthidae	Centropyge	heraldi	Yellow Pygmy Angelfish
Pomacanthidae	Centropyge	multifaciata	Barred Angelfish
Pomacanthidae	Centropyge	nox	Midnight Angelfish

Pomacanthidae	Centropyge	sp.	Unknown Centropyge species
Pomacanthidae	Genicanthus	melanospilos	Blackspot Angelfish
Pomacanthidae	Genicanthus	sp.	Unknown Genicanthus species
Pomacanthidae	Genicanthus	watanabei	Pinstriped Angelfish
Pomacanthidae	Pomacanthus	imperator	Emperor Angelfish
Pomacanthidae	Pomacanthus	semicirculatus	Semicircle Angelfish
Pomacanthidae	Pomacanthus	sp.	Unknown Pomacanthus species
Pomacanthidae	Pygoplites	diacanthus	Regal Angelfish
Priacanthidae	Heteropriacanthus	cruentatus	Glass eye
Priacanthidae	Priacanthus	hamrur	Moontail Bullseye
Priacanthidae	Priacanthus	sp.	Unknown Priacanthus species
Scaridae	Bolbometopon	muricatum	Bumphead Parootfish
Scaridae	Calotomus	sp.	Unknown Calotomus species
Scaridae	Calotomus	spinidens	Raggedtooth Paarotfish
Scaridae	Cetoscarus	bicolor	Bicolor Parrotfish
Scaridae	Chlorurus	bleekeri	Bleeker's Parrotfish
Scaridae	Chlorurus	frontalis	Tan-face Parrotfish
Scaridae	Chlorurus	microrhinos	Steephead Parrotfish
Scaridae	Chlorurus	sordidus	Bullethead Parrotfish
Scaridae	Chlorurus	sp.	Unknown Chlorurus species
Scaridae	Hipposcarus	longiceps	Pacific nose Parrotfish
Scaridae	Hipposcarus	sp.	Unknown Hipposcarus species
Scaridae	Leptoscarus	vaigiensis	Marbled Parrotfish
Scaridae	Scarus	altipinnis	Filament-fin Parrotfish
Scaridae	Scarus	chameleon	Chameleon Parrotfish
Scaridae	Scarus	dimidiatus	Yellow-barred Parrotfish
Scaridae	Scarus	forsteni	Bluepatch Parrotfish
Scaridae	Scarus	frenatus	Bridled Parrotfish
Scaridae	Scarus	ghobban	Blue-barred Parrotfish
Scaridae	Scarus	globiceps	Violet-lined Parrotfish
Scaridae	Scarus	longipinnis	Highfin Parrotfiswh
Scaridae	Scarus	niger	Swarthy Parrotfish
Scaridae	Scarus	oviceps	Dark-capped Parrotfish
Scaridae	Scarus	prasiognathos	Greenthroat Parrotfish
Scaridae	Scarus	psittacus	Palenose Parrotfish
Scaridae	Scarus	rivulatus	Surf Parrotfish
Scaridae	Scarus	rubroviolaceus	Redlip Parrotfish
Scaridae	Scarus	schlegeli	Yellowbar Parrotfish
Scaridae	Scarus	sp.	Unknown Parrotfish Species
Scaridae	Scarus	spinus	Greensnout Parrotfish
Scombridae	Acanthocybium	solandri	Wahoo
Scombridae	Grammatorcynus	bilineatus	Double-lined Macakerel
Scombridae	Grammatorcynus	sp.	Unknown Grammatorcynus species
Scombridae	Gymnosarda	unicolor	Dogtooth Tuna
Scombridae	Rastrelliger	brachysoma	Short Mackerel
Scombridae	Rastrelliger	kanagurta	Long-Jawed Macakerel
Scombridae	Rastrelliger	sp.	Unknown Rastrelliger species
Scombridae	Scomberomorus	commerson	Narrow Barred Spanish Macakerel
Scombridae	Scomberomorus	sp.	Unknown Scomberomorus species
Scombridae	Thunnus	albacares	Yellowfinn Tuna
Scombridae	Thunnus	sp.	Unknown Thunnus species
Serranidae	Aethaloperca	rogaa	Redmouth Grouper
Serranidae	Aethaloperca	sp.	Unknown Aethaloperca species
Serranidae	Anyperodon	leucogrammicus	Slender Grouper

