The Coral Reef Resources of Mu Ko Surin National Park, Thailand

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Executive Summary

This report presents the findings of a coral reef resource assessment study carried out in Mu Ko Surin National Park by Coral Cay Conservation at the invitation of the Department of Marine and Coastal Resources and the Department of National Parks, Wildlife and Plant Conservation of the Ministry of Natural Resources and Environment, Royal Thai Government. Fieldwork was undertaken during March 2005 in collaboration with staff and students from the Marine Biodiversity Research Group from Ramkhamhaeng University, Bangkok.

A total of 1.9 km of reef surveys were conducted at twenty-seven discreet survey sites. Both biotic and abiotic parameters of the coral reef communities as well as data on the reef fish community structure were recorded in ten meter sub-transects.

Using Bray-Curtis multivariate analysis techniques, a dendrogram or cluster plot was produced that identified nine discreet benthic classes comprised of different coral reef communities. These benthic classes are quantified and fully described in this report.

Overlaid onto a high-resolution Ikonos satellite image, this field data was used to perform a supervised classification on the image. A total of 4.25 km^2 of reefal habitat was identified from the image, of which 69% was positively classified into one of the nine benthic classes identified from the field-collected data.

A biodiversity inventory conducted as part of this assessment positively identified two hundred and seventy four species of reef fish in twenty-four families and seventy species of scleractinian reef building corals.

Overall coral reef health in Surin Park is considered to be good. The location of the Park in an offshore area with little development affords it protection. It has however been noted by other authors that the zoning scheme in place in the Park is in need of review and restructuring.

It is recommended that the kind of information collected and presented in this report is extended in its breath and comprehensiveness to include the other Marine National Parks in the East Andaman Sea and that this information be used to formulate additional management initiatives and strategies for an area which is of high International importance.

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1 Introduction

The Surin Islands Marine National Park, situated in the upper Andaman Sea in Phang-Nga Province, consists of five granitic islands. There are two main islands, North and South Surin, with three smaller islands, Torinla, Pachumba and Stork Island, and two exposed pinnacles, Pae and Kong. The Park covers a total area of 135 km² of which 76% (102 km²) is marine habitat. The Park supports 33 km² of terrestrial habitat, consisting mainly old growth tropical forest. The park is administrated by the National Parks, Wildlife, and Plant Conservation Department of the Royal Thai Government Ministry of Natural Resources and Environment.

Biological data on the reefs of Surin are sparse, with only a few recent studies undertaken, including Kasetsart University (Saisaeng 2002; Sittithaweepat 2001; Thamrongnawasawat *et al* 1995; Worachananant 2000). Work undertaken by Thamrongnawasawat *et al* (1995) states that more than 260 species of fishes, 33 genera of soft corals and gorgonians, 68 species of hard coral, 48 species of nudibranchs and 31 species of associated shrimps can be found within the Park. Thamrongnawasawat *et al*. (1995) report that Torinla Island supports the best reef conditions, with more than 90 % live coral coverage. The park is reputed to support some of the best diving in Thailand, with the shallow reef system attracting more than 20,000 visitors per year (Worachananant et al. 2004).

Relative to many of South East Asia's reefs, stressors on Surin's reefs are few. As a result of the considerable distance from the mainland, the surrounding water quality is thought to be high, with a low concentration of pollutants (Worachananant et al. 2004). The El Niño phenomenon of 1998 caused deterioration and bleaching of reefs in some areas, especially Mae Yai Bay. All the islands are covered with healthy forest, reducing sedimentation potential (Worachananant et al. 2004). Most researchers suggest that the major threat is from human related activities (Sittithaweepat 2001; Thamrongnawasawat *et al*., 1995; Worachananant 2000). Sources of pollution include the park's accommodation facilities, oil spillage from boats and frequently used detergents (Worachananant et al. 2004).

For nearly 20 years, the UK-based non-governmental organisation (NGO), Coral Cay Conservation (CCC), has been carrying out ecological surveys on coral reef systems. CCC is dedicated to '*providing resources to protect livelihoods and alleviate poverty through the protection, restoration and sustainable use of coral reefs and tropical forests*' in collaboration with government and non-governmental organisations within a host country. CCC provides a range of services, including data acquisition, assimilation and synthesis, conservation education, technical skills training and other capacity building programmes. CCC is associated with the Coral Cay Conservation Trust (the only British-based charity dedicated to protecting coral reefs) and the USA-based Coral Cay Conservation Foundation.

In the aftermath of the tsunami event of December 26th 2004, CCC launched a project in the Surin Islands Marine National Park. This work was funded by the UK Government's Foreign and Commonwealth Office (FCO). Undertaken during February and March 2005, the project comprised of two independent but complimentary studies: the first to quantify the level of tsunami-induced damage to the reefs, and the second to assess the current state of the marine resources of the park. The results of the former study are presented in the report by Coral Cay Conservation (2005).

This report documents the results of the latter study, the objective of which was to produce a Geographic Information System (GIS) based resource map of the reefs of the Surin Marine National Park. To achieve this, baseline marine ecological data were gathered from a series of biogeographically diverse sites. From these data, a series of ecologically discreet 'habitats' was determined, further examples of which were then identified through the use of remote sensing applications.

Habitat mapping of this kind is playing an increasingly intrinsic role in the creation and evaluation of management strategies for coral reef systems, whose complexity has historically impeded the appropriate implementation of traditional management techniques.

2 Methodology

2.1 Survey Design

The assessment of the marine resources of the Surin Islands was done by SCUBA diving at sites representative of key representative habitats of the Surin group that are heavily influenced by variations in coastal morphology and levels of exposure. Survey sites were pre-determined based on spatial analysis of a high-resolution satellite image of the area and the tsunami assessment.

This report made use of an Ikonos high-resolution image of the Surin Islands. The image was acquired after the December 2004 tsunami on the 25th of January 2005 and was supplied to this program by the Center for Remote Imaging, Sensing and Processing facility of the University of Singapore and Space Imaging South East Asia. Throughout this report, the image is displayed referenced to a Universal Transverse Mercator projection (zone 48N) on a WGS-84 datum.

Site selection was also influenced by time and resource restrictions and previous monitoring. Surveys were undertaken from the 10th to the 13th of March 2005 at twenty eight key habitat sites (see figure 2.1).

