‘CORALS IN HOT WATER: CREATING CONDUITS FOR BETTER COMMUNICATION BETWEEN SCIENTISTS & MANAGERS FOR EFFECTIVE REEF CONSERVATION’

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I. PROJECT SUMMARY:

Coral Reefs are among the most complex, biodiverse, and interconnected ecosystems on the planet (Bellwood 2001 and Knowlton 2001). Though they are found underwater, they are deeply connected to, affected by and themselves impact activities on adjacent islands (Mumby et al. 2004, Angell 2004). On a global scale, they are affected by increasing sea surface temperatures, alterations in seawater chemistry, changes in nutrient levels and overfishing (Hoegh-Guldberg 1999, Myers and Worm 2003, Hughes et al. 2003, Hoegh-Guldberg et al. 2007, Munday et al. 2008). Coral reefs were, and indeed still are by many, predicted to be the first and inevitable ecosystemic victim of anthropogenic climate change (Hoegh-Guldberg 1999). However, scientists are slowly beginning to understand the nuances and subtlety of interactions on a reef, the relevance of activities on adjacent land masses, the diversity of coral species, the still greater diversity of zooxanthellae clades and microbial communities, and the scope for resilience that these biodiverse systems provide (Berkelmans and van Oppen 2006, Bourne et al 2008). From a picture of global doom then, we narrow into an exploration of local hope. It has been shown that one of the most powerful ways of buffering a natural ecosystem, such as a coral reef, that is subject to the uncontrollable tides of global change is to maximize resilience at the local level (Patankar et al. 2013). The goal of this project is to improve the understanding of the status of the reef with all its intricate detail, in the Andaman Island Archipelago, India, and to communicate this understanding to managers to better protect them against global scale changes to come. For a true understanding of the reef ecosystems it is beneficial to know not only its current state at a fine spatial resolution, but also its responses in the past to changes in temperature, water quality and other parameters. This

project will form a holistic picture of the reef by identifying and synthesizing existing data from research projects conducted in the region as well as from local agencies. In so doing, this project will create a semblance of long-term monitoring results adding to an understanding of how the reefs have been affected by different processes over the years. The idea of building this comprehensive story of the reef is to increase the effectiveness of management and conservation of this precious yet fragile resource. These results will identify the factors that are important for reef conservation at a scale relevant to local reef managers, and in order to accomplish the goal of increasing management efficacy an objective of this study is to communicate results to Forest Officials in a way that they find useful. This project will create a template that bridges the formidable gap between scientists and administrators by enabling effective communication between them. Such communication is important as it has the potential to increase the productivity and relevance of both their fields. Science that is confined only to obscure journals – unnoticed by and incomprehensible to the larger community – is limited in its relevance. It is therefore highly vulnerable to sources of funding that will be the first to dry up in a rough economy. It is a less rewarding occupation, financially as well as emotionally, than if the results truly make a difference to the study area and enrich its people. Similarly, the management and protection of the reef, in a changing environment and a multitude of pressures and variables, requires the input of the experts especially when managed by officers unfamiliar with the territory.

II. Introduction

Most countries that have coral reefs are either island nations, for whom the ocean is a deep part of their experience – their economy, food as well as their recreation are dependent on the ocean. This is the case with the Caribbean countries, the Maldives and other small island states. India is different. Compared to its extensive coastline, India has relatively few reefs, they are on islands scattered far out, and most of the Indian population has little interaction or awareness of coral reef environments. As tourism is increasing, and global pressures on the reefs are getting stronger, Indian reef managers can no longer rely on remoteness as an agent of protection. The Andaman & Nicobar Islands are the furthest away landmasses from the Indian mainland, their significance is often unknown even by the people sent to manage them, and they contain extensive reef coverage. Rapidly rising carbon dioxide levels and increasing population pressures, there is an urgent need for new management techniques that are collaborative in nature with scientists, industry and local people. This section will familiarise the reader to the Andaman & Nicobar Islands to provide context to the project.

Figure 1: The Andaman Islands

The Andaman & Nicobar Islands form an archipelago in the Indian Ocean, nestled between the Indian peninsula to the west, Burma much closer to the north and Thailand on the east. The islands are young in geological time – Barren Island is in fact an active volcano that is part of the islands. The Ten Degree Channel separates Andamans to the North, and the Nicobar Islands to the South. The topography, vegetation and communities of the two sets of islands differ significantly. The Andaman Islands have a significant amount of tourism, have the only airport, and are more accessible than the isolated and heavily protected Nicobar Islands. There are 325 islands in the Andamans, constituting an area of 6,408 sq. km. Many of these are just rocks and islets though, and only 29 islands have human inhabitants (Official Website of Andaman & Nicobar Administration). The Andaman Islands have a complex ecosystem, with rainforest, mangrove and coral reef habitats. There are many endemic species of birds, lizards, frogs and snakes in the Andamans, and the region has long been a study site for herpetologists. However, little research has been conducted here in terms of coral reef assessments and monitoring. Kulkarni & Saxena's paper emaphasizes the need for a concerted effort for assessment and monitoring of coral reefs in this area, and for this effort to recommend actions that will promote conservation and management rather than isolated academic exercises (Kulkarni and Saxena).

There are many reasons to be interested in the reefs of the Andaman Islands, other than the fact that coral reef habitats are biodiverse environments and threatened globally. Firstly, the corals in the Andaman Sea are some of the few that seem to be able to survive in warmer waters than usual (LaJeunesse et al 2010). The water temperatures here range between 28°C to 30°C, which is warmer by a few degrees than the rest of the Indian

Ocean. Secondly, many reefs in the Andamans are relatively undisturbed by humans – with no divers except the occasional research team – and no inhabitants on the adjacent islands. Thirdly, a large tsunami that impacted the Indo-Indian region in 2004 resulted in a unique disturbance that impacted some reefs, and changed the land tilt of islands, making it higher in some places – exposing vast amounts of reef (Kumar et al 2009). With a fairly recent yet growing tourism industry, it is important to study these reefs before they are further impacted as a result of human activities and put in place management systems that preempt and prevent problems.

Increasingly, coral reef science is recognizing that there are differences in the way that corals react to various stressors – and the extent to which they are able to resist mortality - depending on factors such as species diversity, fish life-history, ecological adaptations to certain temperatures, depth and surrounding ecosystems (Berkelmans and van Oppen 2006, Bourne et al 2008). The same factors also come into play at determining the rate of recovery (resilience) following a disturbance event (Hughes et al. 2010). Any assessment of coral reefs that hopes to be useful for management and conservation purposes must therefore take these key considerations into account.

Part I of this project will tell a story of the coral reefs in the Andaman Islands, with attention to the factors described above, and Part II will be about presenting them in a way that is useful for the purpose of informing managers. If the local authorities can at be made aware of the local issues that they are able to address and are within their control, instead of being bogged down by the global scale problems related to anthropogenic climate change that are degrading reefs, there might be hope for the Andaman corals.

III. The Study Area

Figure 2: The Andaman Islands with study area marked in red box (above) & The study area zoomed in with MGMNP boundary marked in white (below)

The Andaman Islands are comprised of 325 islands, and are spread over an area of 6408 km2 or 2,474 sq miles (Planning Commission of India). Given the time and the scope of this project, it is impossible to conduct such a detailed study for such a large area. Therefore the project will be confined to the reefs and area around the southern tip of the South Andaman Island (see Fig.2).

This region has been chosen as the study area because it is compact enough to cover in the available time frame, and yet includes representations of different levels of anthropogenic impact. It includes a densely populated area that is Port Blair – the capital of the Andaman & Nicobar Islands – the administrative base and therefore the place where most of the Forest Officials have their offices. The study area also houses a large marine protected area – the Mahatma Gandhi Marine National Park (MGMNP), a sparsely populated island – Rutland, some uninhabited islands – North and South Cinque, amongst others. This wide range of land use types in a small region makes this study area an interesting one, within which many comparisons between reefs with varying population pressures as well as levels of protection, are possible. The map above (Figure 2) shows the study area in the broader context of the surrounding region. Of this area, the white line (coordinates between 11°22.06" and 11°36.34" latitude and 92°30.00"W and 92°40.33"E longitude) borders the Mahatma Gandhi Marine National Park (MGMNP), which covers a total area of 281.5 km^2 (Dam Roy et al, 2007). The National Park was notified in May 1983, and includes 15 small islands which are Alexandra, Red Skin, Boat, Hobday, Tarmugli, Grub, Chester, Snob, Belle, Pluto, Malay, Jolly Buoy, Riflemen, Twins and some parts of Rutland Island. Apart from Rutland, which has a small population of 688 persons (Directorate of Economics & Statistics, Andaman &

Nicobar Administration), all the islands in MGMNP are uninhabited and protected from any extractive activities. Directly adjacent to the National Park, and therefore in its zone of influence, there are a 9 small townships. Their populations are given below (Census of India 2001):

Name of Township	Households	Population
Badakhari	121	440
BambooNallah	28	92
Rutland (area adjacent to MGMNP)	45	154
Hashmatabad	144	616
Guptapara	140	716
Wandoor	309	1511
Maymo	118	575
Pongibalu & Badabalu	27	125
Manjeri & Line Dera	99	460
TOTAL	1031	4689

Figure 3: Name, household and population of towns bordering the MGMNP

The southern section of the main South Andaman Island is another part of my study area and this includes North Bay (a reef area), Ross Island (the old capital of ANI), Chidiyatapu and other small villages along the main road.

Port Blair city has a population of 42,317, and the greater Port Blair area (with surrounding villages) population is about 170,000. 45% of the entire population of the Andaman & Nicobar Islands is concentrated in this area (Andaman & Nicobar Administration Website) as it is the administrative capital of the Andaman & Nicobar Islands. Port Blair has the only airport on the islands, and is also home to the major port. There is a significant military presence here due to the islands being the eastern seaboard of the country. While there is no agricultural activity in urban Port Blair, it is the centre where most fisheries resources are sent for cold storage and transport. The administrative area (tehsil) of Port Blair is 1290 km^2, with a commercially relevant area of 125 km^2.