Serranidae	Cephalopholis	argus	Peacock Grouper
Serranidae	Cephalopholis	aurantia	Golden hind
Serranidae	Cephalopholis	boenak	Chocolate Hind
Serranidae	Cephalopholis	leopardus	Leopard Hind/ Rockcod
Serranidae	Cephalopholis	miniata	Coral Grouper
Serranidae	Cephalopholis	sexmaculata	Saddle Grouper
Serranidae	Cephalopholis	sonnerati	Tomato Grouper
Serranidae	Cephalopholis	sp.	Unknown Cephalopholis species
Serranidae	Cephalopholis	spiloparaea	Strawberry hind
Serranidae	Cephalopholis	urodeta	Flagtail Grouper
Serranidae	Epinephelus	areolatus	Areolate Grouper
Serranidae	Epinephelus	caeruleopunctatus	Whitespotted Grouper
Serranidae	Epinephelus	chlorostigma	Brown-spotted Grouper
Serranidae	Epinephelus	coioides	Orange-spotted Grouper
Serranidae	Epinephelus	cyanopodus	Speckled blue Grouper
Serranidae	Epinephelus	fasciatus	Blacktip Grouper
Serranidae	Epinephelus	fuscoguttatus	Brown-marbeled Grouper
Serranidae	Epinephelus	hexagonatus	Starspotted Grouper
Serranidae	Epinephelus	howlandi	Blacksaddled Grouper
Serranidae	Epinephelus	lanceolatus	Giant Grouper
Serranidae	Epinephelus	macrospilos	Snubnose Grouper
Serranidae	Epinephelus	maculatus	Highfin Grouper
Serranidae	Epinephelus	malabaricus	Malabar Grouper
Serranidae	Epinephelus	melanostigma	One-Blotch Grouper
Serranidae	Epinephelus	merra	Honeycomb Grouper
Serranidae	Epinephelus	miliaris	Netfin Grouper
Serranidae	Epinephelus	ongus	Whitestreaked Grouper
Serranidae	Epinephelus	polyphekadion	Camouflage Grouper
Serranidae	Epinephelus	socialis	Surge Grouper
Serranidae	Epinephelus	sp.	Unknown Epinephelus species
Serranidae	Epinephelus	spilotoceps	Foursaddle Grouper
Serranidae	Epinephelus	tauvina	Greasy Grouper
Serranidae	Gracila	albomarginata	Masked Grouper
Serranidae	Plectropomus	areolatus	Squaretail Coral Grouper
Serranidae	Plectropomus	laevis	Blacksaddle Coral Grouper
Serranidae	Plectropomus	leopardus	Leopard Coral Grouper
Serranidae	Plectropomus	maculatus	Spotted Coral Grouper
Serranidae	Plectropomus	pessuliferus	Roving Coral Grouper
Serranidae	Plectropomus	sp.	Unknown Plectropomus species
Serranidae	Variola	albimarginata	White-edged Lyretail
Serranidae	Variola	louti	Yellow-edged Lyretail
Serranidae	Variola	sp.	Unknown Variola species
Siganidae	Siganus	argenteus	Forktail Rabbitfish
Siganidae	Siganus	doliatus	Barred Rabbitfish
Siganidae	Siganus	guttatus	Golden Rabbitfish
Siganidae	Siganus	punctatissimus	Peppered spinefoot Rabbitfish
Siganidae	Siganus	punctatus	Gold-spotted Rabbitfish
Siganidae	Siganus	sp.	Unknown Siganus species
Siganidae	Siganus	spinus	Scribbled Rabbitfish
Siganidae	Siganus	stellatus	Honeycomb Rabbitfish
Siganidae	Siganus	uspi	Bicolor Rabbitfish
Siganidae	Siganus	vermiculatus	Vermiculate Rabbitfish
Sphyraenidae	Sphyraena	barracuda	Great Barracuda
Sphyraenidae	Sphyraena	flavicauda	Yellowtail Barracuda

Sphyraenidae	Sphyraena	forsteni	Bigeye Barracuda
Sphyraenidae	Sphyraena	jello	Pickhandle Barracuda
Sphyraenidae	Sphyraena	qenie	Blackfin Barracuda
Sphyraenidae	Sphyraena	sp.	Unknown Sphyraena species
Sphyrnidae	Sphyrna	lewini	Scalloped Hammerhead
Sphyrnidae	Sphyrna	mokarran	Great Hammerhead
Sphyrnidae	Sphyrna	sp.	Unknown Sphyrna species
Stegostomatidae	Stegastoma	fasciatum	Zebra Shark
Zanclidae	Zanclus	cornutus	Moorish Idol