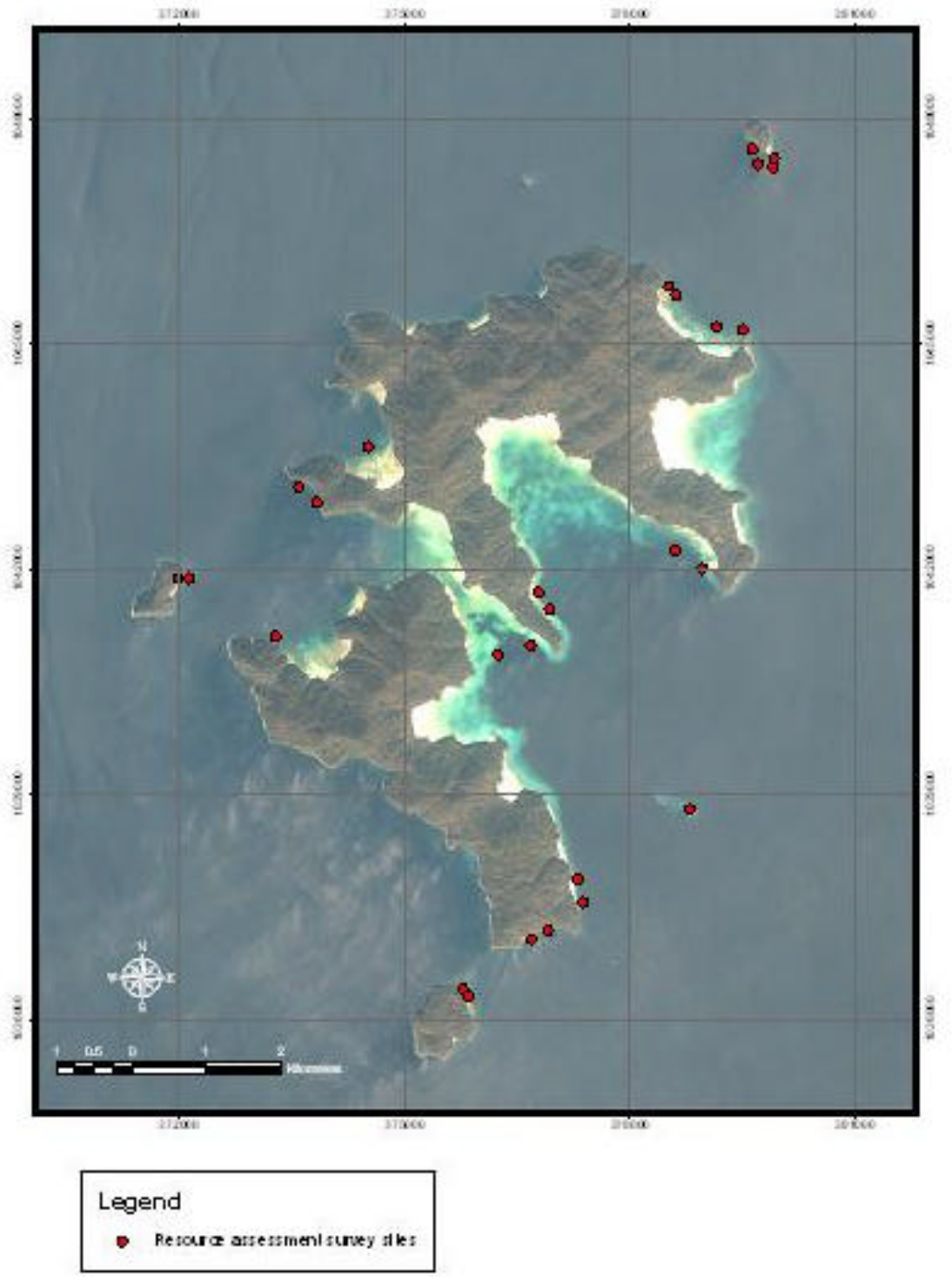


Figure 2.1. Resource assessment survey sites around Mu Ko Surin Island

At each site a quantitative assessment of benthic cover and fish was undertaken. Indicators of benthic cover and fish species diversity were assessed by 2 SCUBA divers along a fixed transect line that was laid parallel to the reef depth contour. The transect covered the full reef profile from the reef crest, down the reef slope to the sandy bottom of the lower reef slope. The length of the line varied from 40-100 m, dependant on the spatial extent of the reef.

Each transect was split into sample units 10 m in length which was a resolution which allowed accurate representation of the reef zones. The depth and orientation of each sample unit was also determined.

The benthic quantitative assessment sample unit was 20 m^2 (10m length x 2m wide). Benthic indicators were chosen to determine substrate cover, coral life forms and algae (refer to table 2.1). Within each 20m^2 sample unit the cover of each indicators as determined to the nearest 5 %. Live hard coral was determined to be either of the Genus Acropora or a non-Acropora. Acropora corals were then placed into one of the following life forms; branching, tabulate, digitate, sub-massive, encrusting or bottlebrush whilst non-Acropora corals were identified to the life form categories; branching, foliose, massive, sub-massive, encrusting or mushroom. In addition, the presence of Fire Coral (Genus Millepora) and Blue Coral (Genus Heliopora) was also recorded.

Benthic Indicator	Explanation
Sand (SAN)	Exposed sediment < 0.5 cm particle size that falls quickly to the bottom after being dropped.
Bedrock (BDK)	Hard substrate whether it is covered in e.g. turf or encrusting coralline algae and also includes dead coral that is more than about 1 year old, i.e. is worn down so that few corallite structures are visible, and covered with a thick layer of encrusting organisms and/or algae.
Rubble (RUB)	Old coral rock and pebbles with a covering of algal turf and coralline algae. It also includes rocks between 0.5 cm and 15 cm in size.
Recently Killed Coral (RKC)	Hard coral that has died recently. The skeleton has a characteristic white colour with no algal growth.
Mud (MUD)	Fine sediment that remains in suspension if disturbed.
Dead Coral with Algae (DCA)	Hard coral still part of its original colony. Corallite structures still recognizable but have been overgrown by algae.
Live Hard Coral (LHC)	Live hard coral cover.
Sessile Invertebrates (SI)	Non-mobile invertebrates including corallimorphs and zoanthids.
Soft Coral (SC)	Soft coral
Turf Algae (TA)	Thick algal turf and fleshy algae
Filamentous Algae (FA)	Fine filamentous algae

Table 2.1. Benthic indicator classes recorded on resource assessment surveys around Mu Ko Surin National Park.

Fish community structure was determined for a 5m wide area (2.5 m either side of the transect line). In each $50m^2$ sample unit, a visual census was taken for key indicators fish and families. Refer to table 2.2. After laying the tape the diver waited 5 minutes to allow the fish to recover from the disturbance.

Target family	Target species
Goatfish	Dash-Dot
Wrasse	Checkerboard
	Bird
	Slingjaw
	Blue Streaked Cleaner
Butterflyfish	Indian Ocean Vagabond
	White Collar
	Chevroned
	Threadfin
Spadefish	
Surgeonfish	Moorish Idol
	Brush Tail Tang
	Striped
Rabbitfish	Black-eyed
Damselfish	Blue-Green Chromis
	Humbug Dascylus
	Scissor Tail Sergeant
	Colombo Damsel
	Clarks Anemonefish
Spinecheek	Bridled Monocle Bream
Triggerfish	Black
	Titan
Snapper	Checkered
	Two-spot
Grouper	Peacock
	Blue-spot
Parrotfish	Swarthy
Angelfish	Regal
Sweetlips	Oriental
Pufferfish	Black-spot
Lizardfish	
Moray Eel	Giant Moray
Fang-Blenny	

Table 2.2. Target family and species of reef fish recorded during the resource assessment around Mu Ko Surin Island

2.2 Data Analysis

The field data were analysed using Bray Curtis Similarity Coefficient in Plymouth Routines in Multivariate Ecological Research software (PRIMER) to cluster the sites according to the similarity of habitat and community composition. Benthic class descriptions are based on reef zones, depth and dominant species. Field data were stored in a MS Access database and linked to a specially designed GIS held in Arc View software to allow spatial analysis and extrapolation.

2.3 Image Processing and habitat mapping

Remote sensing provides a synoptic portrait of the Earth's surface by recording numerical information on the radiance measured for every picture element (or pixel) in each spectral band of a satellite image. To create a habitat map, the operator on the basis of field survey data references pixels as belonging to specific habitats. Using these reference pixels, imagery processing software was used to develop a signature set to represent the reflectance of each benthic class. Subsequently, using these signature sets, the computer was tasked with performing a supervised classification on the pixels in the image for where no field-collected data was available. This form of classification has been shown to produce accuracy levels within acceptable thresholds for the purpose of management decision-making.

2.3.1 Glint removal

One of the disadvantages of using high resolution remotely sensed imagery to map underwater regions such as coral reefs is that any wave action on the seas surface can create areas of abnormally high reflectance. Visible to the naked eye as white wave crests, these glint areas completely obscure the coral reef as the target surface.

This effect can however be corrected using the component bands of the imagery. Ikonos captures four discreet pictures of the subject target. These pictures or bands are taken in the red, green, blue and near infrared areas of the electromagnetic spectrum. Water absorbs nearly all-infrared light within the first few centimetres though areas of wave crests reflect this component of light. Using this phenomenon, the bands present

in the remotely sensed imagery can be mathematically ratioed and then processed to remove the wave crests.

This adds considerably to the potential for the image to be both visually interpreted and perhaps more importantly to be subsequently classified using the digital information in the imagery. Whilst the overall accuracy improvement of the habitat map produced using glint-removed imagery versus non-corrected imagery has not been quantified to date, this method has been shown to be of great value when using high-resolution imagery. The technique employed in this work program is adapted from the un-published paper by Hedley *et al.*

Figure 2.2 shows an area of interest taken from the Ikonos image from the east side of Mu Ko Surin. It shows the effect of the application of the wave crest glint removal process and the increased ability of the imagery to map the underlying coral reef target area.

