

Presenting a standardised national methodology for coral reef surveys in Cambodia

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Introduction

It is well documented that coral reefs are among the most biologically important ecosystems on the planet, but face increasing levels of degradation through environmental and anthropogenic impacts (Roberts *et al.*, 2002). It is estimated that coral reefs are home to 33% of all known fish species, and provide a nursery ground for over 25% of all marine organisms (Spalding *et al.*, 2001). In addition to their own intrinsic biological value, coral reefs are invaluable to millions of coastal communities throughout the tropics for food, coastal protection and for income generation (Burke *et al.*, 2012). Indeed, upwards of 80% of the Cambodia's daily protein intake is sourced from aquatic resources, both inland fresh water and coastal waters (Nam & Bunthang, 2011) and coral reefs in South East Asia are worth an estimated US\$4.8 billion per year for the tourism industry (Cesar *et al.*, 2003). This high dependence on marine resources places a huge pressure on the coral reefs that fringe the near shore and island waters of Cambodia.

With such a high dependence on marine resources the Fisheries Administration (FiA) of the Royal Government of Cambodia sought to establish a national survey method for the assessment of coral reefs. Until recently, very little was known about the status of Cambodia's reefs (Bochove *et al.*, 2011), although an increasing number of organisations are regularly collecting data (Savage *et al.*

2013). This national survey method was developed as part of on-going work in establishing Cambodia's first Marine Fisheries Management Area (MFMA) around the Koh Rong Archipelago. In November 2013, the FiA invited stakeholders, marine managers and NGOs to a methodology design workshop hosted by Coral Cay Conservation (CCC) in the village of Prek Svay, Koh Rong (Thorne & Longhurst, 2013). The method was designed with three primary objectives in mind: (1) the provision of eco-holistic data on the state of Cambodia's reefs; (2) the provision of a straightforward method that is applicable across the country; and (3) the provision of empirical data on anthropogenic impacts, to inform marine resource management decisions, and to help track progress towards government targets (e.g. targets in the National Action Plan for Coral Reef and Seagrass). Allocation of a nationwide survey method allows quantifiable cross-comparison of data from region to region, which in itself, creates a better understanding of the state of country's coral reef ecosystems. This paper presents an overview of this method for future marine researchers in Cambodia to follow.

Survey Method

The national method developed for Cambodia is based on the Reef Check method. Further information for surveyors can be found in the Reef Check manual (Hodgson *et al*, 2006; Hodgson *et al.*, 2010). Reef Check is a global project that aims to provide a worldwide picture of the state of coral reefs. Using target species of fish, invertebrates and other reef organisms, the survey protocol assesses the state of reef health and the level of anthropogenic impact (Hodgson, 1999), presenting a snapshot in time of any given reef system. A limited number of target species are selected as indicators of specific ecological or anthropogenic factors (Table 1). Additional targets have been agreed and added for the Cambodian method based on their importance to commercial fishing, their high abundance in the region or their importance as ecological indicators (Appendix A).

Surveys are conducted by a four-person team along a 100 metre transect ($n = 4$ replicates per site to give power of statistics). Transects lie parallel to shore. Whenever the site allows, transects are conducted at two depth contours, 2-6m and 8-12m in order to survey a range of reef habitat, i.e. reef crest and reef slope. On each transect, four sets of data are recorded: fish species and abundance; substrate type, including hard coral species; invertebrate species and abundance; and qualitative data on anthropogenic impacts, including coral damage and trash. Ancillary data is also recorded at each site to detail distance from nearest population centre, distance from nearest river mouth, weather condition, water temperature at various depths and proposed status of current threats.

Within each 100m transect there are four 20m replicates in which data are recorded. Each replicate is separated by five metres in which no data are recorded, ensuring that the replicates can be independently recognised (Figure 1). Fish data are collected along a 5 m x 5 m x 20 m belt transect. Surveyors swim at a set depth contour, close to the benthos, recording target fish species within the survey corridor. Grouper and parrotfish are sized to the nearest 10 cm in order to provide an indicator of population structure. Furthermore, certain rare or charismatic species such as turtles, rays and sharks may be recorded outside the survey area. Invertebrates and impacts are surveyed along a 5 m x 20 m belt transect, with surveyors swimming an S-shaped pattern to ensure complete coverage of the survey area is obtained. The level of impacts is recorded on a scale, with reference to the number of incidences observed; 0 = None, 1 = Low (1 incidence), 2 = Medium (2-4 incidences), 3 = High (>5 incidences). Coral bleaching is measured as the average percentage of individual colonies bleached and the overall percentage of the coral population effected. White band and black band diseases are recorded as the overall percentage of the coral population effected. Substrate data are recorded along the transect line using a point intercept method. A plumb line is used every 0.5 m to record the benthic substrate. The use of a plumb line reduces inherent bias from the surveyor. Substrates include both biotic (hard coral species, soft coral, anemones, etc.) and abiotic (sand, rock, recently killed coral, etc.) types. Hard coral colonies, less than five cm in

diameter, are recorded as new recruits, with the exception of *Pseudosiderastrea* spp. which naturally grow in small colonies.