Chidiyatapu and the surrounding villages are in the administrative area (tehsil) called Ferrargunj, and have a total area of 1085 km^2, however the inhabited area is only 200 km^2 (Andaman & Nicobar Administration). This area has more agricultural activity, such as plantations of palm, arracanut and other farms. The area is also home to many fishermen and small business owners operating teashops and such like for the day tourists that flood into the area on weekends and holidays. With a brief introduction to the study area covered, this report will now assess how specific threats to coral reefs are applicable, and what the severity of the threat is likely to be in the different locations of my study area.

IV. Part I: Science

A. Local And Global Threats to Coral Reefs

The sheer density and diversity of marine life found in coral reefs is unparalleled. One in four of every life form known in the ocean is found on coral reefs despite the fact that they occupy a mere 0.2% of oceanic area (Burke et al. 2011). Furthermore, coral reefs are found in some of the most nutrient-poor parts of the ocean. Corals are able to form such physically complex structures and provide habitat, hunting ground and nursery to so many organisms because of the tight recycling of nutrients and energy within each coral polyp and its resident zooxanthellae (Hughes et al. 2003, Burke et al. 2011). This symbiotic relationship functions upon the exchange of food (provided by the zooxanthellae algae photosynthesizing) for shelter (provided by the coral polyp in its own tissue). While it may seem like a simple relationship, it is one that has very particular requirements in terms of environmental parameters and is tolerant to a limited range of fluctuation in these parameters. This section will look at the different environmental factors that affect coral reefs, the relevancy of the factors to the reefs in the South Andamans, and the scale and severity of the threat.

'Reefs at Risk Revisited' provides a global analysis of coral reefs, and outlines the magnitude and location of threats to coral reefs (Burke et al 2011). This report by the World Resources Institute identifies local as well as global pressures on coral reefs and then uses proxies to determine the intensity of each pressure at each geographic area of reef. Each pressure is given an appropriate weightage to determine the level of threat that every area of reef faces. This report is comprehensive in covering different pressures on a reef under broader groupings, and covers both local and global threats. In this section of

my report, I will use the factors identified by Reefs at Rick Revisited to evaluate the level to which pressures known to affect reefs are operating on my study area.

i. Coastal development (coastal construction, unsustainable tourism, sewage and waste run-off)

Since the year 1991, India has had a Coastal Regulation Zone (CRZ) law that regulates industrial and commercial activities and construction directly adjacent to the coast. The Andaman & Nicobar Islands fall under the classification of CRZ-IV, created for small island archipelago (Ministry of Environment & Forests). This prohibits any new permanent construction within 200 metres of the coast, and no structure that exceeds 2 stories within 500 metres of the High Tide line. Much of the Andaman Islands were not yet developed at the time this regulation came into effect, and therefore has resulted in a relatively construction-free coastline in the study area. With this extensive no-development zone that has been stipulated, plenty of room is left for the retreat of intertidal areas and mangroves in the event of sea level rises predicted with the current trend in global warming.

Even for construction further afield, the law specifically states “Corals from the beaches and coastal waters shall not be used for construction and other purposes” (Ministry of Environment & Forests, 2001, Section 6.2).

A larger problem than coastal construction is unsustainable tourism and waste management. The Andaman & Nicobar Islands have experienced a surge of tourism since the 1980s, when the total number of incoming tourists was 9596, to the year 2000, where the number reached 86116 (Ferguson AF & Co Management Consultancy). These figures

are only growing, after a brief dip following the tsunami of 2004. Most of all of this activity impacts the South Andaman region as it is home to the only port and airport on the islands. Any tourist visiting any part of the Andamans transits through here, spending at least one night, before going to or returning from the other islands. Many domestic tourists spend their entire stay in the South Andaman region, around Port Blair, Chidiyatapu, Wandoor and the limestone caves at Baratang.

While the number of tourists, as well as the resident population, is growing steadily, the Andaman administration have no clear plan for waste management. The result is already noticeable from the fact that all tourist areas are heavily littered with plastic bottles, chip packets and other non-biodegradable waste. Only the urban area of Port Blair is covered for garbage collection by the Port Blair Municipality, and this is incinerated without sorting or recycling. There is one plastic plant in the study area, where certain types of plastic are shredded, compressed and shipped to the mainland. The remaining areas of the island lack any centralised garbage processing unit, and individual households and villages incinerate their waste in a haphazard manner and much of it finds its way into the ocean and on the high tide line of many beaches.

The sewage system of the Andaman & Nicobar Islands are in similar disarray, with most sewage being discharged untreated off the coast.

Waste and sewage is likely to pose a large threat to the health of the coral reef ecosystem of the South Andamans, especially if tourism continues to rise faster than the infrastructure develops. The saving grace, at present, is that much of the study area is uninhabited thanks to Marine National Park and the Reserve Forest Areas, and will never be subject to fluxes of tourists or local residents.

ii. Watershed –based pollution (agricultural nutrient run-off, sedimentation, litter)

Watershed based pollution can often be a legally complex and seemingly insurmountable problem for reef managers that are on the coasts of large countries with river basins that encompass several states or nations. Luckily, groups of small islands do not face the same problems. While the numbers for agricultural production, fertilizer and pesticide use for my specific study area are not available, they can be extrapolated from the numbers available for the entire Andaman & Nicobar area. Out of the 824,900 ha that comprise the Andaman & Nicobar Islands, only 14,710 ha are used for agricultural purposes (Directorate of Economics & Statistics, Andaman & Nicobar Administration). To cultivate these lands, whose major produce are Paddy, Sugarcane, Banana, Arraccanut, Coconut and Nutmeg, 18 MT of Dry Pesticide and 2473 litres of Liquid Pesticide were used in 2009-10. Additionally, 389 MT of Nitrogenous fertilizer, 340 MT of Phosphate based fertilizer and 188 MT of Potassic fertilizers were used in the same year (Directorate of Economics & Statistics, Andaman & Nicobar Administration). These numbers were a slight increase from the previous financial year. Given that my study area is a small fraction of the total ANI land area, we can assume that on average, a fraction of these numbers apply to this region. To date there are no studies that identify eutrophication as a major problem for coral reefs in the Andamans, and this might be in part due to the small numbers in agricultural production (as most of the produce is shipped in from mainland India) and part due to the extensive mangrove coverage still present on the islands. In my study area, there are 323 hectares of mangroves in the Lohabarak Crocodile Sanctuary,

1053 ha in the Wandoor MGMNP and dense mangrove areas stretching down in Manjery and Rutland (Space Applications Centre).

Despite the mangrove coverage, many sites in the study area do suffer from sedimentation (Patankar et al (2013) indicate sedimentation on the reefs off many islands in MGMNP as well as other sites in the South Andamans. These often coincide with area of low current, so this is one possible explanation. There appears to be no correlation between high sedimentation and live coral levels, indicating that perhaps a small level of sedimentation is natural to the region due to its rich soils and high rainfall.

iii. Marine Based pollution (solid waste, shipping, oil and gas installations, anchor damage)

There are no oil and gas installations in my study area, and the area is not known to be rich in below ground fossil fuels. Most electricity on the islands is made from power plants that import fossil fuels from mainland India. There is very little use of solar power, wind or wave power.

Many uninhabited islands have coastlines littered with plastic bottles, individual footwear, plastic boxes, cutlery and a whole array of clutter and garbage, and it is likely from ships throwing their waste overboard. Eventually the waste, pushed along by the currents, make their way to decorate soft white beaches. Laxity with international shipping rules in Andaman waters is a problem that must be addressed.

Anchor damage has not as yet been noticed as a significant problem. However, none of the dive centers outside of Havelock Island, use permanent buoys to tie their boats to. Many dive centres complain that the anchor buoys are attractive to fishermen and

therefore susceptible to being stolen. For this reason they often choose not to use these, despite the damage they know that their anchors are probably causing. Finding a system to permanently tie the buoys in a way that protects them from theft, but yet is not prohibitively expensive, might be a suitable solution that address the problem of anchor damage even before it becomes one.

iv. Overfishing and destructive fishing (dynamite / poison, trawling, unsustainable harvest)

Fishing, in the Andaman & Nicobar Islands, is managed by the Directorate of Fisheries, an arm of the ANI Administration. They are the issuing authorities of Fishing Licenses which fishermen on all boats are required to carry, and also conduct boat registration for fishing boats, allowing them to keep track of the fishing efforts in the region. As of 2005, there were 13,098 active fishermen in the Andaman & Nicobar Islands (Directorate Of Fisheries Website 2008, Advani 2013, Singh 2012). The region has mainly subsistence fishermen, who fish only enough for their own family needs and artisanal fishermen, who fish off small boats for commercial purposes. Both subsistence and artisanal fishermen use small wooden crafts with outboard motors, and are limited in their range to inshore areas that are close to the coast and coral reefs (Rajan 2003; Advani et al. 2013). According to the figures from the Directorate, 18687 tonnes of fish were landed in the South Andaman region in 2008 (Directorate Of Fisheries Website 2008), from pelagic, demersal and oceanic resources.

The region has neither the history nor current practice of illegal fishing techniques detrimental to coral reefs such as dynamite or poison fishing. This is not a traditional

form of fishing in the Andamans, unlike other parts of Southeast Asia. The ornamental fishery industry, another fishery potentially detrimental to reefs, is not open in the Andamans. While there are on going discussions about opening up this industry, it is currently banned.

Trawling, an extremely destructive fishing technique, does exist in the Andaman & Nicobar Islands. There are a small number of licensed trawling vessels that operate out of Port Blair. The effect that it has on coral reefs is hoped to be negligible as fishing regulations do not trawling boats within territorial waters, where coral reefs may be found. Conversations with local artisanal fishermen revealed that they do, on occasion, spot large fishing boats fishing illegally near MGMNP and Wandoor. These large boats could be trawling or long lining, the fishermen were only able to discern the size of the boat and not the method.