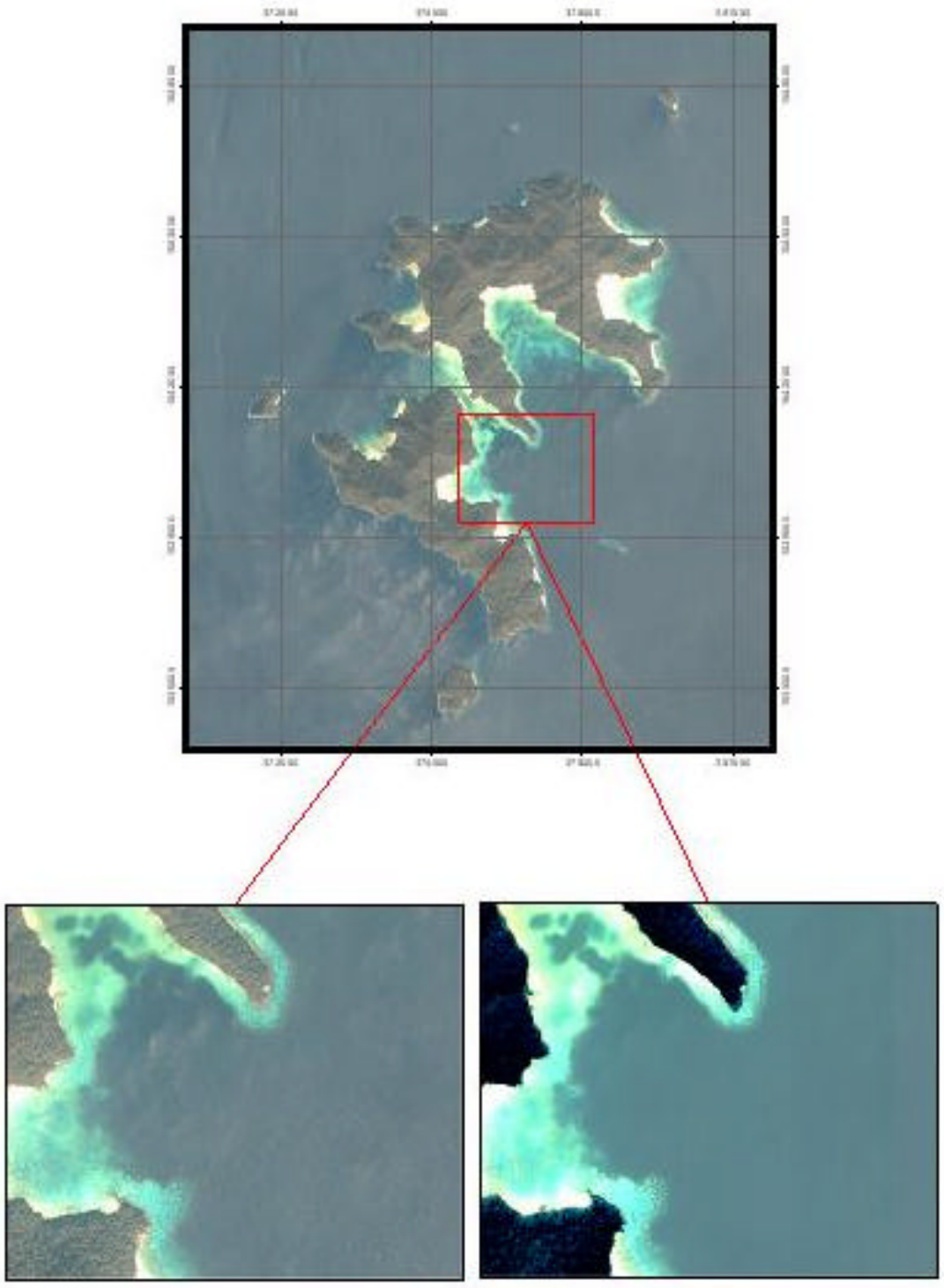


Figure 2.2. The effect of the glint removal process applied to an Ikonos image used in the production of the report. The top image illustrated the areas of interest east of Ko Surin. The bottom left shows the un-corrected image complete with sea surface glint whilst the bottom right image shows the glint corrected image. Subsequent classification stages were performed on the glint corrected image.

3 Results

3.1 Biodiversity inventory

As part of the resource assessment undertaken, a biodiversity inventory of reef fish and scleractinian corals was compiled. A total of two hundred and seventy-four reef fish species in forty-nine families were positively identified. In addition, seventy species of reef building or scleractinian corals in twenty-four families were catalogued. Full species lists are given in appendix one and appendix two for corals and fish respectively.

3.2 Benthic class definition

Figure 3.1 shows the dendrogram produced from hierarchal cluster analysis of the 1.9 km of coral reef survey undertaken in this investigation. Each coloured section on the dendrogram represents a natural clustering of similar coral reef types. It assumed from the clusters that they represent different benthic classes of coral reef found around Mu Ko Surin in this investigation.

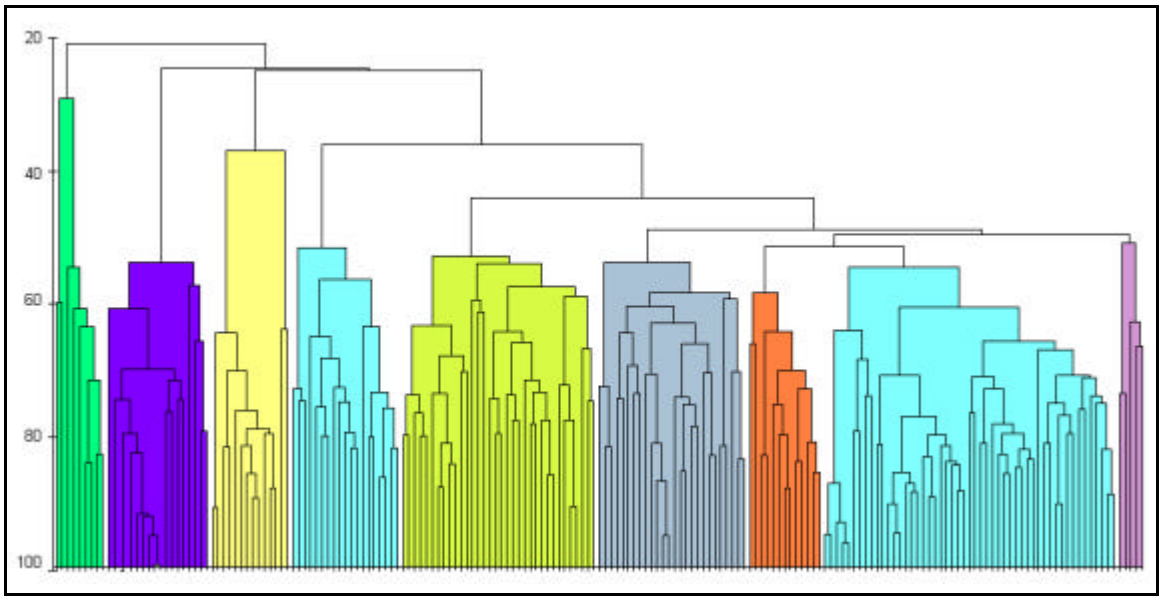


Figure 3.1. Dendrogram derived from Bray-Curtis similarity measures performed on community structure data recorded as part of the resource assessment within Surin Marine Park.

A total of nine statistically discreet benthic classes have been found within the data set collected. These benthic classes have been described both quantitatively and pictorially in table 3.1.

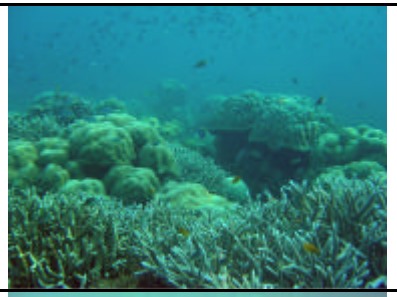
Benthic class	Depth (m)	Substrate	Cnidaria cover	Dominant cnidaria/ scleractinian life form	Benthic class photograph
1- Branching Acropora and massive non-Acropora dominated reef crest	5.9	Rubble (15%), Bedrock (8%)	Scleractinian (68%)	Acropora branching (34%), Non-Acropora massive (14%)	
2- Coral communities developed on terrestrial bedrock substrate	9.4	Bedrock (68%), Rubble (9%)	Scleractinian (21%)	Acropora branching (14%), Non-Acropora massive (6%)	
3- Mid-reef slope Acropora branching communities	6.4	Dead coral with algae (34%)	Scleractinian (45%)	Acropora branching (42%)	

Table 3.1. Benthic classes derived from hierarchal cluster analysis on field-collected data undertaken as part of the resource assessment in Mu Ko Surin National Park. Values in parentheses indicate the percentage cover of the respective variable.