A further measure of reef complexity has been added to the Reef Check method for the purpose of the national survey programme. Reef rugosity is measured using a one metre length of chain which is laid flat over the substrate parallel to the transect line. The distance the chain covers is recorded to provide a measure of reef complexity and rugosity, as per McCormick (1994).

Discussion

The primary focus of the method is to provide broad-scale data on the health of Cambodia's reefs. This eco-holistic approach aims to consider a wide spectrum of parameters including both biotic and abiotic factors. In addition, it considers a range of anthropogenic impacts to determine levels of human influence on reef ecosystems. The data collected is fundamental to the FiA for its future ability to provide sustainable marine management for the protection of Cambodia's reefs and to safeguard nearshore fisheries. By unifying and centralising a national framework for monitoring, the method will provide the FiA with a tool for comparing reefs throughout the country and provide evidence to support the establishment of marine resource regulations and evaluate the effectiveness on management measures.

The Reef Check method was designed to be implemented by non-specialist and inexperienced researchers, under the guidance of marine scientists and is thus straightforward in its approach. It was selected as the basis for the new survey protocol due to its relatively simple design and ease of implementation, thus facilitating a wider range of individuals to be trained to complete the surveys and reducing reliance on trained marine scientists. Furthermore, Reef Check surveys have previously been conducted by a number of international NGOs within Cambodia. This provides a source of historic data that will be comparable with the new method. Once the method is fully

implemented, the FiA will also be able to feed data from Cambodia into the global Reef Check datasets and contribute to the increasing worldwide picture of coral reef health.

In order to provide a broader and more detailed picture of the state of the reefs, the national survey method incorporates a wider array of species than the Reef Check method. This enhanced species list includes a greater variety of fish and invertebrate species which are both important ecologically and commercially in Cambodia, as well as target species of hard coral and other benthic organisms. Fish such as Rabbitfish (*Siganidae* spp.) were added to the species list as they are one of the most commonly observed families in Cambodian waters. Furthermore, they are readily caught for consumption by local fishing communities and thus are an important indicator of fishing pressure. Enhancing substrate categories to include target coral species in addition to life-form enables a greater understanding of reef complexity and diversity of coral species and provides an important indicator of reef health.

This national survey method was developed as part of on-going work in establishing Cambodia's first Marine Fisheries Management Area (MFMA) around the Koh Rong Archipelago. The MFMA incorporates a multi-use zonation scheme that aims to conserve marine biodiversity and support sustainable fishing and tourism, and the national method will be used to assist monitoring the effectiveness of MFMA management.. During the development of the monitoring method, participants were familiarised with the MFMA designation process, as well as the Reef Check method, and contributed to discussion on the purpose, use and implementation of the proposed national monitoring method. The target species list was finalised based on the experience of representatives from the FiA and NGOs who have conducted marine surveys in recent years. The method will initially be used to assess the impact of the MFMA on the reefs contained within its boundaries. In addition it shall be used as the monitoring framework for all reef surveys conducted within Cambodian waters in the future.

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Appendix I

Invertebrates Target Species

Annelids

- o Feather duster worm
- o Christmas tree worm

Platyhelminths

- o All flatworms

Molluscs

- Gastropods
 - o Cowrie
 - o Topshell
 - o Conch (*Strombidae*)
 - o *Drupella* spp.
 - o Murex spp (*Murex*)
 - o Nudibranch
 - o Other gastropod
- Bivalves
 - o Giant clam (*Tridacna* spp.) [size to nearest 10 cm]
- Cephalopods
 - o Squid
 - o Cuttlefish
 - o Octopus

Crustaceans

- o Banded coral shrimp
- o Goby Shrimp (*Alpheidae*)
- o Mantis Shrimp (*Stomatopoda*)
- o Anemone Shrimp (*Hippolytidae*)
- o Lobster
- o True Crab (*Brachyura*)- Blue Swimmer, Other