Predators and herbivores have been identified as two main groups of fishes important to the health of reefs. The importance of apex predators to ecosystem resilience – both marine and terrestrial – has in recent times become a topic of research in ecology studies. Increasing studies show that an ecosystem is less resilient when its top predators are fished out, and this result extends to reefs too (Dale et al. 2011, Estes et al. 2011). The apex predator on reefs is usually shark species. The main shark species found on coral reefs in the Andaman & Nicobar Islands are White-tip Reef Sharks (species *Triaenodon obesus*), Black-tip Reef Sharks (*Carcharhinus melanopterus)* , Nurse Sharks (*Nebrius ferrugineus*) and Leopard sharks (*Stegastoma varium)*. Unfortunately, in most of my study area, they're abundace is very low. Shark fishing or finning is not illegal in India anymore. There was a blanket ban of fishing any shark species whatsoever in 2001, but

this was lifted a year later due to protests from the fishing as well as the scientific community, both of whom thought the ban was ill-thought out. From 2004 onwards, the ANI Fishing Rules & Regulations imposed a closed season for shark fishing for 45 days from 15th April to 31st May every year. The idea of the closure is to allow the shark populations some respite from fishing pressures, with a view, presumably, to allowing the populations to recover. However, the justification for this particular time of year and for such a short period of time is unclear, reflecting a lack of understanding of the lifehistory of the species in question. In the same year, the Directorate also imposed size restrictions for species caught and banned the extraction of certain gravid individuals (Advani et al. 2013). The next order reef predators such as species of groupers (Serranidae) and snappers (Lutjanidae) are fairly abundant in my study area, both in the protected MGMNP as well as the open areas such as off Rutland, Cinque Islands and Chidiyatapu (pers. obs.). The chart below, created from unpublished data collected by Patankar et al (2013), shows the abundance of different fish guilds (for example, piscivores, planktivores, etc) in various parts of my study area:

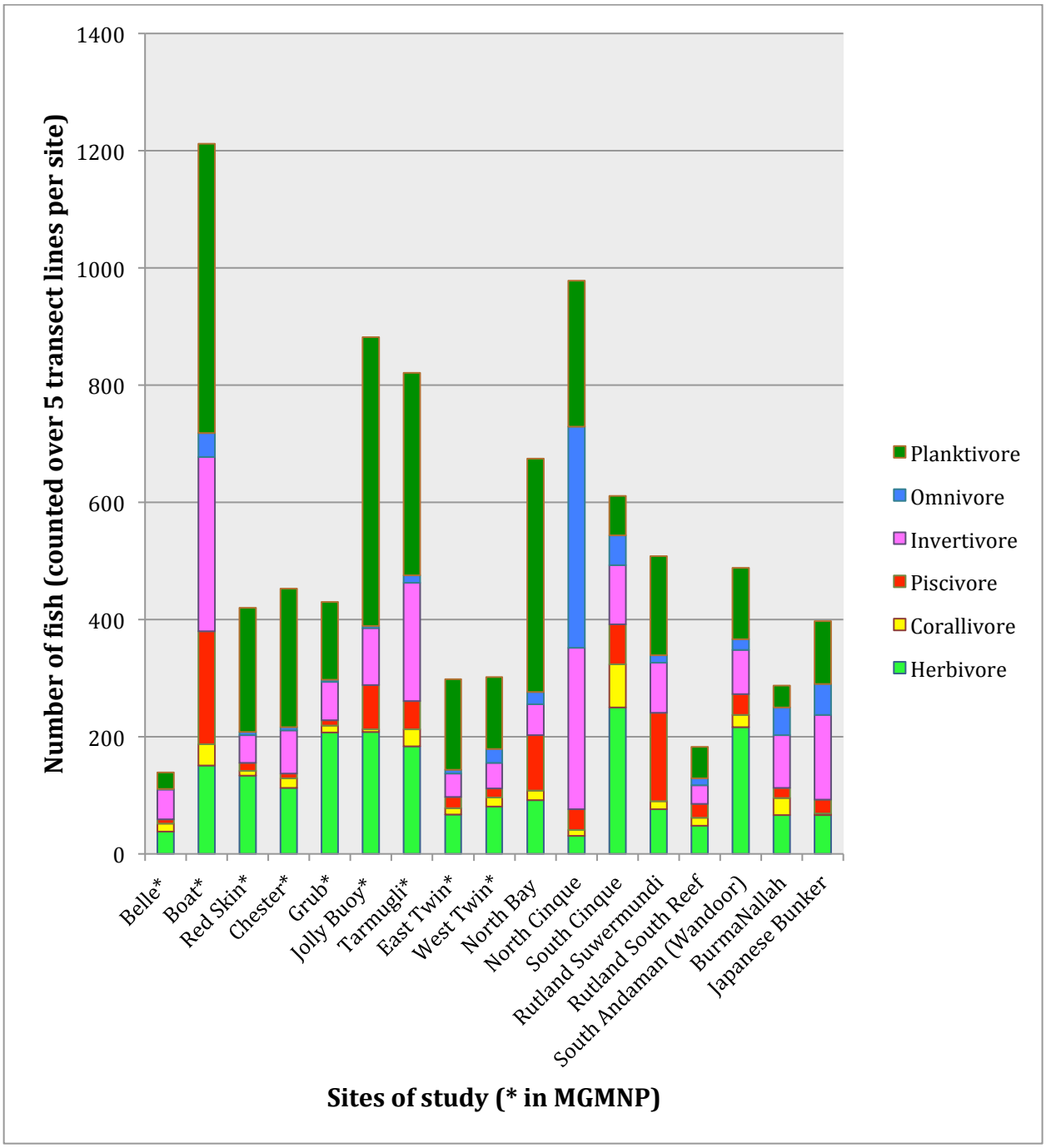

Figure 4: Fish Abundances by Guild (data modified from Patankar et al 2013)

There is a good representation of piscivores and invertivores (red and lilac, respectively), both of which would constitute as reef predators, and herbivores (green) are well represented in most sites too. Experiences from the Caribbean Islands have shown that

decline in herbivores (due to overfishing) can lead to phase shifts of the ecosystem from coral dominated to algal dominated reefs (The Nature Conservancy 2012, Dale et al. 2011). In the Andaman & Nicobar Islands, there is no commercial extraction of reef herbivores such as Scaridae (parrotfishes), Siganidae (rabbitfishes) or Acanthuridae (surgeonfishes) for ornamental or nutritional purposes, and this is a situation that the Directorate of Fisheries should be advised not to change.

v. Global: Thermal Stress

With increased levels of carbon dioxide being pumped into the air by anthropogenic sources such as the burning of fossil fuels, the global ocean is experiencing warming. Coral reefs all over the world are being subject to water temperatures warmer than what they may have experienced as recently as a century ago. Furthermore, climate change is causing more than normal fluctuations in El Nino, making these extreme warming events more frequent. These El Nino bleaching events, where sea surface temperatures rise by 2 or 3 degrees Celsius, lead to mass coral die outs, suggesting that the corals are living close to their thermal maximum. Since the 1990s alone there have been severe bleaching events in 1998, 2004 and 2010, where water temperatures reached a high of 34 degrees Celsius. For instance, sea surface temperatures shot up from 30.4 in April 2010 to 34 in May 2010, which lead to 77% of the corals in Port Blair Bay, and 74% in Havelock, being bleached (Marimuthu et al. 2013). So far there appears to be a good recovery rate, where Marimuthu et al. (2013) found that 21.1% of the coral in Port Blair Bay and 13.29% in Havelock had recovered by January 2011. While local authorities are quite powerless in the face of El Ninos and global fossil fuel consumption, scientists must try

to identify the factors that lead to more recovery in some areas and less in others, and also communicate them effectively to managers, so that the managers may take steps to maximize and protect those factors.

vi. Global: Ocean Acidification

Anthropogenic ocean acidification, also known as 'the other carbon problem' began to be seriously researched in the 1980s (Gattusso & Hansson 2011). Ocean acification refers to a complex series of events that occur when excess carbon dioxide being pumped into the atmosphere dissolves into seawater, changing its chemistry. The ocean's bicarbonate and dissolved inorganic carbon concentrations increase, while pH and carbonate concentration decreases (Gattusso et al.1999). Carbonate is an essential carbon species for the process of calcification, and therefore changes in its availability in the water will have impacts on corals and reef formation. In turn it will effect all the fish and invertebrates and use the coral reef's structural complexity to live, hide, hunt and reproduce. It has been found the different parts of the ocean absorb and process carbon dioxide differently. For instance, the Pacific has lower pH than the Atlantic Ocean, the poles absorb more than the equator, etc (Gattussp et al. 1999). Despite being a 'global problem' its effects vary locally and it is important to study ocean acidification at a finer scale, especially in a region that has an entire calcifying ecosystem.

Unfortunately there is no ocean acidifacation research taking place in the Andaman & Nicobar Islands at the moment. One study measured pH as one of their water parameters, and in my study area, they found that pH varied between 7.5 and 8 at different sites (NRSC 2012). To be able to characterise carbon chemistry accurately however, one

requires the measurement of at least 2 carbon species, and the measurement instruments need to be reliable and calibrated. This is lacking in the Andaman Islands, and the impacts of ocean acidification on net calcification or dissolution are unknown.

B. History of Coral Reef Study in the Study Area

Compared to most other parts of the Indian Ocean, the reefs of the Andaman & Nicobar Islands have had fewer scientific studies (Turner et al. 2009) and there is still less information available about my study area. In situ studies are fairly recent, and before the 1980s, the only information available is taxonomic studies conducted from corals dredged up by ships or from collections in the Indian Museum, Calcutta. Of the papers published about the Andaman Islands, a few had covered my study site. The following few images show the studies conducted in a chronological order, and the box embedded within each image provides details of the data that were collected. These were mapped using ArcGIS.

