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SUMMARY OF CORAL CAY CONSERVATION'S HABITAT MAPPING DATA FROM UTILA, HONDURAS

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CONTENTS

SUMMARY

- The coral reefs of Honduras are of vital national and international importance, both ecologically and economically, but are threatened because of rapid economic and population growth.
- During work on Utila between 1999 and 2000 (the '*Bay Islands 2000'* project), Coral Cay Conservation developed a programme of surveys, training and conservation education aimed at assessing the status of local reefs and improving environmental awareness amongst neighbouring communities.
- This summary report provides an overview of the habitat mapping data collected by the *Bay Islands 2000* project.
- CASA provided software, hardware and skills, on a charitable basis to ensure that the data collected by CCC could be developed into a GIS, not only for mapping the status of the coral reefs of Honduras, but also to provide analysis of the aerial extent of these reefs.
- Data were collected within individual 'study areas', to facilitate analysis at a range of spatial scales, and utilised the CCC standard baseline survey technique for the rapid assessment of the characteristics of reef communities. The surveys, therefore, utilised a series of transects, perpendicular to the reef.
- Baseline transects discriminated nine benthic and six geomorpholgical classes which indicates Utila has a high habitat diversity. Habitat diversity is important since the number of habitat types has been shown to be a good representation of species biodiversity.
- The nine benthic classes that were distinguished were all relatively coral poor because of a suite of relatively long-term local and regional factors, exacerbated by the combination of Hurricane Mitch and coral bleaching in 1995 and 1998.
- Damselfish were the most abundant reef associated fish recorded during baseline transect surveys. Commercially important fish were less abundant that would normally be expected in unfished systems.
- A recurring pattern in the baseline transect data was the greater abundance and diversity of fish in coral rich classes. However, although the link between fish abundance and coral cover was clear, not all species were necessarily most abundant in the most coral rich areas.
- Invertebrates were generally uncommon, partly because of fishing pressure, and the abundances of many invertebrate taxa were correlated with coral cover.
- A habitat map is presented within this report as an indication of the distribution of habitat types around Utila.
- Using the map, estimates of areal extents of each benthic class and habitat type are instructive. For example, there is only approximately 27 km^2 of reefal habitats around Utila. Furthermore, the area supporting the most coral rich benthic classes is only approximately 4 km^2 (15%). These statistics both highlight the damage caused by the bleaching event and Hurricane Mitch and other anthropogenic impacts and the need to conserve remaining coral rich areas.
- If further reserves were to be created, it would be important to try to protect a range of reef and habitat types. For this reason, it appears that the Turtle Harbour Wildlife Refuge is well placed since this areas includes a wide range of habitat types. However, placement of reserves in Utila should favour relatively coral rich habitats over sand dominated areas.
- This study led to six recommendations:

- One or more agencies should collect additional ground-truthing data from around Utila to facilitate both classification of currently ‘Unknown’ polygons and an accuracy assessment of the map.
- Establish an integrated GIS and associated meta-database for Utila, including data from the *Bay Islands 2000* project.
- Examine the potential of using data collected by the *Bay Islands 2000* project as the basis of national habitat classification scheme and subsequent national habitat map.
- Continue to aim to establish one or more additional multiple use marine protected areas around Utila, with an integrated monitoring programme to measure their efficacy, and strengthen the enforcement of regulations in the Turtle Harbour Wildlife Sanctuary. Establish regulations, and enforce existing legislation, to minimise the detrimental effects of coastal development on reef health.
- Additional marine reserves in Utila should integrate factors such as the preference of many fish species for coral rich habitats and the protection of areas incorporating a range of habitat types, including mangroves and seagrass beds, in order to allow for nursery areas, ontogenetic shifts and species that rely on non-coral rich habitats. The corollary of the preference of fish species for coral rich habitats is to protect coral cover within the reserves.
- The reef on the south coast of Utila appears to be a good candidate for protection because it is relatively sheltered from storm and hurricane damage.