Echinoderms

- Sea stars

- o Crown of thorns starfish (*Acanthaster planci*)
- o Cushion star (*Culcita novaeguineae*)
- o (*Protoreaster nodosus*)
- Sea urchins
 - o Long-spine sea urchin (*Diadema* and *Echinotrix* spp.)
 - o Other urchin
- Crinoids
 - o Feather stars
- Holothurians
 - o Prickly redfish (*Thelenota ananas*)
 - o Greenfish (*Stichopus chloronotus*)
 - o Pinkfish (*Holothuria edulis*)
 - o Synaptids (*Synaptidae*)
 - o Lollyfish (*Holothuria atra*)

Fish Target Species

Butterflyfishes (*Chaetodontidae*):

- o Long-beaked coral fish (*Chelmon rostratus*)
- o Bannerfish (*Heniochus acuminatus*)
- o 8-banded butterflyfish (*Chaetodon octofasciatus*)
- o Orange Banded Coral Butterflyfish
- o All other butterflyfish

Angelfishes (*Pomacanthidae*):

- o Blue-ringed angelfish (*Pomacanthus annularis*)

Batfishes/Spadefishes (*Ephippidae*)

Rabbitfishes (*Siganidae*):

- o Coral rabbitfish (*Siganus corallinus*)
- o Virgate rabbitfish (*Siganus virgatus*)
- o Java rabbitfish (*Siganus javus*)
- o Vermiculated rabbitfish (*Siganus vermiculatus*)

- o Golden rabbitfish (*Siganus guttatus*)

Damselfishes (*Pomacentridae*):

- o Sergeant damselfish (*Abudefduf* spp.)
- o Anemonefish (*Amphiprioninae*)

Snappers (*Lutjanidae*):

- o Checkered snapper (*Lutjanus decussatus*)
- o Red snapper (*Lutjanus bohar*)
- o Blacktail snapper (*Lutjanus fulvus*)
- o All other snappers

Monocle breams (*Nemipteridae*):

- o Bridled monocle bream (*Scolopsis bilineatus*)
- o Rainbow (*Scolopsis temporalis*)
- o Whitestreak (*Scolopsis ciliatus*)

Emperors (*Lethrinidae*)

Jacks (*Carangidae*)

Barracudas (*Sphyraenidae*):

- o Yellowtail barracuda (*Sphyraena obtusata*)
- o Great barracuda (*Sphyraena barracuda*)
- o All other barracudas

Fusiliers (*Caesionidae*)

Groupers (*Serranidae*) – sized to the nearest 10 cm:

- o Barramundi cod (*Cromileptes altivelis*)
- o Chocolate grouper (*Cephalopholis boenak*)
- o Peacock grouper (*Cephalopholis argus*)
- o Blue-lined grouper (*Cephalopholis formosa*)
- o Honeycomb grouper (*Epinephelus merra*)
- o All other groupers

Soapfishes (*Serranidae*):

- o Doublebanded soapfish (*Diploprion bifasciatum*)

Sweetlips (*Haemulidae*)

Parrotfish (*Scaridae*) [size to nearest 10 cm]:

- o Bumphead parrotfish (*Bolbometopon muricatum*)
- o All other parrotfish

Wrasse (*Labridae*):

- o Humphead wrasse (*Cheilinus undulatus*)
- o Checkerboard Wrasse (*Halichoeres hortulanus*)
- o Bluestreak Cleaner (*Labroides hortuanus*)
- o Crescent wrasse (*Thalassoma lunare*)
- o Redbreasted wrasse (*Cheilinus fasciatus*)
- o Tripletail wrasse (*Cheilinus trilobatus*)

Goatfish (*Mullidae*)

- o Freckled (*Upeneus tragula*)
- o Indian (*Parupeneus indicus*)

Squirrelfish/Soldierfish (*Holocentridae*)

Cardinalfish (*Apogonidae*)

Lizardfish/Sandperch (*Synodontidae/Pinguipedidae*)

Gobies (*Gobiidae*)

Blennies (*Blenniidae*)

Scorpionfish (*Scorpaenidae*)

Boxfish (*Ostracidae*)

Sweepers (*Pempheridae*)

Pufferfish (*Tetraodontidae*)

Porcupinefish (*Diodontidae*)

Seahorse (*Syngnathidae*)

Pipefish (*Syngnathidae*)

Moray eel (*Muraenidae*)

Bamboo shark (*Hemiscylliidae*)

Blue-spotted ribbontail ray (*Dasyatidae*)

Diamondfish (*Monodactylus argenteus*)

Lionfish

Needlefish

Mullet (*Crenimugil/Liza/Neomyxus*)

Hard Coral Target Species and Lifeforms

Acropora spp.

- o Branching
- o Tabulate
- o Encrusting
- o Submassive
- o Digitate

Astreopora spp.

- o Massive
- o Encrusting
- o Foliose

Massive *Porites* spp.