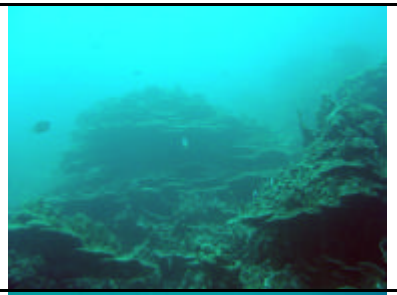
Benthic class	Depth (m)	Substrate	Cnidaria cover	Dominant cnidaria/ scleractinian life form	Benthic class photograph
4- Mid to lower reef slope supporting high live hard coral	13.1	Sand (13%), Rubble (8%)	Scleractinian (75%)	Non-Acropora massive (32%), Non-Acropora branching (27%), Non-Acropora foliose (16%)	
5- Reef crest dominated by sub-massive and massive non-Acropora coral colonies	5.2	Rubble (11%), Bedrock (8%)	Scleractinian (61%)	Non-Acropora sub-massive (37%), Non-Acropora massive (24%)	
6- Rubble dominated mid reef slope	8.8	Rubble (75%), Sand (5%)	Scleractinian (9%)	Acropora branching (2%), Non-Acropora sub-massive (2%)	

Table 3.1. continued Benthic classes derived from hierarchal cluster analysis on field-collected data undertaken as part of the resource assessment in Mu Ko Surin National Park. Values in parentheses indicate the percentage cover of the respective variable.

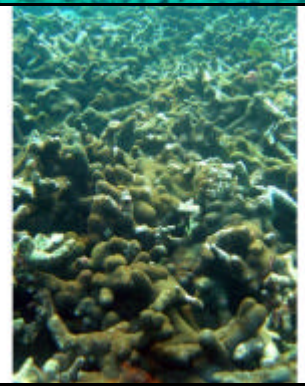
Benthic class	Depth (m)	Substrate	Cnidaria cover	Dominant cnidaria/ scleractinian life form	Benthic class photograph
7- Bare sand	Variable	Sand (68%)	Scleractinian (4%)	Non-Acropora massive (3%), Acropora branching (3%)	
8- Sand and patchy live hard coral cover	Variable	Sand (24%), Rubble (21%)	Scleractinian (22%)	Acropora branching (10%), Non-Acropora massive (8%)	
9- Reef crest dominated by zoanthids colonising dead coral skeletal material	5.6	Dead coral with algae (27%)	Sessile invertebrates (51%), Scleractinian (10%)	Zoanthids (47%), Acropora branching (4%), Heliopora (2%)	

Table 3.1. continued Benthic classes derived from hierarchal cluster analysis on field-collected data undertaken as part of the resource assessment in Mu Ko Surin National Park. Values in parentheses indicate the percentage cover of the respective variable.

3.3 Benthic habitat map

Figure 3.2 shows the benthic classification map produced from the combination of field collected and analysed data together with a high resolution Ikonos satellite image of the Surin Island area.

The areal coverage of each of the benthic classes has been summarised in table 3.2.

Habitat	Number of pixels	Square kilometres	Percentage
1- Branching Acropora and massive non-Acropora dominated reef crest	641660	0.64	15.1
2- Coral communities developed on terrestrial bedrock substrate	140041	0.14	3.3
3- Mid-reef slope Acropora branching communities	289407	0.29	6.8
4- Mid to lower reef slope supporting high live hard coral	451159	0.45	10.6
5- Reef crest dominated by sub-massive and massive non-Acropora coral colonies	373787	0.37	8.8
6- Rubble dominated mid reef slope	87138	0.09	2.1
7- Bare sand	375120	0.38	8.8
8- Lower reef slope with patchy live hard coral cover	508296	0.51	12.0
9- Reef crest dominated by zoanthids colonising dead coral skeletal material	72056	0.07	1.7
Unclassified	1307761	1.31	30.8
Total	4246425	4.25	100

Table 3.2 Coverage statistics for each coral reef benthic class identified by supervised classification on an Ikonos image of Mu Ko Surin National Park

The statistics calculated from the Ikonos image indicate that the shallow benthic areas of the Mu Ko Surin National Park that are likely to support reefal development cover 4.25 km^2. Of this, using the techniques employed in this investigation, positive classification into one of the benthic classes described from the field data collected has been secured on 69% of this area.

The most frequently occurring benthic class found was the branching Acropora and massive non-Acropora reef crest class which occupied 15% of the total described area. The benthic class map indicates that this benthic class has a wide distribution throughout the Surin Islands. Areas of particular concentration of this class include

around the North East section of North Surin Island, at the West entrance to the channel between the Islands and also around the southern tip of South Surin Island and the northern side of Koh Torinla.

The benthic class comprised of coral reef communities developed on terrigenous granitic bedrock boulders was confined in its distribution to the monsoon-exposed west facing coastline predominately of South Surin Island and Koh Torinla. In these areas, the large granitic boulders support patchy branching Acropora coral colonies interspersed with more wave-resistant encrusting coral communities, especially from the Family Faviidae and Poritidae.

The area of highest concentration of benthic class three- the mid-reef branching Acropora assemblage can be found on the southern side of Ao Suthep bay. Here, extensive mono-specific stands of *Acropora nobilis* extend from within six meters of the surface down to sixteen meters where reefal development ceases and is replaced by a predominately sand dominated class.

The distribution of benthic class four- the mid to lower reef slope supporting high live hard coral cover was found to be confined largely to the east and north-east of North Surin Island. In the northern section of the Island, this benthic class was found occurring below what were exceptionally high live hard coral reef crests comprised of a mixture of massive and sub-massive Porites colonies and extensive stands of branching and tabulate Acropora colonies. Patches of this benthic class were also found around Ao Pakkard on the southern most point of South Surin Island.

The massive and sub-massive non-Acropora dominated reef crest areas (class five) were confined largely to the northern and northeastern coastlines of North Surin Island. In these regions, the reef crest occurred as a mixed community of this class and also the branching Acropora dominated reef crest class (class one). The dominant species in this benthic class were species of massive growth form Porites and also of the sub-massive growth form of *Porites rus.* In sections of the north coastline of North Surin Island towards the east end of Ao Jaak, this class formed an extensive and wide reef crest band with; in places, 100% live hard coral cover.

The rubble dominated benthic class six occurred in extremely isolated locations. In fact, the one area that comprised over 80% of the distribution of this benthic class was found on the northern side of the east entrance to the channel between North and South Surin Island. Here, the reef slope was dominated by rubble derived from what once appears to have been a particularly high live hard coral community dominated by branching Acropora species. This pattern continued to the south side of the channel entrance though here the un-consolidate rubble borne of dead branching Acropora was replaced at depth by fields of dead foliose non-Acropora species, the likely Genus of which was Turbinaria. This area did not however appear in the benthic class determining multivariate analysis as a rubble dominated area, because, as the dead coral was still in situ and was not unconsolidated, the divers did not classify it as rubble.

Classes seven and eight comprised largely of sand. When processing the satellite image and performing the supervised classification, the difference in the reflectance of these areas proved similar and therefore problematic in the classification scheme. This is likely because instead of being two discreet benthic classes, there is in reality a continuum of benthic classes with either an increasing or decreasing sand component. Using the imagery, it proved easier to classify shallow back-reef areas as being comprised of the more bare sand class (class seven) and lower reef slope areas in deeper water as being in class eight. Indeed, examination of the benthic classification map indicates that areas classified as class seven are restricted to shallow areas, whereas the more turbid and deeper west entrance to the channel between North and South Surin has been classified as being the area of greatest density of class eight of mixed sand and live hard coral.

Finally, benthic class nine described as reef crest areas dominated by zoanthids growing on dead coral skeletal material was found in abundance only in a very isolated region on the southern tip of Koh Stock. In this region however, the band of this benthic class was, in places, over forty meters wide and extended from deeper mixed coral communities to the boulder foreshore.