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Pete Todd

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ABBREVIATIONS

ANOISM	-	Analysis of Similarity
BICA	-	Bay Islands Conservation Association
CCC	-	Coral Cay Conservation
COHDEFOR	-	Coorporación Hondureña de Desarrollo Forestal
GCP	-	Ground Control Points
GIS	-	Geographic Information System
GPS	-	Global Positioning System
IUCN	-	World Conservation Union
NGO	-	Non Government Organisation
p	-	Probability value of a statistical test.
PMAIB	-	Programa Manejo Ambiental Islas de la Bahía
PRIMER	-	Plymouth Routines in Multivariate Ecological Research
PS	-	Project Scientist
SIMPER	-	Similarity Percentage
SO	-	Science Officer
SMB	-	Surface marker buoy
UNAH	-	Universidad Nacional Autonoma de Honduras
UNEP	-	United Nations Environment Programme

FIGURES, TABLES AND APPENDICES

Appendix 1. Median abundances of substratum categories, biological life forms and species (algae, gorgonians, sponges, invertebrates, corals and fish) found in each of the nine major benthic classes identified during the *Bay Islands 2000* project:

1. INTRODUCTION

Honduras covers approximately 112,000 km^2 of land on the widest part of the isthmus of Central America. Honduras represents the southern end of the Mesoamerican Barrier Reef System, although it's marine resources are less extensive and studied than nearby Belize and Mexico. However, the coastal zone contains mainland reef formations, mangroves, wetlands, seagrass beds and extensive fringing reefs around its offshore islands and has a key role in the economy of the country. These ecosystems have close links with the coastal zones of the other Mesoamerican countries. For example, in the Gulf of Honduras, the watershed of the Rio Ulúa is an order of magnitude greater than any river in southern Belize and hence has a significant impact on the Belize Barrier Reef (Heyman and Kjerfve, 1999).

Although the coral reefs of Honduras are of vital national and international importance, both ecologically and economically, they are threatened because of rapid economic and population growth. For example, the countries' coral reef ecosystems are being adversely affected by a range of anthropogenic activities including over-fishing, sedimentation and pollution, which has resulted in a decrease of coral cover. The desire to generate urgently required revenue within Honduras has also led to increased tourism which provides an over-arching stress to marine resources since most tourists spend time in the coastal zone. Recent coral bleaching events and storm damage has exacerbated these effects by acting synergistically to reduce reef health further. Such impacts represent substantial long- and short-term threats to the ecological balance and health of reef ecosystems which, if left unchecked, will ultimately lead to reduced income for coastal communities and other stakeholders relying on fishing and marine-based tourism. Furthermore, any natural or anthropogenic impacts on reef health will inevitably affect other countries in Latin America, and *vice versa*, since the marine resources are linked via currents and the functioning of the system transcends geo-political boundaries.

Effective coastal zone management, including conservation of coral reefs, requires a holistic and multi-sectorial approach, which is often a highly technical and costly process and one that many developing countries cannot adequately afford. With appropriate training, non-scientifically trained, self-financing volunteer divers have been shown to be able to provide useful data for coastal zone management at little or no cost to the host country (Hunter and Maragos, 1992; Mumby *et al*., 1995; Wells, 1995; Darwall and Dulvy, 1996 and Erdmann *et al*., 1997). This technique has been pioneered and successfully applied by Coral Cay Conservation (CCC), a British not-for-profit organisation.

Founded in 1986, 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 does not charge the host country for the services it provides and is primarily self-financed through a pioneering volunteer participatory scheme whereby international volunteers are given the opportunity to join a phase of each project in return for a financial contribution towards the project costs. Upon arrival at a project site, volunteers undergo a training programme in marine life identification and underwater survey techniques, under the guidance of qualified project scientists, prior to assisting in the acquisition of data. Finances generated from the volunteer programme allow CCC to provide a range of services, including data acquisition, assimilation and synthesis, conservation education, technical skills training and other capacity building programmes. Readers are referred to Harborne *et al*. (In press) for an overview of CCC's full role in Utila, which was wider than the collection of the data presented in this series of reports. 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.

The Bay Island of Utila (Figure 1) has been the focus of tourism development in Honduras for many years and the industry is very much aware of the value of conserving the coral reefs and fostering sustainable development. Therefore, between 1995 and 1998, teams of Honduran and British undergraduates participated in 'Project Utila'. The aim of this project was to continuously monitor the state of the coral reefs surrounding Utila in order to provide data that could be used to assist with effective management of the marine resources. One of the outputs of Project Utila was the recommendation that the survey work should be expanded to include a detailed systematic survey of Utila's marine resources with the aim of establishing an environmental database and a management plan for these resources. Unfortunately, the Project Utila team was unable to continue the project beyond 1998 and sought another means of continuing the work.