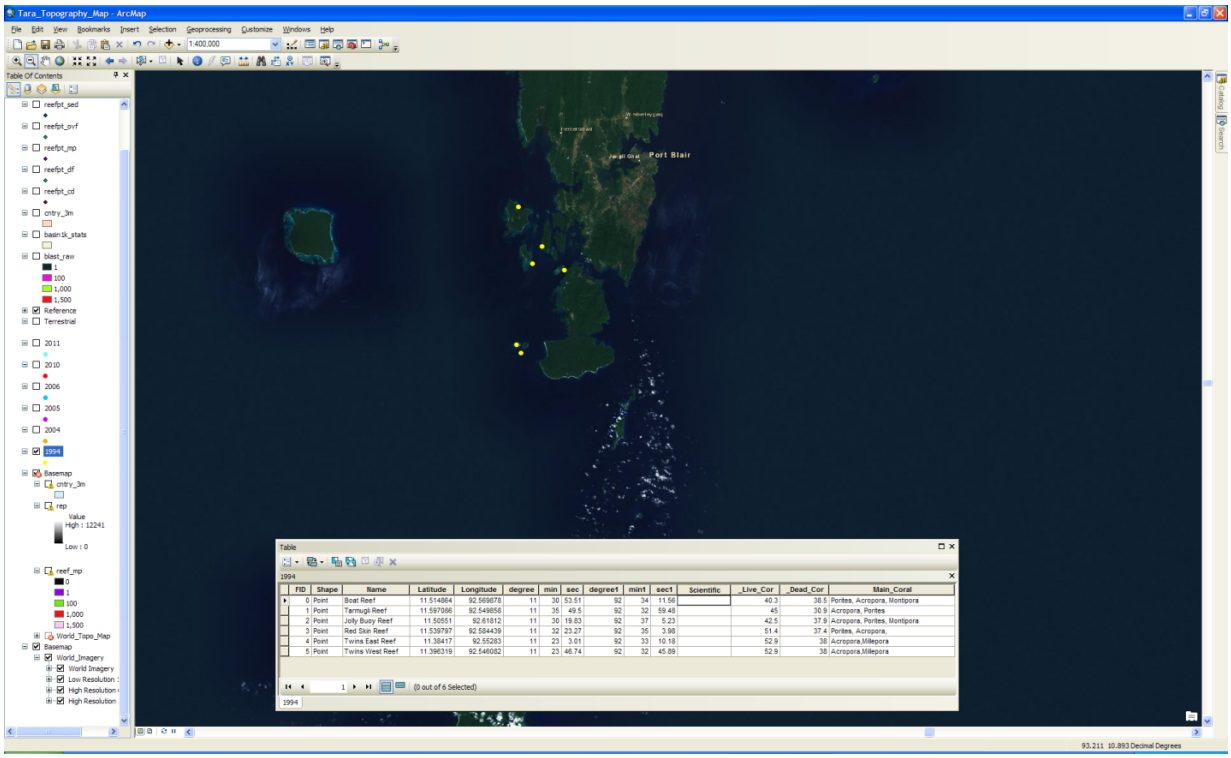

Figure 5: Studies conducted in the Study Area in 1994

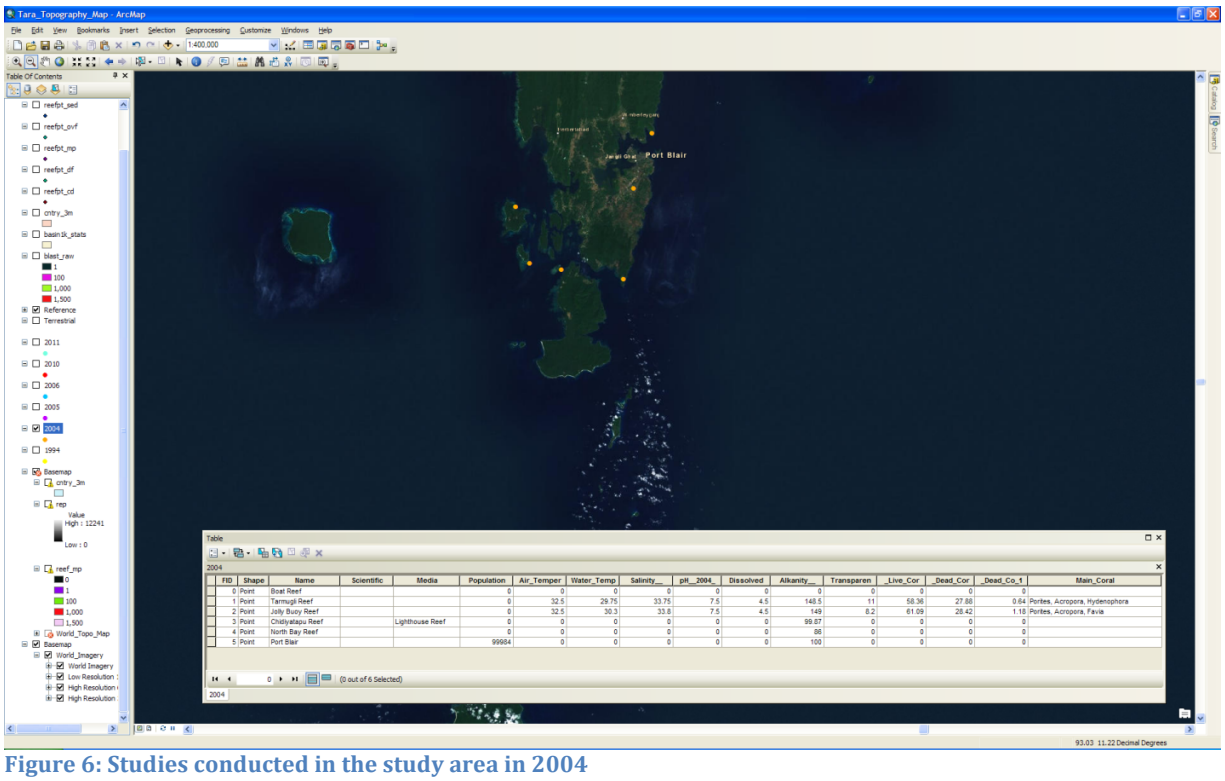

Figure 6: Studies conducted in the study area in 2004

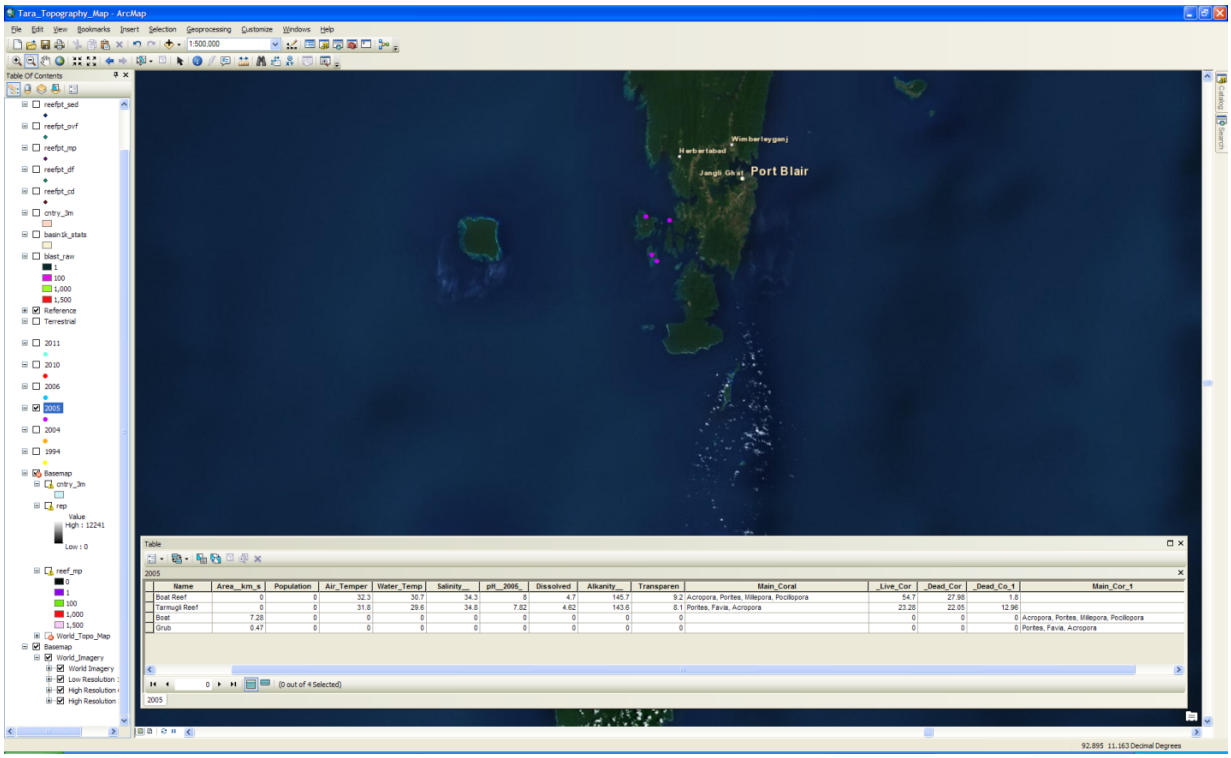

Figure 7: Studies conducted in the study area in 2005

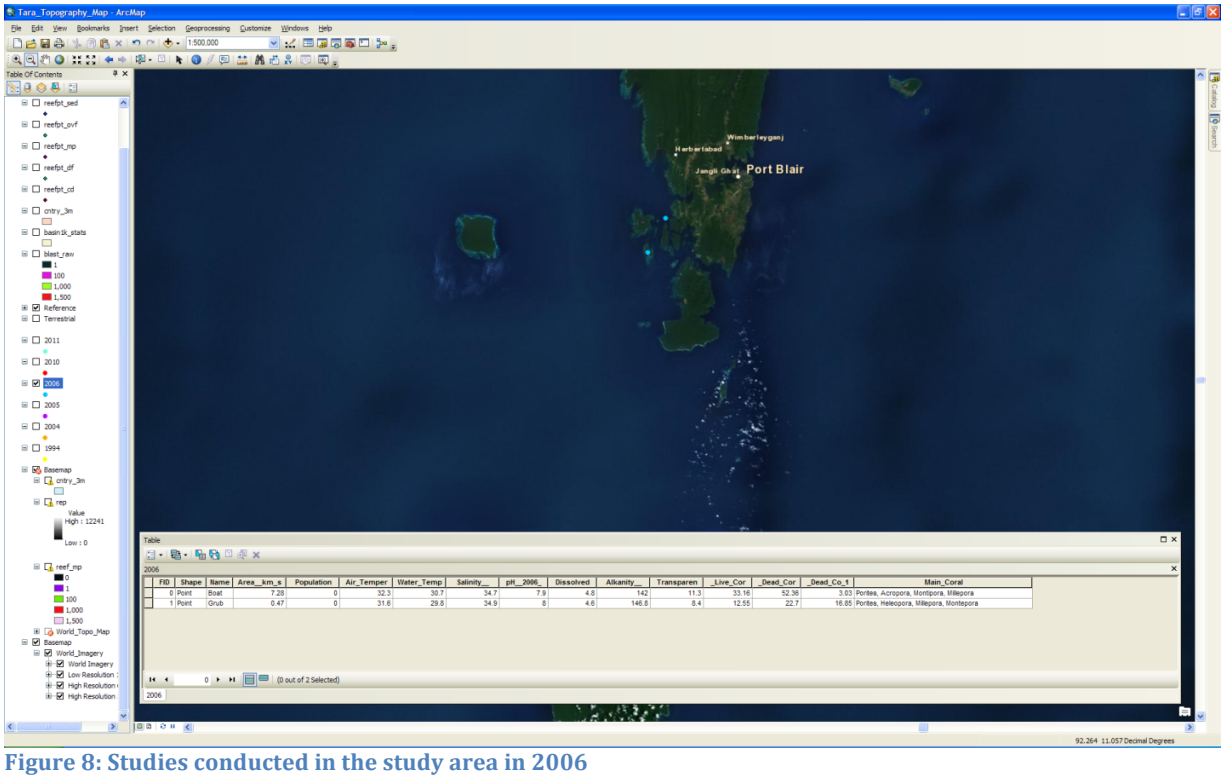

Figure 8: Studies conducted in the study area in 2006

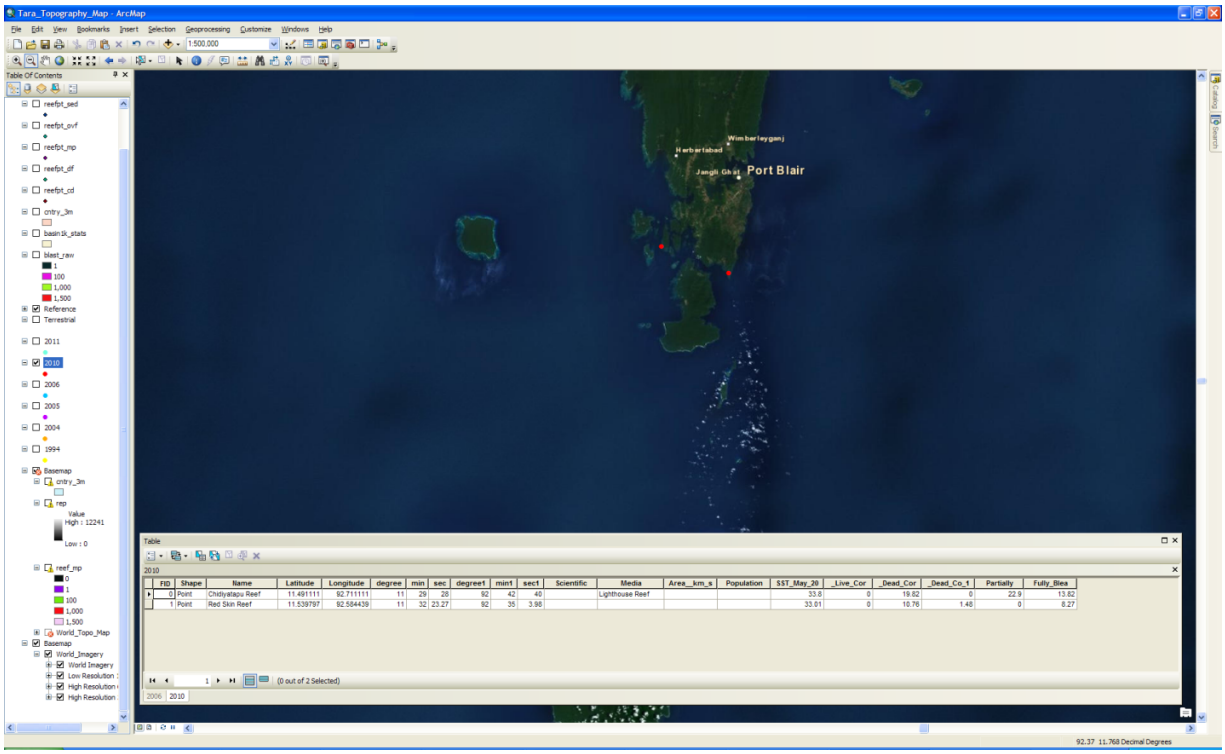

Figure 9: Studies conducted in the study area in 2010

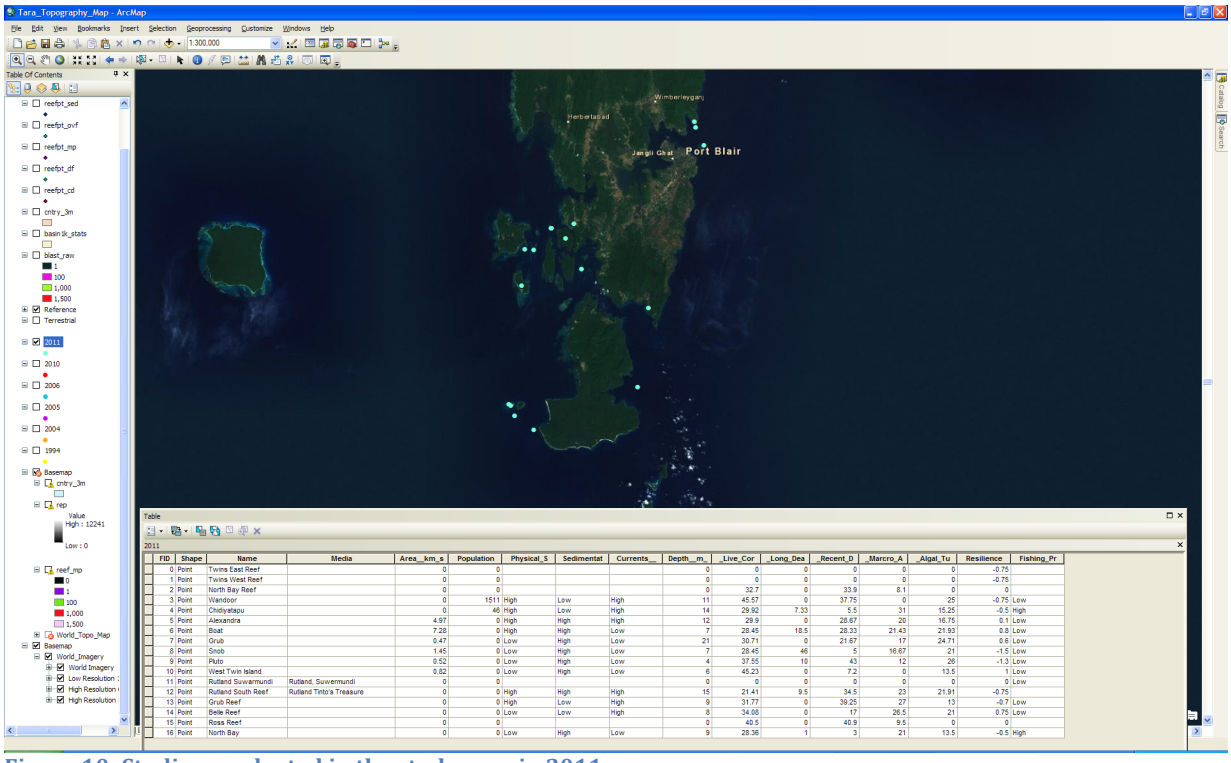

Figure 10: Studies conducted in the study area in 2011

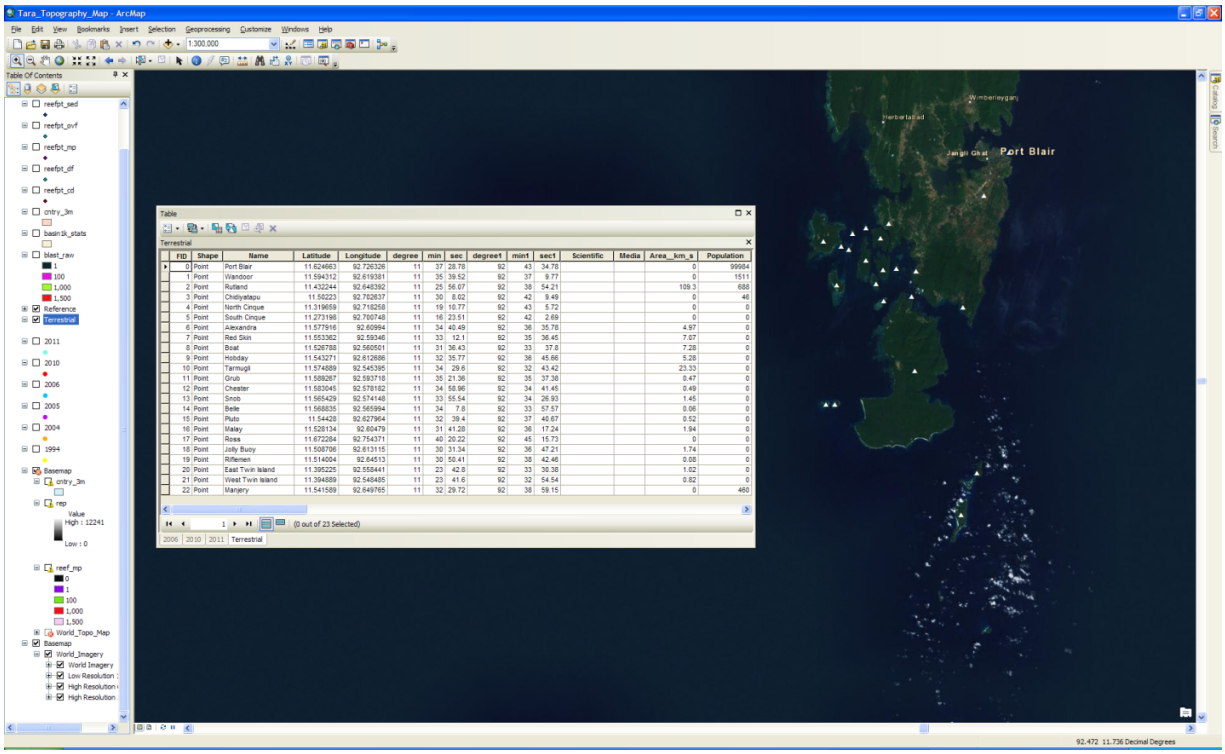

Figure 11: Studies conducted in the study area in 2012

Table

Terrestrial

FID	Shape	Name	Latitude	Longitude	degree	min	sec	degree1	min1	sec1	Scientific	Media	Area__km_s	Population
0	Point	Port Blair	11.624663	92.726326	11	37	28.78	92	43	34.78			0	99984
1	Point	Wandoor	11.594312	92.619381	11	35	39.52	92	37	9.77			0	1511
2	Point	Rutland	11.432244	92.648392	11	25	56.07	92	38	54.21			109.3	688
3	Point	Chidiyatapu	11.50223	92.702637	11	30	8.02	92	42	9.49			0	46
4	Point	North Cinque	11.319659	92.718258	11	19	10.77	92	43	5.72			0	0
5	Point	South Cinque	11.273198	92.700748	11	16	23.51	92	42	2.69			0	0
6	Point	Alexandra	11.577916	92.60994	11	34	40.49	92	36	35.78			4.97	0
7	Point	Red Skin	11.553362	92.59346	11	33	12.1	92	35	36.45			7.07	0
8	Point	Boat	11.526788	92.560501	11	31	36.43	92	33	37.8			7.28	0
9	Point	Hobday	11.543271	92.612686	11	32	35.77	92	36	45.66			5.28	0
10	Point	Tarmugli	11.574889	92.545395	11	34	29.6	92	32	43.42			23.33	0
11	Point	Grub	11.589267	92.593718	11	35	21.36	92	35	37.38			0.47	0
12	Point	Chester	11.583045	92.578182	11	34	58.96	92	34	41.45			0.49	0
13	Point	Snob	11.565429	92.574148	11	33	55.54	92	34	26.93			1.45	0
14	Point	Belle	11.568835	92.565994	11	34	7.8	92	33	57.57			0.06	0
15	Point	Pluto	11.54428	92.627964	11	32	39.4	92	37	40.67			0.52	0
16	Point	Malay	11.528134	92.60479	11	31	41.28	92	36	17.24			1.94	0
17	Point	Ross	11.672284	92.754371	11	40	20.22	92	45	15.73			0	0
18	Point	Jolly Buoy	11.508706	92.613115	11	30	31.34	92	36	47.21			1.74	0
19	Point	Riflemen	11.514004	92.64513	11	30	50.41	92	38	42.46			0.08	0
20	Point	East Twin Island	11.395225	92.558441	11	23	42.8	92	33	30.38			1.02	0
21	Point	West Twin Island	11.394889	92.548485	11	23	41.6	92	32	54.54			0.82	0
22	Point	Manjery	11.541589	92.649765	11	32	29.72	92	38	59.15			0	460

1 (0 out of 23 Selected)

2006 | 2010 | 2011 | Terrestrial

Figure 12: Information about towns & village in the study area

The ArcGIS maps were created by overlaying the raw data contained in all the studies on to a basemap. The raw data, such as percentage of live coral cover, percentage of dead coral, major coral genera, temperature, currents and sedimentation was first added into a spatially referenced database, which I have attached with this paper. I hope to be able to make this data publically available once I have obtained the permissions of all the scientists whose data I have used.

The maps above show clearly that research is sporadic – and that the sites are not studied in an organized and thorough manner. I could not fund any studies conducted between 1994 and 2004. When this information is easily accessible in a single database, spatially referenced in this way, scientists and students will be able to easily identify gaps in research to cover and reef managers to can provide grants and calls for papers for key areas that they need to know more about.