Appendix 5. Coral Genera Found in Fiji

Family	**Genus**	**Family**	**Genus**
Acroporidae	*Acropora*	Fungiidae (cont.)	*Heliofungia*
	Anacropora		*Herpolitha*
	Astreopora		*Polyphyllia*
	Montipora		*Sandolitha*
	Isopora		*Zoopilus*
Agariciidae	*Coeloseris*	Merulinidae	*Hydnophora*
	Gardinoseris		*Merulina*
	Leptoseris		*Paraclavarina*
	Pachyseris		*Scaphophyllia*
	Pavona		
		Mussidae	*Acanthastrea*
Astrocoeniidae	*Stylocoeniella*		*Blastomussa*
			Lobophyllia
Dendrophyllidae	*Turbinaria*		*Scolmya*
	Tubastrea		*Symphyllia*
Euphyllidae	*Euphyllia*	Oculinidae	*Galaxea*
	Physogyra		
	Plerogyra	Pectiniidae	*Echinophyllia*
			Mycedium
Faviidae	*Barabattoia*		*Oxypora*
	Caulastrea		*Pectinia*
	Cyphastrea		
	Diploastrea	Pocilloporidae	*Pocillopora*
	Echinopora		*Seriatopora*
	Favia		*Stylophora*
	Favites		
	Goniastrea	Poritidae	*Alveopora*
	Leptastrea		*Goniopora*
	Leptoria		*Porites*
	Montastrea		
	Oulophyllia	Siderastreidae	*Coscinaraea*
	Platygyra		*Psammocora*
	Pleisiastrea		
		Trachyphylidae	*Trachyphyllia*
Fungiidae	*Podobacia*		
	Lithophyllon		
	Cantharellus		
	Ctenactis		
	Cycloseris		
	Diaseris		
	Fungia		
	Halomitra		

List based on Lovell and McLardy (2008)

Appendix 6. General Diving and Boating Protocol

A. Dive Planning

All dives must be well planned and organised and adhere to WCS dive policy. A dive plan completed at the start of each day must include:

- The location of the dives
- Considerations of surface and underwater conditions and hazards
- The maximum depth and bottom time of the dive
- Tasks of all the members of the dive team
- Emergency procedures
- The agreed system or procedure for recalling divers that is effective below and above water
- The agreed procedure for retrieving a diver
- The dive plan must be clearly communicated to all involved in the diving operation including those that are not actually entering the water.
- The names of buddy pairs
- The name of the nominated dive leader on each boat

Additionally:

- All non-WCS divers must sign a waiver form
- At the end of the day, each diver must log all dives

B. Emergency Planning

An Emergency Plan must be completed and a written copy of this document is to be maintained at the field site until all diving activity has ceased.

The emergency plan must include:

- Contact details of emergency authorities
- Details of nearest hyperbaric treatment facilities
- Contact details of any local area designated diving doctor
- Evacuation Plan

(See **Appendix 7** for sample **Emergency Plan**, **Appendix 8** for Fiji Recompression Chamber Emergency Procedure Notes, and **Appendix 9** for Accident/Incident Report form)

C. First aid

There must be available on site sufficiently trained first aid personnel, first aid equipment to ensure a successful response to any diving injury or illness that may occur.

D. Dive Officer

Each research unit shall appoint a Dive Officer. The role of the dive officer is as follows:

- Must be an experienced diver with the qualifications and experience appropriate to the types of diving operations undertaken
- Must be familiar with any legislation and guidelines which apply to the diving operations
- Has the power to restrict, prohibit and suspend any diving operations which he or she considers unsafe.
- Has the power require such additional safety practices, procedures or equipment necessary in any diving operation
- Must assess divers competencies
- Must keep copies of maintenance records of all diving equipments
- Must assess all dive plans and emergency plans

E. Dive Gear Maintenance

- Dive officer is responsible for service and issuing of dive gear
- All personnel is responsible for their dive gear in the field
- After every dive gear must be rinsed in fresh water and stored away properly
- Dive tanks must be filled after every dive and valves purged before fitting filling yoke
- Keep tank air intake away from exhaust fumes and flammable objects
- Tanks must never be fully emptied and should always have pressure
- Compressor oil, engine oil and fuel must be checked before starting compressor and filling
- After field work all gear must be washed and checked into the store by the dive officer upon return from expedition
- All repairs must be noted and arranged for service/repair by the dive officer

F. Boat Skipper

All activities involving WCS boats must adhere to WCS boat policy.