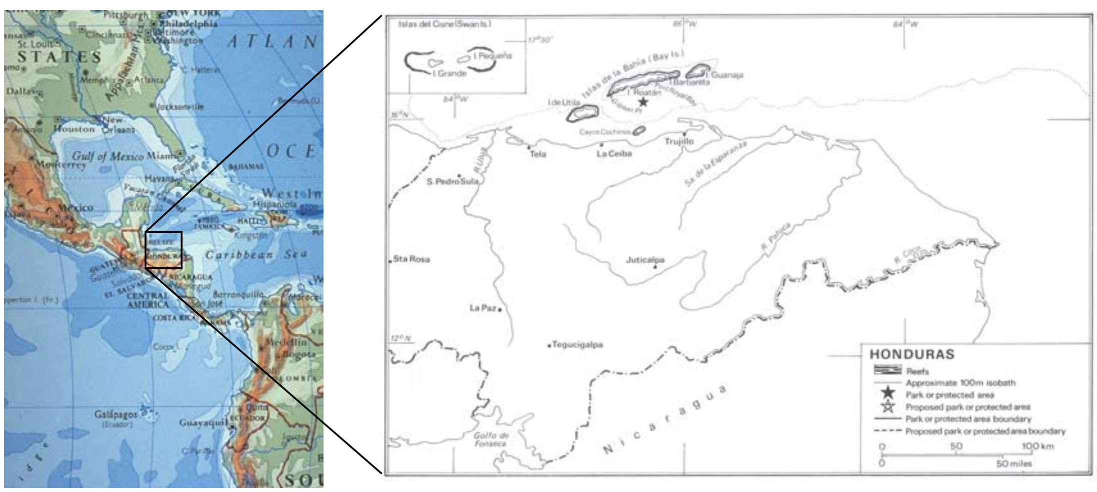

Figure 1. The location of (a) Honduras and (b) the locations of the Bay Islands (Utila, Roatán and Guanaja).

In order to build on the work and achievements of Project Utila, the *Bay Islands 2000* project, therefore, was initiated as a collaborative Honduran / British partnership project between Coorporación Hondureña de Desarrollo Forestal (COHDEFOR), the Universidad Nacional Autonoma de Honduras (UNAH) and the Bay Islands Conservation Association (BICA). The *Bay Islands 2000* project was subsequently accepted as a partner of the Ministry of Tourism's 'Bay Islands Environmental Management Project' (Programa Manejo Ambiental Islas de la Bahía; PMAIB).

The project was established initially in Utila in June 1999 with the aims to:

1. undertake a systematic and detailed survey of the marine resources of Utila and provide data for the development of an integrated coastal zone management plan for the protection and sustainable utilisation of Utila's coral reefs;
2. continue and expand monitoring programmes previously established on the reefs of Utila by Project Utila;
3. establish an environmental database at UNAH for the Bay Islands;
4. provide SCUBA and scientific training and research opportunities for Honduran project counterparts;
5. provide conservation education opportunities for local communities.

This summary report provides an overview of the habitat mapping data collected by the *Bay Islands 2000* project in Utila between June 1999 and August 2000.

2. PROJECT BACKGROUND

Note that a review of the status of the coastal zone of Honduras has recently been published (Harborne *et al*., 2001). Readers are referred to this paper for further background information.

2.1 The coastal zone of Honduras

Honduras lies within the wider Caribbean region that stretches from the Gulf of Mexico to the French Guiana - Brazil border. This region has well known interactions throughout its area and the marine resources of Honduras are inextricably linked to a much larger area via water exchange. Such links lead to, for example, Sullivan Sealey and Bustamante (1999) defining the Tropical Northwestern Atlantic as the largest biogeographical province in the western hemisphere and places Honduras within the large, complex Central Caribbean 'ecoregion'. However, although there are obvious oceanographic connections between Honduras and neighbouring reefs in Central America, and also the wider Caribbean, little is known about migration of adult populations or larval interchange.

The Caribbean coast of Honduras itself stretches from the border with Guatemala in the west to the border with Nicaragua in the east and also encompasses a number of offshore island systems including the Islas de la Bahía (Bay Islands) archipelago. Hence this coastline encompasses more than 91% (735 km) of the country's 820 km coastline (Merrill, 1995) and includes coral reefs, mangrove forests, seagrass beds, estuaries, coastal lagoons, wetlands and tropical coastal fisheries. Such ecosystems are possible because of the tropical climate that is affected by seasonal easterly tradewinds, which cause a rainy season for approximately eight months and a dry season from November to February.