C. Areas that require further research

Using ArcGIS I have constructed a long term monitoring effort by collating the common parameters measured by different studies of reefs in the South Andaman region over time. By so doing the gaps in research become clear, and will be discussed in this section. In an area where long term monitoring has not really been conducted, and where there are limited funds available for such efforts, it is a useful proxy to be able to piece together information collected especially during key timeframes such as during or after a bleaching event, a storm event or the implementation of a new rule or regulation regarding reefs, fishing or land use. For this to be possible, all studies that are conducted

over any section of reef in the Andaman & Nicobar region should also collect data on the following parameters:

- Environmental factors: Water temperature, pH, Sedimentation
- Coral Cover: Live coral cover, Dead Coral Cover, Macro-algal cover
- Spatially referenced with GPS coordinates.

The parameters above should be fairly easy to measure, and would not take away too much time from the question any researcher is attempting to answer. If such data is clearly spatially referenced, it could continue to be fed into the ArcGIS product I have created and add to a growing body of information related to the reefs of the Andaman Islands. The

database could then be used to answer a wide spectrum of questions that various researchers and managers might have, and could become an important repository of baseline data. Research occurs in quite a centralized manner in the Andaman & Nicobar Islands, as many studies are conducted by government scientists from the Zoological Survey of India (ZSI) or the Central Agricultural Research Institute (CARI), and any scientist from a private institution requires permits from the Chief Wild Life Warden to conduct research, especially if their study area includes a protected area. Therefore implementing this recommendation, even as a request to scientists studying reefs, should be a relatively achievable task.

Internationally, coral reef research is advancing beyond line transects and photo-quadrats into genetic research at the zooxanthellae clade level, isotope analysis to determine their dependence on different nutritional sources, changes in coral biology at different depths

and on different facades of individual coral heads. There is also increasing attention being paid to the future of reefs in a more corrosive ocean, given the problem of ocean acidification due to access carbon dioxide. Both genetic research as well as ocean acidification research requires not only the appropriate technology and lab setups, but also the legal framework needs to be more accommodating to allow extraction of coral pieces for research purposes. At present that is almost impossible given that all scleractinian corals fall under the schedule one protected list of the Wild Life (Protection) Act, 1972. Another recommendation of this paper is to create streamlined channels by which researchers can apply for permission to extract small pieces of coral in order to conduct research that will eventually help with conservation in the long run.