- Ensure that operation of the boat complies with any relevant Maritime safety Authority and departmental requirements
- Ensure that the boat is at all times manned by a competent person able to respond immediately to the skippering requirements for any diving emergency situation that may develop
- Be aware of the agreed system or procedure for recalling divers
- Cancel any diving operation when the safety of the vessel and / or personnel would be at risk

G. Boat Equipment (onboard at all times)

- Life saving devices (life-jackets, flares, radios, mobile phone, and epirb)
- Anchor and ropes
- Torches (spare batteries)
- Tools and spare parts
- First aid box
- Alternative form of propulsion (e.g. collapsible oars)

H. Boating Procedures

- Always ensure dedicated person on land knows of the boats destination and maintains radio communication
- Always ensure boat has competent personnel onboard when anchored at dive site
- Ensure safe anchorage at all times

I. Boat Maintenance

Before Expedition

- Ensure boat is in good working order
- Ensure boat is clean
- Run engines for 1 hour
- Look for hull damage
- Ensure safety equipment is on board

Daily Operation

- Ensure proper fuel is used
- Ensure sufficient fuel is on board for entire outing
- Keep boat clean
- Run engines for 2 minutes in idle before every trip
- Make sure tell tale water is flowing
- Check filter for water and drain if necessary
- Ensure safe and secure anchorage

After Expedition

- Flush the engine with fresh water
- Wash the entire boat with fresh water and soap
- Spray CRC to all electrical and metal engine parts to protect from corrosion
- Ensure boats are secure
- Remove and secure all equipment

Appendix 7. Sample Emergency Plan

These notes are to be used in conjunction with the Fiji Recompression Chamber Emergency Procedure Notes

		Notes
Procedures		
If you have an actual or suspected case of DCS, put the diver on O2 immediately and then contact DAN Emergency Help Line	+61 8 8212 9242	Follow their advice precisely
If you can't reach DAN Australia, call DAN America	+1 919 684 8111	
If you can't reach either, contact the Duty doctor in Fiji	+679 999 3500	
DAN will advise you if recompression is needed. If so you need to contact DAN Travel Assist then the Duty doctor in Fiji.	+1 919 684 3483 or call the international operator and place a collect call to Durham, North Carolina, USA on 919-684 3483	DAN advise you should contact them in the first instance always.
Location	Kubulau	
Base of operation	Navatu Village	
	Greenforce Camp	
	Natokalau Village	
Nearest major town	Savusavu	
Nearest airstrip	Savusavu	
Contact Numbers		
Navatu village phone	+679 851 0140	
Turaga-ni-Koro (Sailosi)	+679 851 1121	
Greenforce Camp	+679 828 3397 / 6	
Natokalau village phone		
Provincial Office Bua		
Location for the Sea Plane landing		
If sea conditions are good, landing at Navatu should be possible. The location of the landing area is.	16^{o} 55.46 S 179^{o} 00.57 E On the Eastern side of Nasonisoni Island	
If the sea state is too bad, wind too strong or visibility poor, then the sea plane pilot may choose a different landing spot or alternatively, Savusavu airfield.	Arrange a 4x4 to transport the casualty to the nearest landing place or Savusavu airstrip.	

Appendix 8. Protocol for Dive Injuries

THE FIJI RECOMPRESSION CHAMBER FACILITY

PO Box 264, Savusavu, Fiji Islands

Admin phone (679) 885 0630; Fax (679) 885 0344

Email seafijidive@connect.com.fj

CHAMBER SITUATED AT SUVA PRIVATE HOSPITAL

IF DAN IS NOT DIRECTLY AVAILABLE AND IF YOU HAVE A SUSPECTED DIVE INJURY OR DIVE ACCIDENT CALL

999 3500

(HYPERBARIC DOCTOR: Dr Ali Husnoor, Lami, Suva)