There has been limited research in the coastal zone of Honduras and, for example, the marine resources of the mainland are very poorly studied and there is virtually no published literature on the presence or absence of coral reefs (UNEP/IUCN, 1988). However, Kramer *et al*. (2000) and Cortés (1997) state that because of high levels of runoff there are only scattered, poorly developed coral communities around Puerto Cortés, La Ceiba and Trujillo. It is also known that there are extensive continental mangrove forest and wetland systems along the central section of coastline and bordering the Gulf of Honduras but severe degradation from overfishing, mangrove clearance and pollution has been reported (Sullivan Sealey and Bustamante, 1999). The extensive mangrove system contains a number of lagoons, riverine estuaries as well as offshore mangrove cays (MacKenzie, Jr and Stehlik, 1996). The eastern Mosquitia region of mainland Honduras also has a complex environment of reefs, lagoons, wetlands and barrier beaches in an expansive savanna which plays a key role in fisheries health (Sullivan Sealey and Bustamante, 1999) and is an important breeding ground for waterbirds. The inaccessibility of the Mosquitia region has limited deforestation and agriculture and part of it is further protected by the Río Plátano Biosphere Reserve (Richards, 1996).

The Caribbean coastline of Honduras includes a highly developed small island reef system which can be divided into three groups, the Bay Islands and Cayos Cochinos archipelago, the Mosquitia cays and banks and the small Swan Islands with a coastline length of only 6 km (Cortés, 1997; Sullivan Sealey and Bustamante, 1999). The Bay Islands group, on the edge of the 75 km wide continental shelf, has a number of smaller cays but is dominated by three major islands; Utila, Roatán and Guanaja. These islands are the centre of both reef related tourism and the fishing industry in Honduras and in addition to the coral reefs they also contain significant mangrove wetlands.

There is only limited published information describing the reefs of Honduras (UNEP/IUCN, 1988), although the Cayos Cochinos archipelago has been relatively well studied by scientists working at the Cayos Cochinos Research Station. However, wind generated wave energies are generally higher on more exposed northern coasts and subsequently, for example, the north coasts of the larger islands of the Cayos Cochinos are dominated by massive colonies such as *Montastraea annularis* (Ogden and Ogden, 1998). In contrast, lee areas support a more diverse coral assemblage. Currently unpublished reef mapping work in the Bay Islands by the Ministry of Tourism's 'Bay Islands Environmental Management Project' and Coral Cay Conservation has extended knowledge of the extent and complexity of the reef systems in this area significantly.

The reefs of the Swan Islands and the Mosquitia cays and banks are poorly known because of their inaccessibility and the results of research visits are mainly restricted to unpublished grey literature. Cortés (1997) reports that the Mosquitia cays are surrounded by fringing reefs and patch reefs in lagoonal areas. An expedition in 1960 to the Swan Islands indicated that coral growth may be less abundant than on the reefs of Panama (UNEP/IUCN, 1988) and there is some evidence that the biota of some taxa are less diverse than the Bay Islands because they have a lower habitat diversity and less protection from severe storms (Keith, 1992). More recent anecdotal reports indicate that, because of their isolation and use for only small-scale artisanal fishing, the coral health and fish populations of the Swan Islands may be higher than those of the Bay Islands and Cayos Cochinos. However, the reefs are likely to have suffered significantly from wave damage in 1998 because of the proximity of the Swan Islands to the path of Hurricane Mitch.

The need for coastal zone management and sustainable development in Honduras is well documented and recognised both nationally and internationally. Marine protection in Honduras dates back to the 'Ley de Pescar' decree of May 1959 which declared coral reefs as 'protected areas'. More recently, a particularly significant step for marine conservation in Central America was the signing of the Tulum Declaration in 1997, when Mexico, Belize, Guatemala and Mexico agreed to work towards regional conservation of the Mesoamerican Barrier Reef System. Instigating such initiatives inevitably relies on the support of local stakeholders and despite the continued problems, Honduran ecologists are encouraged by the increasing environmental consciousness among many sectors of the community (Merrill, 1995). For example, there is some evidence that local communities appreciate the benefit of marine protected areas. A study by Barahona and Guzman (1998) showed that 77% of survey respondents believed it was important to protect the marine and terrestrial habitats of Cayos Cochinos and 66% thought that commercially important species were more abundant since fisheries restrictions were enforced.