There is also currently very little research that looks at recruitment in the Andamans, and this will be an important area of study especially as there have been warming events with increasing frequency, and recruitment is an important part of reef recovery.

V. Part II: Communicating Science to Reef Stakeholders

Part I of this paper told a story of the reefs of the South Andaman Island by combining results from studies conducted in the region over the years by various scientists. It also identified and elaborated upon factors relevant to coral reefs such as coastal development, land-based pollution, mangrove coverage, fishing pressures and protective measures. While these are all publically available information sets, they are not immediately accessible to those who are affected by coral reefs or to those who have the power to affect reef health. This paper will now discuss the key points from the information set above that different stakeholders need to know, and how best to communicate it to them,

in order to promote reef conservation. The stakeholders included in this report are reef managers, the science community, the fisher community and the vendors as well as the patrons of tourism activities. These recommendations are drawn from informal conversations with many members of the Andaman community.

A. The Forest Department: The problem of Imperfect Information

The management, monitoring and conservation of coral reefs in India is entrusted to the Ministry of Environment and Forests (MoEF) of the Government of India. The senior positions in this department, who are in charge of implementing the directives of the government for reef conservation, are officers of the Indian Forest Service. These officers are deployed in the Andaman Islands for fixed tenures, most often not exceeding 5 to 8 years. As their titles imply, they are more knowledgeable about and experienced in managing terrestrial forests, which have considerably different attributes from coral reefs, no matter how many times they are referred to as the ‘rainforests of the ocean’. I had extensive interviews and discussions with three main officers, the Deputy Conservator of Forests, the Additional Principal Chief Conservator of Forests (Wildlife) and the Chief Conservator of Forests. The Deputy Conservator of Forests (DCF) was a local man, who was holding the post temporarily. The Additional Principal Chief Conservator of Forests (APCCF-W) was an officer from mainland India who was quite passionate about reef conservation and engaging with NGOs, and the head of the Department, The Chief Conservator of Forests (CCF), was very recently transferred from the North-east of India and had no interaction with or knowledge of the ocean at all. These three gentlemen were the some of the most senior individuals currently managing the reefs of the Andaman & Nicobar Islands. They are in a position where they are able to make positive

contributions, and yet do not have the luxury of time, experience or knowledge. In such a situation it becomes even more important conservation scientists and ecologists share their knowledge with the managers.