OR

999 3506

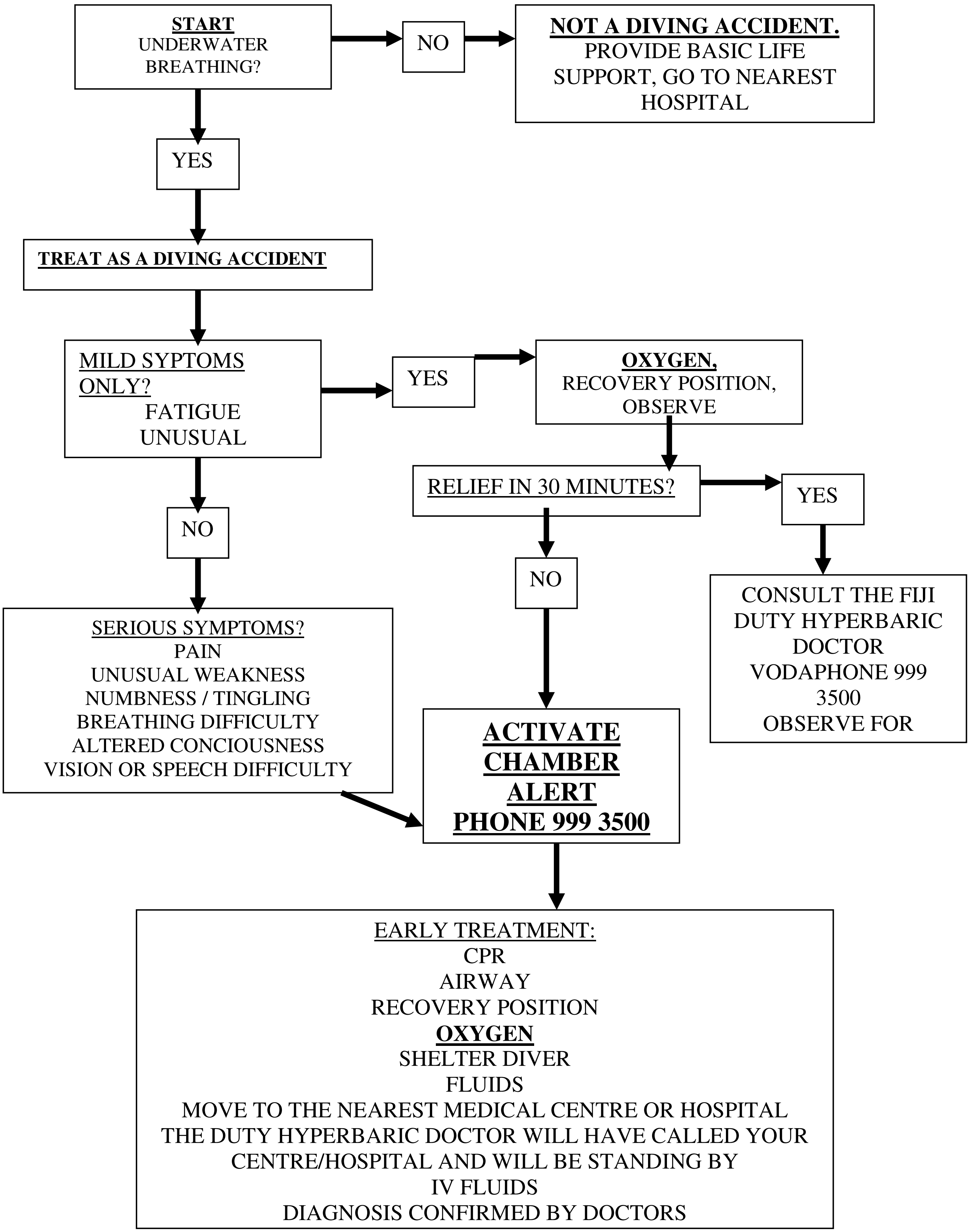
(NATIONAL COORDINATOR Curly Carswell, Savusavu)

IMMEDIATELY

IMPORTANT – YOU MUST PLACE THE PATIENT ON OXYGEN!

ACCIDENT MANAGEMENT FLOW CHART

Amended for the Fiji Islands



FIJI CHAMBER ALERT FOR SERIOUS SYMPTOMS PROCEDURE AND RECORD SHEET

1. **DIVER HAS SERIOUS SYMPTOMS** DATE:__________________
   - CPR TIME:___________________
   - AIRWAY TIME:___________________
   - RECOVERY POSITION TIME:___________________
   - OXYGEN TIME:___________________
   - SHELTER DIVER TIME:___________________
   - ORAL FLUIDS TIME:___________________

2. **INITIATE FIJI CHAMBER ALERT** BY CALLING
   HYPERBARIC DOCTOR (DR ALI HUSNOOR) 999 3500
   OR NATIONAL COORDINATOR (CURLY CARSWELL) 999 3506
   TIME:___________________