The national government recognises the ecological and economic needs to conserve marine resources but is severely limited by capacity, funding and expertise. However, in order to co-ordinate and expand local and national initiatives, the Ministry of Tourism has established the 'Bay Islands Environmental Management Project' (Programa Manejo Ambiental de las Islas de la Bahía; PMAIB). This multi-faceted project is funded by a US$19.1 million loan from the Inter-American Development Bank, along with further funding from national government to a total of US$27 million, and has four sub-programmes covering natural resources, sanitation, real estate census and institutional strengthening. Conservation in the Bay Islands will be further strengthened by the World Bank / Global Environment Facility project 'Conservation and sustainable use of the Mesoamerican Barrier Reef System'. This project's objective is to assist the countries of Belize, Guatemala, Honduras and Mexico manage the Mesoamerican Barrier Reef System as a shared, regional ecosystem, safeguard its biodiversity values and functional integrity and create a framework for its sustainable use (Kramer *et al*., 2000).

In addition to international programmes, there is an NGO movement in Honduras but it is relatively nascent. However, there are, for example, groups present in the Bay Islands and their activities are reviewed by Forest (1998). Further assistance for coastal zone conservation initiatives in Honduras is increasingly being provided by international NGOs and for example, the Wildlife Conservation Society has assisted management planning in the Bay Island's existing reserves and the Municipalities of Utila and Roatán, along with PMAIB, have been assisted with data collection, technical advice, training and environmental education programmes by Coral Cay Conservation (Harborne *et al*., in press).

Environmental legislation in Honduras is relatively extensive and Forest (1998) reviews a series of coastal regulations relating to the Bay. The Honduran government has also set several regulations on its fisheries (MacKenzie, Jr and Stehlik, 1996). Despite the range of regulations, enforcement capacity is extremely limited and many stakeholders are able to ignore germane legislation with impunity (Fielding, 2000a). However, the recent recognition of the importance of reserves for conservation means that a total of 15% of Honduras (1.7 million hectares) is now protected via 106 'natural areas' including national parks, wildlife refuges, biological reserves, national forests, anthropological reserves, protected watersheds, natural monuments, cultural monuments and multiple-use areas (Hodges, 1997). Within this system, there are 25 marine protected areas covering 4,300 km^2 (Kramer *et al*., 2000). Indeed, in 1997 legislation was passed declaring most of the Bay Islands as a marine park with varying levels of restrictions on resource use. Among other objectives, this park aimed to strengthen the municipal reserves of Turtle Harbour in Utila and Sandy Bay in Roatán which were designated in 1982. However, although the whole perimeter of Roatán and Guanaja and parts of Utila were included, enforcement is limited and the forestry department, which is responsible for protected areas, has virtually no capacity on the islands. Furthermore, many stakeholders are unaware of the reserve's status or its consequences.

2.2 The Bay Islands

Foreign tourists are attracted to Honduras by, for example, the opportunities for SCUBA diving in the Bay Islands and impressive Mayan ruins. The importance of the income from this industry is well recognised and the Bay Islands were designated as an important tourism zone by the Honduran congress as early as 1982 and laws to promote this industry were passed in the 1990s (Rijsberman, 1999). Between 1987 and 1991, tourist arrivals in Honduras grew at average annual rates of approximately 15%, which exceeded global trends (Fielding, 2000b). By 1993, the annual number of international tourists to the Bay Islands (approximately 30,000, with a high season from September to December) exceeded the local population (Fielding, 2000a).

The Bay Islands, stretching in an arc between 29 and 56 km off the coast of Honduras, sit upon the Bonacca Ridge, an extension of the Sierra de Omoa Mountains. The Bonacca Ridge forms the edge of the Honduran shelf and, as a result, on the northern, ocean-facing side of the islands, shallow water extends only a short distance before the shelf-break. There are also several terrestrial ecological zones in the Bay Islands, including pine and oak savanna, arid tropical forest, beach vegetation, mangrove swamps and uplifted, fossilised coral or iron shore. Most of the dense forest has been removed to provide building materials and the only areas left are on the island of Barbareta and in the hills of Roatán and Guanaja. The height of the islands generally increases from west to east, from the lowland swamps of Utila to the low ridges of Roatán and the two peaks of Guanaja. The Bay Islands were once host to many animal species that have now been hunted to extinction.