I learnt that there are two times a Forest Officer becomes aware of a coral reef study that is being carried out in the South Andaman Islands. The first is when the keen researcher applies for his or her research permit, and the second is when the officer is presented with the report, often in the form of a thick book, to be filed away in a cabinet. I also learnt that the reason is that firstly, there is a lot in the reports that the officers feel are irrelevant to their needs and that they either are too ambitious or unclear in their recommendations, which are found anyway at the very end of the report. I asked them if it would be beneficial to have a short, 2 page, Summary for Policy Makers (as they have in the IPCC Reports), with current reef (or any other study subject) status and recommendations for conservation, and they were supportive of the idea. Additionally, they added, that the recommendations should only be given to them if it is something in their direct jurisdiction, as they were powerless beyond that. For instance, if a change in law is required, they felt it would be better for the scientists to take their recommendations to NGOs or activist groups.

The DCF, who is the officers in charge of the Marine National Park, talked about the difficulty in the enforcement of the no-fishing and no-poaching rules in an area of 281.5 km^2 with only one 'rib' (inflatable boat) and only two operational rangers. While strengthening the strength of the enforcement staff is an important recommendation to be made, I believe it would also be enormously helpful to mark out core areas to protect when the department is going through periods of staff shortage. Scientists who study reef

resilience and are therefore informed about sections of the reef that are highly resilient, that have high percentages of live coral cover, are important in terms of fish habitat should identify the most important areas of reef to protect, and include it in a map-based product in their Policy-makers Summary. Scientists should strive not only to make their results available to the policy makers, but also go a further step to highlight the parts of their results that are relevant and accessible, and must offer practical suggestions.

When I was talking to the DCF about enforcement, he mentioned that the department is budgeting for jet skis (water scooters) for the rangers to traverse the park in, and chase poachers. I informed him that jet skis are in fact very detrimental to coral reefs because they leak a lot of fuel directly into the water, break corals from the propulsion they generate underneath and also produce enormous noise pollution for the reef inhabitants. I also emphasized that if they had a difficult time maintaining the small inflatable boats in their possession, they were unlikely to have the wherewithal to handle jet skis. The DCF received this news with surprise and wondered what would be a good, fast alternative for the rangers. This conversation revealed that there might be room in the management structure for an advisory board, which includes scientists, rangers and perhaps even Coast Guard (or other enforcement agencies knowledgeable about appropriate technologies) representatives so that decisions are informed by expertise from varied sources on a regular basis.

Conversations with the Chief Conservator of Forests (CCF) illustrated that very often the managers of reef ecosystems are completely disconnected from what they are supposed to be protecting. This officer was from the North Eastern landlocked region of mainland India, and only recently posted to the Andamans. While he had heard of coral reefs

before, he had no real conception of what they looked like, where they were, and what their importance was. I offered to take him for an introductory dive to acquaint him with his surroundings, but since he did not know how to swim and was terrified of water, a dive, he said, was absolutely out of the question. I then started asking the other officers about their personal interactions with the reef, and learnt that most had none. While there are thousands of videos of coral reefs available for browsing, I believe it would be a valuable to have a GIS forum for the Andamans, where a new officer than click on an area of a map and see a short video of the reef there. If this is done for a variety of sites, the officers can become personally acquainted with what a healthy reef in their backyard looks like, how it looks when it is stressed and all the associated organisms. I have created a product like this, for my study area, as a prototype (see next section for details). Especially since there is a high turnover of officers it would be enormously beneficial to create a product that introduces them to their charge by showing them what it looks like, where they are located, what risks they face, what protection they have and how to make it more effective.

The Additional Principal Chief Conservator of Forests (Wildlife) pointed out though, that no amount of regulation or enforcement, even in the 'core areas' that I had suggested, would be effective unless there was voluntary and enthusiastic endorsement from the local people. The local people of the Andamans need to begin seeing the reef as their pride, as a local treasure that makes them unique. Just like they take to the streets in demonstrations if their city or economics are not being managed properly, they need to hold their executive officials responsible for and answerable to them if the reefs are being improperly managed. The APCCF-W felt that the only way this could be done is if the

reef was tied in to their priorities, which he felt were primarily livelihood, then comfort and finally the future security of their children. Measures need to be taken to educate the local people that live in close proximity to coral reefs and MGMNP (see Figure 2), towards understanding that their livelihood, comfort and future is indeed closely linked in with the services that a (healthy) reef provides. These include services such as tourism revenue, fish for consumption, shoreline protection from storms, which does indeed maximize their economic, social and future well-being in the face of global change and sea level rise. The Andaman Islands have high literacy rates compared to the Indian average of 73%. 88.49% of the population in the South Andaman region is literate (Directorate of Economics & Statistics, Andaman & Nicobar Administration), however this must not be mistaken for education. Most of these farmers, fishermen and labourers are educated only till about 8th grade and therefore this information should be presented in a manner that recognizes this. The importance of the reef to their own well-being must be conveyed to them in a experiential way rather than an academic one. For instance, the tsunami of December 2004 has left a very deep imprint on the Andaman psyche and everything is still referred to as 'before tsunami' and 'after tsunami', and so the importance of healthy reefs in protecting the shorelines from big waves can be emphasized by giving proxies of where the water line might have reached if not for reefs. Not many fishermen fish directly off the reefs, but the importance of the reefs and mangroves as nursery areas for commercially important fish should be illustrated in an interactive, graphic manner rather than in a didactic and academic way. These are people that have learnt through experience rather than formal education, and the past shows that when they witness the importance of a conservation measure they respect it. For instance,

a new material for nets was introduced on the islands, *current jaal* or nylon monofilament. These nets were notoriously unselective, leading to very high amount of by-catch. The fishermen saw immediately the fish stocks were being decimated, and surveys by Advani et al (2013) revealed that the majority of fishermen supported the Directorate of Fisheries' decision to ban these nets.

The APCCF-W felt that with suggestions from the scientists and pressure from the people, the Forest Department would be truly empowered to protect the reefs and related ecosystems.

The reason for why they, a government department entrusted with reef care, would need empowerment to do their job was pointed out by the DCF. He raised another difficulty with coral reefs – the overlap of jurisdictions. The Forest Department is in charge of the conservation of reefs, but simultaneously, the Department of Tourism operates from coral reefs to maximize revenue and the Fisheries Department's agenda is to maximize the extraction of fisheries resources. Beyond just the problem of overlapping jurisdictions, talks with the DCF revealed that there was the problem of different visions. The Forest Department and the Department of Tourism perceive themselves to be against each other because the former is mandated with conservation while the latter's is to maximize tourism revenues by exploiting the resource. There is a need for a joint vision, for tourism officials to realize that without adequate conservation the flow of tourists will ebb before long. Keeping with the times, there is lip service given to 'ecotourism', but it is clear that the tourism department does not really see it as a viable replacement (rather than an addition) to commercial mass tourism.

B. Tourism: A capricious player

The tourism industry is a double-edged sword. It can encourage responsibility to the environment and reward it richly, but equally, it is capable of extensive destruction and disregard for the natural environment. A long-sighted and all encompassing vision of the tourism industry needs to prevail over a chaotic development of the industry. For this, stakeholders such as the Directorate of Information Publicity & Tourism (IP&T), tour operators of different kinds (e.g. resort owners, taxi drivers, watersports operators and travel agencies), the Forest Department, conservationists and economists all need sit down together and come up with a plan that has sufficient buy-in. At present, the stakeholders are not on the same page, and consequently have different agendas. Conversations with a few different resort owners on Neil Island revealed that they are very worried about the IP&T's goal to triple the number of visitors arriving at Neil everyday. As far as IP&T is concerned, they feel that increased numbers mean increased revenue. The resort owners however, know better, having learnt from the example of a neighbouring island. They have recognized that long staying tourists are bigger cash cows than the whirlwind tourist who sees as many sights as quickly as possible before heading back. They also have understood that the long stay tourists who want solitude, serenity and expensive hobbies like SCUBA diving, leisurely meals and massages tend to avoid places where there are too many of the latter, gawking tourists. The resort operators despair at the thought of the litter, the noise and the volumes that will never translate into profits that will come to pass if IP&T is successful. The ironic part of this is that IP&T feel that in doing this, they are benefitting the tourism operators on the island. Having these people exchange views and develop an agenda that is beneficial in the long term to

all of them will be an enormous step forward towards conservation as a clean, undisturbed environment is what the discerning tourist is paying for.

IP&T needs to commit itself to a green, ecotourism policy, and abandon its fascination for quantity over quality. The Directorate is already favourable towards, and quicker to award permits to, businesses that show themselves to be eco-friendly, but now it needs to go a step further and actively discourage businesses that are not.

The problem with mass tourism is that the pressure it puts on these islands is more than the infrastructure can currently support. To put this in context, 127504 tourists visited the Andaman & Nicobar Islands in 2008 (EQUATIONS, INTACH ANI Chapter, SANE, TISS, ActionAID) This means that for every 100 local residents, there are at any given time of year, 3 tourists on the islands. In my study area, which includes Port Blair – the airport town and capital from which all tourists must arrive and depart – there are 10 tourists on any given day for every 100 locals. This adds a great deal more pressure on infrastructure and resources that are already limited, such as fresh water, electricity, waste disposal. The Andaman Islands are blessed in their natural resources and are not densely populated, and this should be used to its full potential. There is currently a stay on conversion of land from 'Agricultural' or 'Hilly' land to 'Commercial'. This is the perfect time to introduce certain criteria for conversion such as installing rain water harvesting (there is local expertise in this as most farms and houses have a small reservoir in the backyard that is filled every monsoon with rainwater and then used through the year for domestic purposes), insisting on having Reverse Osmosis or similar filtration units (to reduce the number of plastic mineral water bottles that litter the island) and perhaps even solar power installations for larger resort projects.