- o Massive
- o Encrusting

Porites rus (submassive)

Goniopora spp./*Alveopora* spp. (submassive)

Pavona decussata (submassive)

Ctenactis echinata (mushroom)

Herpolitha limax (mushroom)

Polyphyllia talpina (mushroom)

Podabacia spp.

- o Foliose
- o Encrusting

Galaxea spp. (submassive)

Pectinia spp. (submassive)

Lobophyllia spp. (submassive)

Favia spp.

- o Massive
- o Encrusting

Favites spp.

- o Massive
- o Encrusting

Diploastrea heliopora

- o Massive
- o Encrusting

Echinopora spp.

- o Foliose
- o Encrusting
- o Submassive

Euphyllia spp. (submassive)

Plerogyra spp. (submassive)

Tubastrea micrantha (branching)

Turbinaria spp.

- o Foliose
- o Encrusting

Pseudosiderastrea spp. (encrusting)

Brain coral (massive or encrusting)

- o Small (groove <0.5 cm deep)

- o Medium (groove 0.5-1 cm deep)
- o Large (groove >1 cm deep)

Seriatopora

Symphillia

Pocillopora damicornis

Merulina

Montipora

Pavona cactus

P. clavus

Fungia

Other:

- o Organ pipe *Tubipora* spp.
- o Fire coral *Millepora* spp.
- o Blue coral *Heliopora* spp.

Soft Coral Target Species

Bamboo (*Isididae*)

Dead Man's Fingers (*Alcyonium*)

Flower (*Clavularia*)

Leather (*Sarcophyton*)

Pulsing (*Xenia*)

Teddy Bear

Tree

Other Soft Coral

Impacts and Substrate Classification

Impacts	Substrate classification	
Coral Damage	Hard Coral	Other:
- Boat/Anchor	Soft Coral	- Anemone
- Dynamite	Sponge	- Zoanthid
- Other	Rock	- Corallimorph
Rubbish	Rubble	- Halimeda
- Fishing Gear- Nets, Pots, fishing lines (In use, or Ghost fishing)	Sand	- Tunicate
- General	Silt	- Other
Bleaching	Recently Killed Coral	
Disease	Nutrient Indicator Algae	
- White band		
- Black band		

Figures and Tables

Table 1. Reef Check target species lists.

Fish	
Butterflyfish (Chaetodontidae)	Bumphead Parrotfish (<i>Bulbometopon muricatum</i>)
Sweetlips (Haemulidae)	Parrotfish (Scarridae)
Snapper (Lutjanidae)	Moray Eel (<u>Muraenidae</u>)
Barrimundi Cod (<i>Cromileptes altivelis</i>)	Grouper (Serranidae) (sized to the nearest 10cm)
Humphead Wrasse (<i>Cheilinus undulates</i>)	
Invertebrates	
Banded-coral shrimp (<i>Stenopus hispidus</i>)	Crown of Thorns (<i>Acanthaster planci</i>)
Diadema urchin (<i>Diadema</i> spp.)	Triton (<i>Charonia tritonis</i>)
Pencil urchin (<i>Heterocentrotus mammillatus</i>)	Lobster (<i>Palinuridae</i> spp.)
Collector urchin (<i>Tripneustes</i> spp.)	Giant Clam (<i>Tridacna</i> spp.)
Sea Cucumber (<i>Holothuroidea</i> spp.)	
Substrates	
Hard coral	Rock
Soft Coral	Rubble
Recently Killed Coral	Sand
Nutrient Indicator Algae	Silt
Sponge	Other

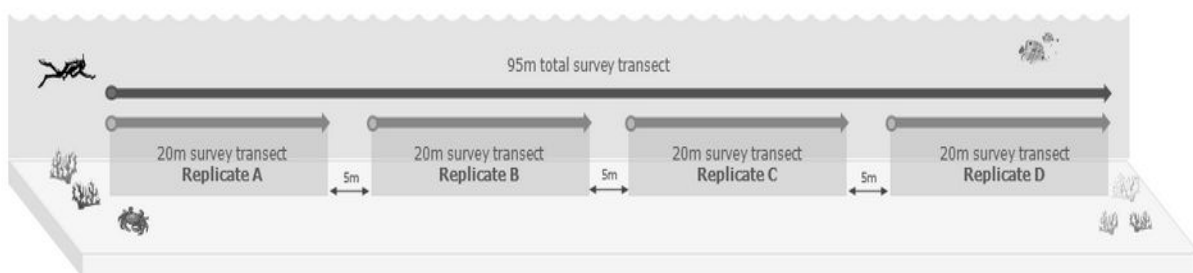


Figure 1 – Schematic diagram of transect set up (Figure courtesy of Coral Cay Conservation)