The Bay Islands are generally surrounded by fringing reefs, but the north coast of Roatán, the largest and best known island, is dominated by a nearly continuous barrier and fringing reef (UNEP/IUCN, 1988). In contrast, the south coast of Roatán supports a discontinuous fringing reef broken up by channels and bights that were formed by erosion during glacial events. Reefs on both coasts have a relatively narrow landward lagoon dominated by seagrass and additional information on zonation is provided in UNEP/IUCN (1988), Fenner (1993) and Kramer *et al*. (2000). Similarly, on the reefs of Utila, zonation is much more pronounced to the north of the island and the reefs of the leeward side typically comprise of a narrow shelf characterised by a poorly developed reef crest and with little reef development beyond a depth of 25 m. Since Hurricane Mitch and the bleaching events of 1995 and 1998, coral cover is generally low, for example rarely being higher than 30% on Utila and only reaching 50% at the west end of Roatán (Kramer *et al*., 2000). In addition to the fringing reefs, throughout the Bay Islands and Cayos Cochinos there are numerous seamounts which are poorly studied but some are known to have relatively high coral cover and fish populations. These seamounts are also important locations for local fisherfolk and at least some are important as fish spawning areas (Fine, 1992).

Reefs in the Bay Islands and coastal areas are subject to the same threats as those faced by many other islands throughout the Caribbean. These threats, accentuated by rapid development of coastal areas and the influx of overseas investors wishing to build homes on the islands, include:

Sedimentation and watershed management

Corals require clear, sediment free water to ensure sufficient sunlight for photosynthesis by symbiotic algae. Similarly, physical smothering by sediment can kill coral colonies. After Hurricane Mitch and during the following ‘rainy season’ high levels of sediment from the mainland were evident around the Bay Islands. In the future, attempts to provide access from the sea to many of the proposed development sites may include dredging shallow channels through the reefs and / or lagoons. Dredging often results in direct disturbance of nearby habitats and wider sedimentation of adjacent coral reefs. Indeed, anecdotal reports by local researchers indicate that sedimentation caused by erosion from road building and hotel construction is one of the most important impacts to reefs of the Bay Islands (Fielding, 2000b).

Further inland, Honduras lost 1.8 million hectares of forest from 1964 to 1988 and it has continued to decline, partly from agriculture but also from the focus on logging rather than management (Merrill, 1995). As in many other countries, such deforestation threatens the health of marine resources by increasing sediment loads but such links are poorly understood in Honduras. Since Honduras is a water-rich country with numerous rivers draining the highlands, this threat is significant. For example, the large river Ulúa drains into the Caribbean west of the Bay Islands after flowing 400 km through the economically important Valle de Sula (Merrill, 1995).

Mangrove deforestation

On small islands, where good building land is at a premium, it is likely that there will be demands to remove areas of mangrove forest. Deforestation of the limited areas of mangrove will result in a loss of important nesting habitats for birds and other important terrestrial species and will remove breeding and nursery grounds for commercially important marine species such as conch and lobster.

Effluent and waste run-off

Increased nutrient levels, especially close to large towns and cities, is now regarded as a significant reef stressor throughout the Mesoamerica Barrier Reef System. Most buildings in the Bay Islands employ septic tanks to store and treat human waste, many of which are situated on low land immediately adjacent to the coast. Improper installation and maintenance of these septic systems may pollute the ground water system (causing a health risk) and leach out into the marine environment causing nutrification and excessive algal growth along the reefs. The need for better public access to water supplies and sewerage has been a major element of development programmes in Honduras and throughout Central America.

Physical damage

There is an extremely high level of diver activity around the Bay Islands (particularly Utila and the western end of Roatán), often by inexperienced or trainee divers. Physical damage from divers and boat anchors can be significant at popular dive sites. However, in Utila, the local community has done an exemplary job of installing and maintaining mooring buoys for the local dive shops to utilise (thus limiting anchor damage). If not properly controlled, diving activity may result in significant physical damage to the Bay Islands' reefs. Furthermore, cruise shipping has been promoted in the Bay Islands and the first cruise ship arrived in Utila in 2000 (Fielding, 2000b). However, this represents a significant environmental threat and case studies from elsewhere in the region show negative effects from dredging, coastal development, mechanical damage to marine resources and sewage (Fielding, 2000b).