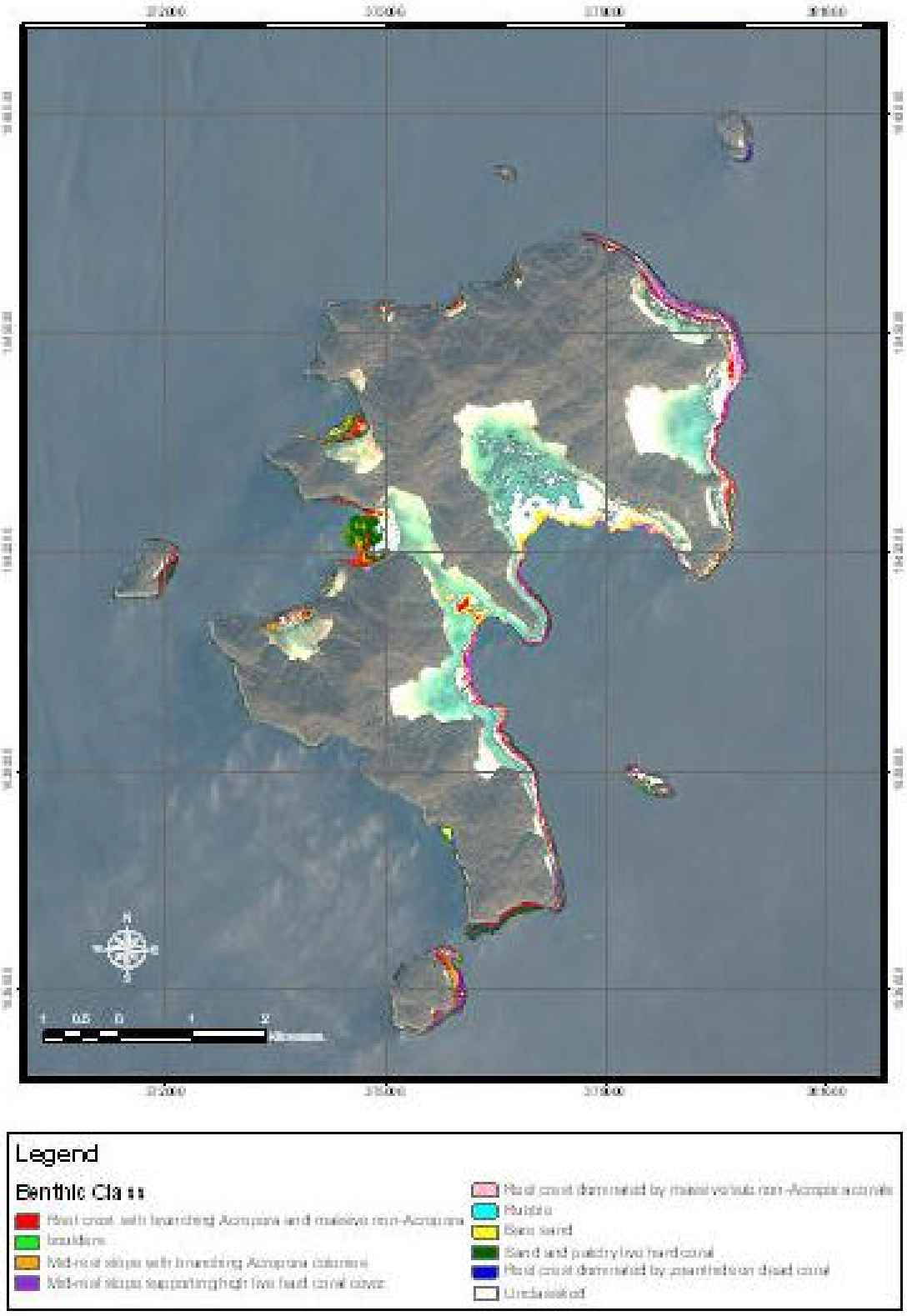


Figure 3.2. Benthic class map of the coral reef areas of Mu Ko Surin National Park. Derived from field-collected data in combination with an Ikonos high-resolution satellite image. See text for full benthic class definitions.

3.4 Reef fish community composition

Figures 3.3-3.5 illustrate the data collected on coral reef fish community structure as part of the resource assessment undertaken.

The data for overall fish populations are represented in figure 3.3 by benthic class. The magnitude of the values recorded in the areas of high coral cover (classes 1, 3, and 5) and rubble (class 6) are ascribable to the complex nature of these habitats, which provide a multitude of refuges, encouraging habitation. Conversely, the high values recorded in sand habitats (class 6) may be accounted for in part by the lack of cover (increasing the observable incidence of the fishes), and in part by the presence of large numbers of Goatfishes (Mullidae) and Gobies (Gobiidae).

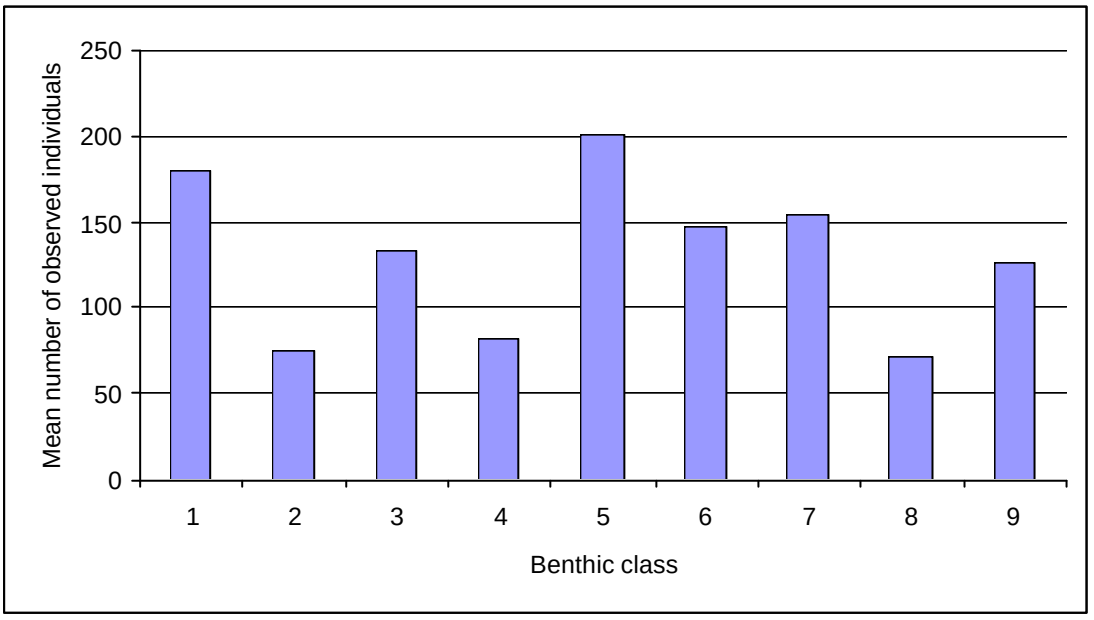


Figure 3.3. Mean number of observed reef fish individuals per 250 m^3 water volume by benthic class.

The data for the populations of large carnivores are represented in figure 3.4 comprising of the values recorded for members of the Snapper family (Lutjanidae) and Grouper family (Serranidae). As large carnivores such as these are highly valued targets for fisheries, they can be used as indictors of over fishing. The populations are high across all habitats, with particularly notable values recorded in most of the coral dominated communities (classes 1,3 and 5).

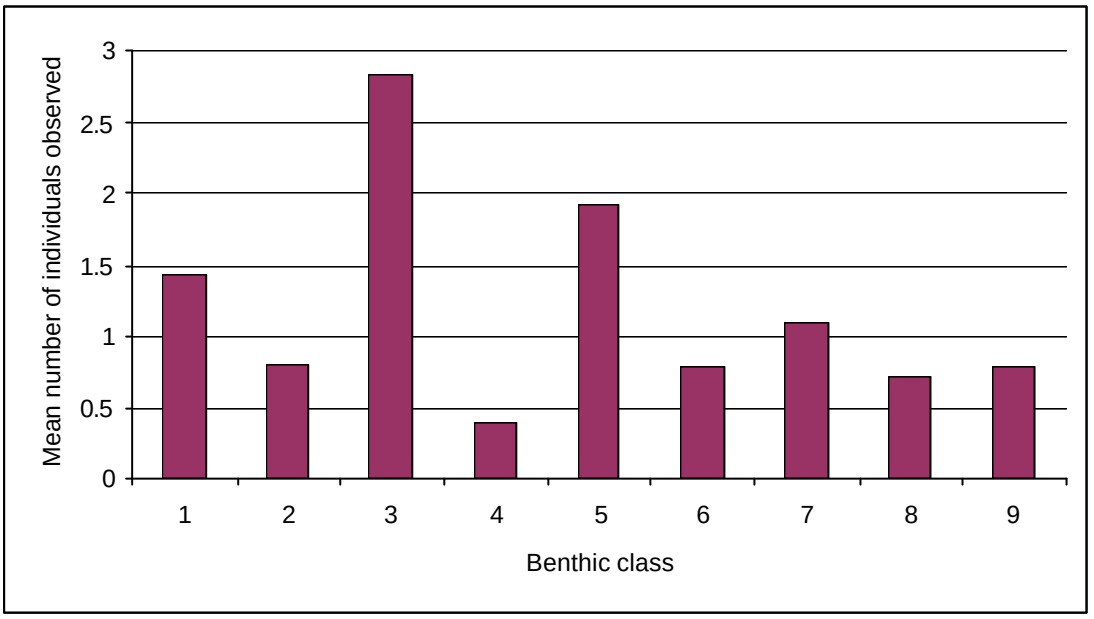


Figure 3.4 Mean number of observed carnivorous reef fish individuals (Grouper and Snapper families) per 250 m^3 water volume by benthic class.