SAY: A) WE HAVE A SERIOUS DIVER EMERGENCY
B) THIS IS A CHAMBER ALERT
C) MY NAME IS _______________________________________
D) OUR DIVE OPERATION IS _____________________________
E) WE ARE MOVING PATIENT TO __________________________
(name of Hospital / Medical Centre)
F) OUR ESTIMATED TIME OF ARRIVAL IS ____________________
G) THE PATIENTS SYMPTOMS ARE AS FOLLOWS:

i	Unusual fatigue or weakness	Yes / No
ii	Skin itch	Yes / No
iii	Pain on arms, legs or torso	Yes / No
iv	Dizziness	Yes / No
v	Numbness, tingling or paralysis	Yes / No
vi	Shortness of breath	Yes / No
vii	Visual blurring	Yes / No
viii	Chest pain	Yes / No
ix	Disorientation	Yes / No
x	Personality change	Yes / No
xi	Blood froth from mouth / nose	Yes / No
xii	Other symptoms (list)	

____
____

3. **INITIATE AND COMPLETE THE TREATMENT / RECORD SHEET** WHICH MUST ACCOMPANY THE PATIENT

4. **MOVE PATIENT TO NEAREST GOVERNMENT MEDICAL CENTRE / HOSPITAL,** ENSURING TREATMENT / **OXYGEN** IS PROVIDED AND OBSERVATION EN ROUTE. TAKE ALL DOCUMENTATION I.E. CHECK IN FORM / PREVIOUS DIVES / LOG BOOK / LATEST DIVE PROFILES AND ALL DIVE EQUIPEMENT USED BY PATIENT.

5. ON ARRIVAL AT THE MEDICAL CENTRE / HOSPITAL **ADMIT THE PATIENT AND STANDBY** TO ASSIST IF NECESSARY

6. **ASSIST HOSPITAL / MEDICAL CENTRE STAFF** WITH ANY INSTRUCTIONS FOR MEDEVAC

7. **MEDEVAC** WILL BE ARRANGED BY THE FIJI RECOMPRESSION CHAMBER FACILITY

SYMPTOMS / TREATMENT RECORD SHEET

TO BE COMPLETED BY THE PATIENT'S DIVE OPERATOR AND TO BE SENT WITH THE PATIENT

DIVER PATIENT:

NAME:____ AGE:__________

ADDRESS:____

____

CONTACT: ________________________________ PHONE: ____________

( ) RELATIVE ( ) FRIEND

SIGNIFICANT MEDICAL HISTORY: (Allergies, medications, diseases, injuries etc)

SIGNS/ SYMPTOMS: (note time of each as it arises)

FIRST AID PROCEDURES INITIATED: (note time of each)

COMMENTS:

PREVIOUS DIVES IN FIJI:
RESORTS:____

DIVE OPERATORS:
____

DATES OF DIVING PROFILES IF KNOWN:

1. TIME IN /OUT _______________ / _________________ DEPTH __________
2. TIME IN /OUT _______________ / _________________ DEPTH __________
3. TIME IN /OUT _______________ / _________________ DEPTH __________

COMMENTS:

GENERAL REMARKS:

Appendix 9. Accident Report Form

WCS FIJI: ACCIDENT/INCIDENT REPORT FORM

Part A. Recorder Information

Your name:

Your contact #:

PartB. About the Incident

On what date did the incident/accident occur:

At what time did the incident/accident occur:

Where did the incident occur (give address):

Part C. About the Injured Person

Full name:

Home address:

Contact #:

Age: Sex:

Job Title:

Was the injured person (tick one):

- ☐ WCS employee
- ☐ Volunteer
- ☐ Staff trainee
- ☐ Visitor
- ☐ Member of the public

Part D. About the Injury

What was the injury (e.g. fracture, laceration)

What part of the body was injured?

Part E. About the Type of Accident/Incident

Tick the box that best describes what happened

- ☐ Contact with moving machinery
- ☐ Hit by a moving, flying or falling object
- ☐ Hit by a moving vehicle
- ☐ Hit something fixed or stationary
- ☐ Injured while handling, lifting or carrying
- ☐ Slipped, tripped or fell
- ☐ Fell from height. How high?
- ☐ Trapped by collapsed object
- ☐ Drowned or asphyxiated
- ☐ Exposed to harmful substance
- ☐ Exposed to fire
- ☐ Exposed to an explosion
- ☐ Contact with electrical discharge
- ☐ Injured by an animal
- ☐ Physically assaulted by a person
- ☐ Dive injury
- ☐ Other

side 1

Part f. Describe what Happened

Give as much detail as you can. For instance:

- The name of any substance involved
- The name and any type of machine involved
- The events that led to the incident
- The part played by any people
- Actions the injured person was taking prior to accident
- First aid performed

side 2