Speaking with some of the tour operators, it became apparent that often they could see the damage that their activities were doing, for instance by taking snorkelers into extremely shallow areas and allowing them to trample on them, but they had no choice because the tourists demanded it as they couldn't swim and would threaten to go with another operator. Most Indian tourists also have the habit of indiscriminately throwing their garbage all over the place, turning the beaches and the forests into giant garbage dumps. Serious efforts need to be put into cultivating a civic sense in the tourists, at least while they are on small islands that have no municipality service to clean up behind them. In my study area both Red Skin Island and Jolly Buoy Island of MGMNP, where tourists are allowed, suffer from extensive damage in the shallow reef regions due to trampling. The same is true of other touristic reef regions such as North Bay and Havelock Island's Elephant Beach. Tourists must be educated, made aware of the damage in the past and be shown a responsible and ethical way of conducting themselves with respect to the natural environment that they have traveled so far to enjoy. A study with extensive surveys given out to tourists, tour operators and IP&T officials was conducted in 2008 (EQUATIONS, INTACH ANI Chapter, SANE, TISS, ActionAID) and it revealed that the most common reason for choosing the Andaman & Nicobar Islands, in the domestic as well as the foreign tourists, was 'natural beauty' (p.209). If this is the case, then the natural beauty, which includes healthy coral reefs, clean beaches and dense forests, must be protected by the tourists themselves as well as the operators. Another interesting finding from this study was the profile of the tourists visiting the islands. They found that 53.6% of all domestic tourists, and 95% of the foreign tourists were between 20 – 40 years of age (p. 36). Of the domestic travelers, who are most guilty of littering and coral reef destruction,

72% were male. Demographics like this should be kept in mind and effective ways of communicating the importance of conservation-oriented activities while on the island should be devised. Big groups of men usually do not like to be lectured, and big signages of 'Dos and Don'ts' can often be counterproductive, as is evidenced by their blatant disregard (big piles of trash next to a 'Do not litter' sign, graffiti on signages, etc). But perhaps there can be more engaging literature given out to tourists on their flight in to the islands. One of my recommendations would be to hand out well-designed leaflets, or play a short 15 minute documentary, on incoming flights for 3 months to test out if this changes tourist behavior for the better while on vacation. The majority of domestic tourists are also 'passive' tourists. Their preferred activities are sightseeing, and are part of 'mass tourism' (EQUATIONS, INTACH ANI Chapter, SANE, TISS, ActionAID). Attempts should be made to change this into a more interactive, engaging form of tourism, so that the individuals feel connected to the islands and a part of them rather than passive bystanders who are less invested in its wellbeing.

C. Scientists & Managers: a necessary alliance

Coral reefs in the Andaman Islands need to be managed in a way that is more scientifically informed and proactive. Simply guarding the borders of a marine national park against poaching is no longer an adequate measure in the face of the global threats that the corals face. My discussions with the forest officials revealed that they were aware of the importance of scientific contributions to their management efforts. Every two years they had scientists from the Zoological Survey of India going through the results from the monitoring buoy stationed in the reef off Grub Island, to see how the water parameters

were changing, and the DCF was appreciative of this. Scientists do provide the Forest Department with copies of the papers and reports they publish, but the significance of these papers are not clearly communicated. From my discussions with the forest officials, I received the following requests:

- A concise version of the parts of the study relevant to management needs to be provided.
- Visual and spatially situated results are useful.
- The results should be presented to them, before being left with them. Scientists should take the time to talk through their key results in an interactive process.

In light of the conversations I had with the reef managers, I designed some products using data from older studies conducted on the reefs in my study area. This would be a successful way of bridging the scientist-manager chasm and would require only minimal additional efforts from both parties. The following section will discuss the product and outline its implementation.

D. Moving Forward: a prototype

Part One of my report was the task of constructing an idea of the state of the reefs in my study area, the intensity of the local and global level pressures they are under, and (where there were studies available) their health over time. This was done by reading the studies conducted my study area since the 1990s, and communicating with the authors of the studies to clear doubts and obtain further details from the data that they didn't always include in the paper. I also collected additional details such as populations living near the

reefs, mangrove coverage in each area, fisheries data to create a more comprehensive picture that recognizes the interdependencies and interactions between a coral reef and its surrounding ecosystems.

Ideally, this is the level of knowledge about a reef that a manager needs to be equipped with to implement good protective measures. It also needs to be accomplished in half the time. The product that I have created is essentially a map of the study area, using Geographic Information Systems (GIS), that shows the reefs in the region. It also points out the spots where research has been conducted, and provides details of that research (the year it was conducted, important results like live coral cover, main coral species, water parameters, etc). The studies conducted can be viewed by year of study, author, or by area. Additionally, there is information included about the villages and towns in the study area as well, since coastal development can be immensely impactful on reef health. This information includes population, area and mangrove coverage. Finally, the product has a video layer, where the officer can click on a spot and be able to watch a short underwater video of the reef.

All the information in the map is also saved in a geodatabase, which I have obtained permission make available online when one of the papers who's data I have used is published. Stored in this manner, the officials can use it to highlight a whole range of different attributes to explore relationships between various factors. I hope that this product, eventually widened to include all of the Andaman & Nicobar Islands as scientists continue to add their data to it, is also used as an introductory tool for newly-posted officials to get acquainted with the region.

Keeping in mind the importance the government officials placed in having the results presented to them in an interactive way, I intend to present my GIS product to them personally when I return. Preliminary steps have been taken to organize a mini-conference inviting the scientists whose data I have used as well as key officials from the Forest Department and IP&T, and take them through the software. Since the scientists will be present too, the officials will have the opportunity to ask the primary authors directly about their work. The second reason for asking the scientists to be present is so that they can see a different way in which their work can be presented. Upon seeing their own data in a new format, as well as seeing their study in the context of the other studies that have been conducted in the region, and gaps on information in the region, they might find new questions and areas to study. I also hope to be able to get their buy in, in spatially locating all the data they gather, and allowing it to be entered into this geodatabase repository which will then become more comprehensive and complete over time. Managers, scientists and students might all find such a product useful in the future. Officials from the Directorate of Information, Publicity & Tourism need to also be included in this meeting so that they feel like a part of the conservation process. If they are able to see the direction that the reefs are currently heading in now, they might, for their own self-interest and revenue, be more inclined to be a part of the solution. Since some of the recommendations involve policy for granted commercial conversion permits on land and communications to tourists, the support and inclusion of IP&T is essential. Once the GIS product is presented to the officials, I hope that their curiosity and interest in the subject of coral reef status and conservation is piqued. At this point, as further

detail, and to provide narrative explanation and introduction to the Andaman Islands, I would also present to them Part One of this paper.

I discussed these ideas with the APCCF-W, who felt also that collaboration moving forward, especially if sustained beyond just a one-off conference attended as a formality, would be enormously beneficial for reef conservation. He also felt that I would have more validity in presenting my results to this mixed forum that included scientists, forest and tourism officials, if I was representing a larger organization rather than myself as an individual. I have therefore taken this project to an Indian NGO called Reefwatch Marine Conservation, and will be representing them in the future and carrying forward this project in that forum. Reefwatch was established in 1993, as a Research and Education Organization, and has the credibility to act in an advisory role as the NGO has conducted many reef monitoring and SCUBA training modules for government scientists and has been a Member of the National Board for Wildlife, Govt. of India, since 2007.

The scope of this project has not allowed me to create products for audiences beyond the government and the scientific community, but I have outlined above (Section xxx) the mandate for the kind of communication that would be effective for local fishermen, incoming tourists, and other parties. Creating this communication could be an interesting project for students of Sociology or Mass Media & Communications, and through Reefwatch I hope to offer it to students in prestigious Indian Humanities institutions such as the Tata Institute of Social Sciences, Lady Sri Ram College for Women and the Symbiosis Institute for Media & Communications.

VI. Conclusion

This project has presented a detailed study of a small region of the Andaman & Nicobar Islands, namely the south tips of South Andaman Island, with Ross Island as its very north point and South Cinque as its southern boundary. The study area included the Mahatma Gandhi Marine National Park, uninhabited islands as well as densely populated areas such as Port Blair and sparsely populated islands like Rutland. In this paper, I looked at the intensities of different threats to coral reefs and how much pressure they exert on my study area. I also looked at various studies conducted here since the 1990s, and incorporated their results in a database so that they can be easily accessed for analysis and policy making. The idea of this collation of the research conducted by scientists was to create a prototype of effective communication between them and the user groups of the reef. I had conversations with the scientists, with Department of Forest officials who are in charge of reef conservation, with officials from the Directorate of Fisheries and tourism operators such as resort owners and tour operators whose revenues are tied in with the reef. Through these conversations I designed a way of communicating results from scientific studies to the people who have responsibilities and livelihoods tied in with the reef in an effective way. An important part of effective communication is regular and sustained communication. To this end I approached a NGO called Reefwatch, with whom I will be involved with in the future to expand the prototype that I have created for the rest of the Andaman & Nicobar Islands and also to set up a formal panel with representatives from the relevant departments and scientists so that future decision making can be done in consensus and the decision makers can do their job with the benefit of the best available science and information. Through Reefwatch, I also hope to

make the results of scientific research available, and more engaging for other audience groups such as tourists who visit the island, school students and fishermen. The gains of science must benefit at least the subject that they are studying, and especially in the case of coral reefs influenced by myriad different factors in the ocean as on land this can only be done if the insights are shared, communicated and used.

VII. Acknowledgements

The only part of this project that was all mine was the writing, and the errors. The idea of this project was born out of discussions with my mentor, Brian Zgliczynsky. It became possible because Dr. Stuart Sandin agreed to chair my committee, and helped find its focus and relevancy. Heidi Batchelor gave me the tools to represent my results visually. Manish Chandi, also on my committee, helped me in organizing my thoughts and create a compact study area without which I probably would still be in the process of gathering information.

With an outline in mind, I headed to the Andaman & Nicobar Islands, hoping the outline would translate into reality. I found wonderful support in everyone I spoke with. The Deputy Chief Conservator, the AP – Chief Conservator of Forest, the Chief Wildlife Warden as well as numerable other Forest Department officials gave me their time and were frank with their opinions. The officials from the Department of Information, Publicity & Tourism, and from the Directorate of Fisheries were equally helpful. I spoke to scientists from the Central Agricultural Research Institute (CARI), from the Zoological Survey of India (ZSI) as well as scientists from private institutes who were all so open and willing to share their data. In particular I would

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