The data recorded for large herbivores are represented in figure 3.5. Although herbivores can be used as indicators of algal overgrowth, the larger species belonging to the families of Surgeonfishes (*Acanthuridae*), Parrotfishes (*Scaridae*) and Rabbitfishes (*Siganidae*) can also be used as indictors of over fishing, as they are also valuable target families for fisheries. As would be expected within any 'healthy' coral reef ecosystem, the number of large herbivores is greater than the number of large carnivores across all classes, with the highest values being recorded in most of the coral-dominated communities (classes 1,3 and 5) and the rubble and/or dead coral - dominated communities (classes 6 and 9). The elevated levels of algal cover normally associated with these latter communities may account for this.

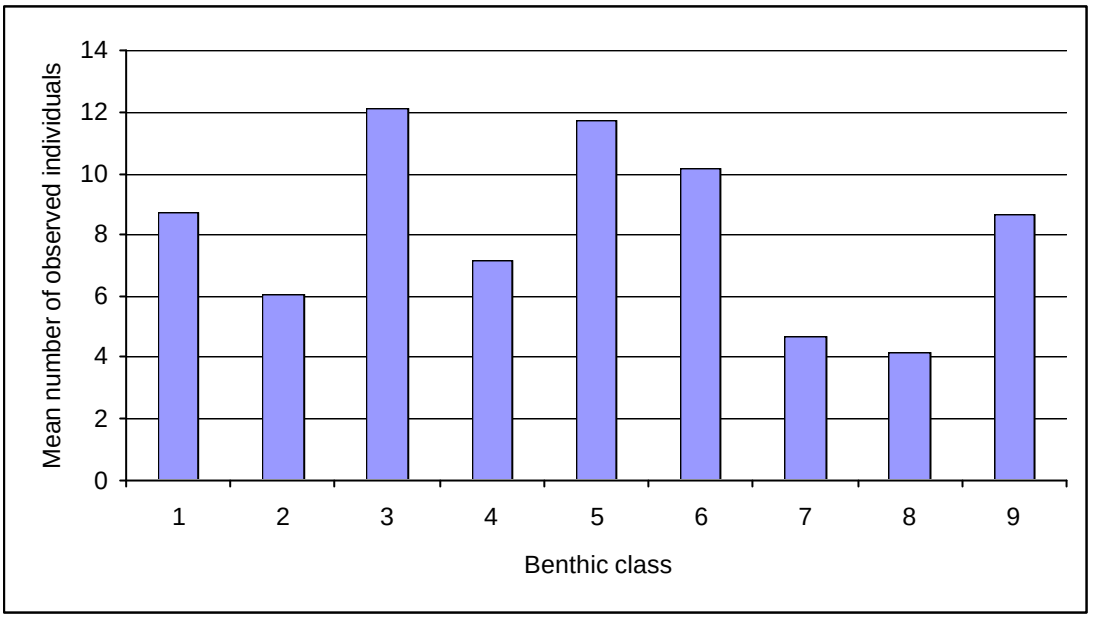


Figure 3.5. Mean number of observed herbivorous reef fish (Rabbitfish, Surgeonfish and Parrotfish families) individuals per 250 m^3 water volume by benthic class.

4 Discussion and Recommendations

The data presented in this report indicate that the coral reef resources of Mu Ko Surin National Park are of international importance. The work of Thamrongnawasawat *et al* (1995) found there to be 260 species of reef fish and 68 species of hard reef building corals. The work undertaken in the production of this report has found additional species to enhance these inventories.

Surin plays host to a wide range of coral reef types, with large variations in levels of apparent disturbance and intrinsic health. The presence of areas dominated by unconsolidated rubble consisting of hard coral skeletal material indicates that an agent of disturbance has acted on the area. By contrast, much of the northern coastline of North Surin Island is characterised by extremely healthy, biodiverse and productive shallow reef crest areas. These reef crests exhibit exceptionally high complexity and structural rugosity, in many areas consisting of one hundred percent live hard coral cover.

This resource assessment is not intended to be complete and exhaustive. The benthic class definitions are based upon 1.9 km of reef surveys in many of the reef geomorphological classes. It is likely that, with additional data, the number of reef types classified herein will increase.

The value of high resolution remotely sensed imagery has been strongly demonstrated in this project. Processing of Ikonos imagery has allowed not only the accurate mapping of the shallow coral reef habitats of Mu Ko Surin, but also the quantification of these habitats.

The complementary report to this document quantifies some of the impacts of the 2004 Indian Ocean tsunami event on the reefs in Surin National Park. It indicates that whilst impacts are apparent in the Park, these impacts are extremely localized in nature and do not have a major significant impact on the overall health of the coral reef resources. Conversely, from evidence presented in both these reports, it is

apparent that Surin Park has been impacted in the past by agents that have caused far greater perturbations to the coral reef ecosystems.

The offshore location of the Surin Islands may be considered to be of great benefit to its coral reefs. The waters surrounding the park are oceanic in nature and levels of pollutants are likely to be negligible overall, although the small-scale developments existing on the islands may create isolated 'hotspots'. Effectively, Mu Ko Surin currently represents what can be considered to be a largely pristine Andaman Sea coral reef area. It is likely, however, that to consider the Surin Islands in isolation is to overlook its role as a constituent part of a larger, complex system of larval dispersal and recruitment along many of the granitic Islands of the east Andaman Sea.

Given the protection that the Surin Islands' status as a National Park provides, this is likely to continue into the future. However, as has been observed by Worachananant et al. (2004), the existing zoning scheme for resource use is in need of restructuring and consolidating.

Recommendations

- To facilitate further in-depth resource assessment programs to include an increased number of biotic and abiotic variables in the reef assessment. The inclusion of these additional data would allow the refinement and extension of the benthic classification scheme represented in this report

- Additional benthic classes should then be mapped using high resolution satellite imagery as has been initiated in this work program

- Effective and incisive management decision-making tools should be designed and implemented to monitor development and to safeguard the extant condition of the reefs and to safeguard against degradation. These tools could provide the basis for the restructuring of the zoning scheme in place around Mu Ko Surin National Park

- A comprehensive national and potentially trans-boundary management scheme should be developed that encompasses all of the Islands found in the East Andaman Sea. This would result in Mu Ko Surin and the other Marine National Parks being considered as part of a complementary network of sustainably managed marine natural resources, rather than in isolation.

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Appendix one
Scleractinian Biodiversity Inventory of Mu Ko Surin Marine National Park

Family	Genus	Species
Acroporidae	*Acropora*	*formosa*
	Acropora	*hyacinthus*
	Acropora	*nobilis*
	Acropora	*palifera*
	Acropora	*robusta*
	Astreopora	*myriopthalma*
	Montipora	*confusa*
	Montipora	*porites*
	Montipora	*spumosa*
	Montipora	*stellata*
Astrocoeniidae		
Pocilloporidae	*Pocillopora*	*damicornis*
	Pocillopora	*eydouxi*
	Pocillopora	*verrucosa*
	Seriatopora	*hystrix*
	Stylophora	*pistillata*
Euphyllidae	*Euphyllia*	*ancora*
	Euphyllia	*glabrescens*
	Physogyra	*lichtensteini*
	Plerogyra	*simplex*
	Plerogyra	*sinuosa*
Oculinidae	*Galaxea*	*astreata*
	Galaxea	*cryptoramosa*
	Galaxea	*fascicularis*
Meandrinidae		
Siderastreidae	*Psammacora*	*digitata*

Family	Genus	Species
Agariciidae	*Coeloseris*	*mayeri*
	Gardineroseris	*planulata*
	Leptoseris	
	Pachyseris	*gemmae*
	Pachyseris	*rugosa*
	Pachyseris	*speciosa*
	Pavona	*cactus*
	Pavona	*clavus*
	Pavona	*decussata*
	Pavona	*duerdeni*
	Pavona	*explanulata*
	Pavona	*varians*
Fungiidae	*Ctenactis*	*echinata*
	Herpolitha	*limax*
	Sandalolitha	*robusta*
Rhizangiidae		
Pectiniidae	*Oxypora*	*lacera*
	Pectinia	*paeonia*
Merulinidae	*Hydnophora*	*excesa*
	Hydnophora	*microconos*
	Hydnophora	*rigida*
	Merulina	*scabricula*
Dendrophylliidae	*Tubastrea*	*micrantha*
	Turbinaria	*reniformis*
Caryophyllidae		
Mussidae	*Lobophyllia*	*hemprichii*

Family	**Genus**	**Species**
Faviidae	*Cyphastrea*	*micropthalma*
	Diploastrea	*heliopora*
	Favia	*favus*
	Favia	*lizardensis*
	Favia	*stelligeri*
	Favites	*abdita*
	Goniastrea	*edwarsi*
	Goniastrea	*pectinata*
	Leptastrea	*transversa*
	Leptoria	*phrygia*
Trachyphylliidae		
Poritidae	*Alveopora*	
	Echinopora	*horrida*
	Echinopora	*lamellosa*
	Echinopora	*pacificus*
	Goniopora	
	Portites	*attenuata*
	Portites	*australensis*
	Portites	*cylindrica*
	Portites	*nigrescens*
	Portites	*rus*
Milleporidae	*Millepora*	*intricata*
	Millepora	*platyphylla*
Helioporidae		

Appendix two
Reef Fish Biodiversity Inventory of Mu Ko Surin Marine National Park

Family	Latin name	Common name
Acanthuridae*	*Naso unicornis*	Bluespine unicornfish
	Zebrasoma scopes	Brushtail tang*
	Acanthurus triostegus	Convict tang
	Naso brachycentron	Humpback unicornfish
	Acanthurus tristis	Indian mimic surgeonfish
	Ctenochaetus striatus	Lined bristletooth
	Acanthurus auranticavus	Orange socket surgeonfish
	Naso lituratus	Orangespine unicornfish
	Acanthurus leucosternon	Powderblue surgeonfish
	Acanthurus blochii	Ringtail surgeonfish
	Naso brevirostris	Spotted unicornfish
	Acanthurus lineatus	Striped surgeonfish*
	Acanthurus guttatus	White spotted surgeonfish
Anthiinae	*Pseudanthias squamipinnis*	Scalefin anthias
Apogonidae	*Apogon lateralis*	Coastal cardinalfish
	Apogon properupta	Coral cardinalfish
	Apogon fragilis	Fragile cardinalfish
	Archamia fucata	Narrowlined cardinalfish
	Apogon exostigma	Narrowstriped cardinalfish
	Apogon compressus	Split band cardinalfish
	Cheilodipterus macrodon	Tiger cardinalfish
Aulostomidae	*Aeoliscus strigatus*	Razorfish
	Aulostomus chinensis	Trupetfish
Balistidae*	*Melichthys niger*	Black triggerfish*
	Balistoides conspicillum	Clown triggerfish
	Sufflamen chrysopterus	Flagtail triggerfish
	Melichthys indicus	Indian triggerfish
	Balistapus undulates	Orange lined triggerfish
	Odonus niger	Red toothed triggerfish
	Balistoides viridescens	Titan triggerfish*
	Pseudobalistoides flavimarginatus	Yellow margin triggerfish

Family	Latin name	Common name
Blenniidae	*Ecsenius bicolor*	Bicolor blenny
	Plagiotremus rhinorhynchos	Bluestriped fang blenny
	Cirripectes filamentosus	Filamentous blenny
	Salarias sinuosus	Fringelip blenny
	Plagiotremus phenax	Imposter fangblenny
	Ecsenius lineatus	Lined blenny
	Plagiotremus tapeinosoma	Piano fangblenny
	Meiacanthus smithi	Smith's fangblenny*
	Petroscirtes xestus	Smooth fangblenny
	Petroscirtes variabilis	Variable fangblenny
Caeionidae	*Caesio teres*	Blue and yellow fusilier
	Pterocaesio tile	Bluestreak fusilier
	Pterocaesio tessellate	Narrow striped fusilier
	Perocaesio marri	Twinstripe fusilier
	Caesio xanthonota	Yellowback fusilier
Carangidae	*Caranx melampygus*	Bluefin travally
	Caranx ignobilis	Giant trevally
	Elagatis bipinnulatus	Rainbow runner
	Seriola lalandi	Yellowtailed kingfish
Carcharhinidae	*Carcharhinus melanopterus*	Blacktip reef shark

Family	Latin name	Common name
Chaetodontidae*	*Chaetodon andermanensis*	Anderman butterflyfish
	Forcipiger longirostris	Big long nose butterflyfish
	Chaetodon melannotus	Black backed butterflyfish
	Hemitaurichtys zoster	Black pyramid butterflyfish
	Chaetodon trifascialis	Chevroned butterflyfish*
	Chaetodon semeion	Dotted butterflyfish
	Chaetodon bennetti	Eclipse butterflyfish
	Chaetodon octofasciatus	Eight banded butterflyfish
	Heniochus varius	Humphead bannerfish
	Chaetodon trifasciatus	Indian redfin butterflyfish
	Chaetodon decussatus	Indian vagabond butterflyfish*
	Chaetodon rafflesi	Latticed butterflyfish
	Chaetodon lineolatus	Lined butterflyfish
	Heniochus acuminatus	Longfin bannerfish
	Heniochus monoceros	Masked bannerfish
	Chaetodon meyersi	Meyer's butterflyfish
	Heniochus varius	Phantom bannerfish
	Chaetodon lunula	Racoon butterflyfish
	Chaetodon falcula	Saddleback butterflyfish
	Chaetodon ephippium	Saddled butterflyfish
	Heniochus diphreutes	Schooling bannerfish
	Heniochus singularius	Singular bannerfish
	Chaetodon auriga	Threadfin butterflyfish*
	Chaetodon triangulum	Triangular butterflyfiah
	Chaetodon vagabundus	Vagabond butterflyfish
	Chaetodon collare	White collar butterflyfish*
	Chaetodon mertensii	Yellowback butterflyfish
	Chaetodon xanthocephalus	Yellowheaded butterflyfish
Congeridae	*Heteroconger hassi*	Spotted garden eel
Dasyatidae	*Himantura fai*	Tahitian stingray
Diodonthidae	*Diodon liturosus*	Black blotched porcupinefish
Echeneidae	*Echeneis naucrates*	Sharksucker

Family	Latin name	Common name
Ephippidae*	*Platax teira*	Longfin spadefish*
	Platax pinnatus	Pinnate spadefish
Fistulariidae	*Fistularia commersonii*	Cornetfish
Gobiidae	*Gnatholepis anjerensis*	Eyebar goby
	Amblygobius semicinctus	Half banded goby
	Eviota sigillata	Sigillata pygmygoby
	Ctenogobiops crocineus	Silverspot shrimp goby
	Oplopomus olopomus	Sinecheek goby
	Eviota mikiae	Yellow & whitestriped pygmygoby
	Amblygobius hectori	Yellowstripe goby
Haemulidae*	*Plectorhinchus gibbosus*	Blubberlip
	Plectorhinchus chaetodonoides	Many spotted sweetlips
	Plectorhinchus vittatus	Oriental sweetlips*
Holocentridae	*Myripristis adusta*	Shadowfin soldierfish
Kyphosidae	*Kyphosus bigibbus*	Gray drummer
	Kyphosus vaigiensis	Lowfin drummer

Family	Latin name	Common name
Labridae*	*Hilichoeres podostigma*	Axelspot wrasse
	Hemigymnus fasciatus	Barred thicklip
	Coris batuensis	Batu coris
	Labroides bicolor	Bicolour cleaner wrasse
	Gomphosus varius	Bird wrasse*
	Bodianus mesothorax	Black belt hogfish
	Macropharyngodon negrosensis	Black wrasse
	Hemigymnus melapterus	Blackeye thicklip
	Labroides dimidiatus	Blue streaked cleaner wrasse*
	Cirrhilabrus cyanopleura	Blueside wrasse
	Helichoeres leucoxanthus	Canarytop wrasse
	Halichoeres hortulanus	Checker board wrasse *
	Halichoeres cosmetus	Cosmetic wrasse
	Thalassoma lunare	Crescent wrasse
	Bodianus diana	Diana'a hogfish
	Halichoeres marginatus	Dusky wrasse
	Cirrhilabrus exquisitus	Exquisite wrasse
	Stethojulis trilineata	Fourline wrasse
	Halichoeres nigrescens	Greenback wrasse
	Cheilinus undulates	Humphead wrasse
	Helichoeres vrolikii	Indian pinstripe wrasse
	Thalassoma jansenii	Jensen's wrasse
	Oxycheilinus digrammus	Linecheeked wrasse
	Anampses lineatus	Lined wrasse
	Oxycheilinus rhodochrous	Oriental wrasse
	Cheilinus fasciatus	Redbreasted wrasse
	Hologymnosus annulatus	Ring wrasse
	Bodianus bilunulatus	Saddleback hogfish
	Thalassoma hardwicke	Six bar wrasse
	Pseudocheilinus hexataenia	Sixstripe wrasse
	Epibulus insidiator	Sling jaw wrasse*
	Thalassoma lutescens	Sunset wrasse
	Cheilinus trilobatus	Tripletail wrasse
	Labrichthys unilineatus	Tubelip wrasse
	Anampses meleagrides	Yellowtail wrasse

Family	Latin name	Common name
Lethrinidae*	*Monotaxis grandoculis*	Humpnose bigeye bream
	Lethrinus lentjan	Pinkear emperor
	Lethrinus harak	Thumbprint emperor
Lutjanidae*	*Macolor niger*	Black snapper
	Lutjanus ehrenbergii	Blackspot snapper
	Lutjanus kasmira	Blue striped snapped
	Lutjanus decussates	Checker snapper *
	Lutjanus quinquelineatus	Five lined snapper
	Lutjanus gibbus	Humpback snapper
	Macolor macularis	Midnight snapper
	Lutjanus monostigma	Onespot snapper
	Lutjanus bohar	Red snapper
	Lutjanus russelli	Russell's snapper
	Lutjanus timorensis	Timor snapper
	Lutjanus biguttatus	Two spot snapper *
Malacanthidae	*Malacanthus latovittatus*	Blue blanquillo
Mobulidae	*Manta birostris*	Manta ray
	Aetobatus narinari	Spotted Eagle ray
Monacanthidae	*Amanses scopas*	Broom filefish
	Oxymonacanthus longirostris	Longnose filefish
	Aluterus scriptus	Scrawled filefish
Mullidae*	*Upeneus arge*	Bandtail goatfish
	Parupeneus heptacanthus	Cinnabar goatfish
	Parupeneus barberinus	Dash dot goatfish*
	Parupeneus cyclostomus	Goldsaddle goatfish
	Mulloidichthys vanicolensis	Yellowfin goatfish
Muraenidae*	*Gymnothorax javanicus*	Giant moray*
	Scuticaria tigerina	Tiger snake moray

Family	Latin name	Common name
Nemipteridae*	*Scolopsis ghanam*	Arabian monocle bream
	Scolopsis bilineatus	Bridled monocle bream*
	Scolopsis taeniopterus	Lattice monocle bream
	Scolopsis xenochros	Pearl streaked monocle bream
	Pentapodus trivittatus	Three striped whiptail
	Scolopsis ciliatus	Whitestreak monical bream
Ostraciidae	*Ostracion meleagris*	Spotted boxfish
	Ostracion cubicus	Yellow boxfish
Pempheridae	*Pempheris vanicolensis*	Vanikoro sweeper
Pinguipedidae	*Parapercis hexophthalama*	Speckled sandperch
Plesiopidae	*Calloplesiops altivelis*	Comet
Plotosidae	*Plotosus lineatus*	Striped catfish
Pomacanthidae*	*Centropyge eibli*	Blacktail angelfish
	Pomacanthus annularis	Blue ringed angelfish
	Centropyge multispinis	Brown pigmy angelfish
	Pomacanthus imperator	Emperor angelfish
	Pygoplites diacanthus	Regal angelfish *
	Pomacanthus semicirculatus	Semicircle angelfish
	Pomacanthus sexstriatus	Six banded angelfish
	Pomacanthus xanthometopon	Yellow masked angelfish

Family	Latin name	Common name
Pomacentridae*	*Cheiloprion labiatus*	Big lip damsel
	Neoglyphidodon melas	Black damsel
	Plectroglyphidodon dickii	Blackbar damsel
	Abudefduf lorenzi	Blacktail sergeant
	Pomacentrus pavo	Blue damsel
	Cromis viridis	Blue green chromis*
	Pomacentrus azuremaculatus	Blue spotted damsel
	Pomacentrus simsiang	Blueback damsel
	Amphiprion clarkia	Clark's anemonefish *
	Pomacentrus proteus	Colombo damsel *
	Amphiprion ocellaris	False clown anemonefish
	Amblyglyphidodon aureus	Golden damsel
	Amblyglyphidodon indicus	Green damsel
	Dascyllus aruanus	Humbug dascyllus *
	Dascyllus carneus	Indian dascyllus
	Chromis dimidiate	Indian half and half chromis
	Plectroglyphidodon lacrgmatus	Jewel damsel
	Pomacentrus moluccensis	Lemon damsel
	Cromis flavipectoralis	Malayan cromis
	Chrysiptera unimaculata	Onespot demoiselle
	Amphiprion ephippium	Red saddleback anemonefish
	Neopomacentrus cyanomos	Regal demoiselle
	Chrysiptera rollandi	Rolland's demoiselle
	Abudefduf sexfasciatus	Scissortail sergeant damsel *
	Amphiprion akallopisos	Skunk anemonefish
	Dascyllus trimaculatus	Three spot dacyllus
	Chrysiptera biocellata	Twospot demoiselle
	Chromis weberi	Weber's cromis
	Amblyglyphidodon leucogaster	White belly damsel
	Dischistodus perspiciliatus	White damsel
	Pomacentrus chrysurus	Whitetail damsel
	Neoglyphidodon nigroris	Yellowtail damsel
	Neopomacentrus azysron	Yellowtail demoiselle
	Abudefduf notatus	Yellowtail sergeant
Priacanthidae	*Priacanthus blochii*	Bloch's bigeye

Family	Latin name	Common name
Ptereleotridae	*Ptereleotris microlepis*	Pearly dartfish
	Ptereleotris evides	Twotone dartfish
Rachycenteridae	*Rachycentron canandan*	Cobia
Scaridae*	*Cetoscarus bicolor*	Bicolor parrotfish
	Scarus ghobban	Blue barred parrotfish
	Scarus frenatus	Bridled parrotfish
	Chlorunus sordidus	Bullethead parrotfish
	Bulbometopon muricatum	Bumphead parrotfish
	Chlorurus troschelii	Greenhead parrotfish
	Chlorunus capistratoides	Indian parrotfish
	Scarus psittacus	Palenose parrotfish
	Scarus rubroviolaceus	Redlip parrotfish
	Scarus rivulatus	Surf parrotfish
	Scarus niger	Swarthy parrotfish *
Scombridae	*Rastrelliger kanagurta*	Long jawed mackerel
	Acanthocybium solandi	Wahoo
Scorpaenidae	*Pterois muricata*	Indian lionfish
	Pterois antennata	Spotfin lionfish
	Scorpaenopsis oxycephala	Tasselled scorpionfish

Family	Latin name	Common name
Serranidae*	*Cromiletes altivelis*	Barramundi
	Epinephelus fasciatus	Blacktip grouper
	Cephalopholis formosa	Bluelined grouper
	Cephalopholis cyanostigma	Bluespot grouper *
	Cephalopholis miniata	Coral grouper
	Cephalopholis urodeta	Flagtail grouper
	Epinephelus quoyanus	Longfin grouper
	Epinephelus malabaricus	Malabar Grouper
	Cephalopholis argus	Peacock grouper*
	Aethaloperca rogaa	Redmouth grouper
	Plectropomus pessuliferus	Roving coral gouper
	Anyperodon leucogrammicus	Slender grouper
	Epinephelus cyanopodus	Speckled grouper
	Plectropomus areolatus	Square tail grouper
	Variola albimarginatal	White edge lyretail
	Epinephelus ongus	Whitestreaked grouper
Siganidae*	*Siganus pulloides*	Blackeyed rabbitfish*
	Siganus fuscescens	Dusky rabbitfish
	Siganus punctatus	Gold spot rabbitfish
	Siganus guttatus	Golden rabbitfish
	Siganus stellatus	Honeycomb rabbitfish
	Siganus javus	Java rabbitfish
	Siganus magnificus	Magnificent rabbitfish
	Siganus virgatus	Variegate rabbitfish
	Siganus vermiculatus	Vermiculate rabbitfish
Sphyraenidae	*Sphyraena qenie*	Blackfin barracuda
	Sphyraena barracuda	Great barracuda
	Sphyraena jello	Pickhandle barracuda
	Sphyraena flavicauda	Yellowtail barracuda
Syngnathidae	*Corythoichthys flavofasciatus*	Network pipefish
Synodontidae*	*Synodus dermatogenys*	Clearfin lizardfish
	Synodus variegates	Reef lizardfish
	Synodus binotatus	Twospot lizardfish

Family	Latin name	Common name
Tertraodontidae*	*Arothron nigropunctatus*	Blackspot puffer*
	Arothron caeruleopunctatus	Bluespot puffer
	Canthigaster solandri	Spotted toby
	Arothron stellatus	Star puffer
Zanclidae*	*Zanclus cornutus*	Moorish idol*

* = species and families recorded for Surin Islands reef resource assessment