Fishing pressure

The population of the Bay Islands is now supplemented by hundreds of tourists each month who all enjoy eating the local fish catch and this has placed significant pressures on local fisheries. For example, finfish, particularly groupers (Serranidae), snappers (Lutjanidae), grunts (Haemulidae) and jacks (Carangidae) are targeted by artisanal fisherfolk via a variety of traditional techniques. Although quantitative data are sparse, intensive fishing effort has clearly impacted populations and now, for example, fishermen in the Bay Islands favour more remote offshore banks compared to the heavily exploited fringing reefs. Furthermore, decreases of herbivorous fish populations, in conjunction with the disease induced loss of sea urchins and decreasing water quality, also contributes to increasing reef coverage by algae, to the detriment of corals.

Similarly, lobster and conch are a significant fishery resource on reef formations bordering the islands and mainland (Tewfik *et al*., 1998a). These species are caught by both artisanal and industrial fisherfolk and indeed Honduras maintains the largest lobster fleet of all Central American countries with 190 vessels by the early 1990s (Ehrhardt, 2000). Although detailed data are lacking, the lobster and conch fisheries are generally considered to be over-exploited.

Coral bleaching

Coral bleaching events occur during occasional periods when climate conditions raise seawater temperatures and solar irradiance (summarised in Westmacott *et al*., 2000). Coral bleaching, the paling of coral tissue from the loss of symbiotic zooxanthellae, has presumably occurred previously in Honduras but evidence of severe events prior to the mid-1990s is sparse. However, a mass bleaching event was recorded in 1995 by Guzmán and Guevara (1998) which affected 73% of scleractinians along with over 90% of all hydrocorals, zoanthids and octocorals. More detailed information is available for the more severe mass bleaching event in 1998 when high sea-surface temperatures affected Honduras in September and October. Interestingly there is some evidence that the water movements caused by Hurricane Mitch may have reduced sea-surface temperatures and allowed some corals to recover. However, the effects of bleaching were severe, leading to an average regional coral mortality of 18% on shallow reefs and 14% on forereefs along with subsequent increases in the prevalence of diseases and will have long-term ecological and socio-economic consequences (Kramer *et al*., 2000; Kramer and Kramer, 2000). Although the community of the Bay Islands cannot change global warming, there is evidence to suggest that a well managed reef will recover quicker than a stressed one.

Coral disease

Caribbean corals have been affected by a number of diseases, defined as an impairment of an organism's vital functions or systems. Diseases have many causes, especially micro-organisms, and can affect not only an individual organism but also the community in which it lives. Diseases can alter the reproductive potential of a population, alter interactions among populations and cause mortalities, leading to changes in ecosystem composition, structure, processes and function. Corals become susceptible to diseases from natural and human-induced physical and chemical changes in water conditions; abrasion or smothering by sediment; changes in temperature and salinity and increased exposure to nutrients and toxic chemicals. Many of these causes are present around the Bay Islands. Furthermore, Kramer and Kramer, 2000 present evidence that Hurricane Mitch increased the prevalence of disease in the Bay Islands.

Hurricane damage

Honduras lies within the hurricane belt but hurricanes are relatively infrequent. However, damage has been reported from, for example, Hurricane Fifi in 1974 which killed 8,000 people (Merrill, 1995; Ogden and Ogden, 1998). Hurricane Mitch in 1998 (category 5 with occasional wind speeds greater than 250 km per hour) is regarded as the most deadly hurricane to strike the western hemisphere for the last two centuries (Fielding, 2000a). Hurricane Mitch had significant effects on the marine resources of Honduras, particularly as it occurred shortly after a mass coral bleaching event. Kramer *et al*. (2000) report losses in coral cover of 15-20% across the Central American region and damage to 50-70% of corals in parts of Honduras, although recent mortality was only moderately high (<25%). Physical damage (broken, knocked over and abraded colonies) from the hurricane's direct action was approximately 11% of corals on shallow reefs and 2% on deep reefs in Honduras (Kramer and Kramer, 2000). Damage was particularly severe in the Bay Islands as the hurricane slowed and stalled close to Guanaja for two days. Secondary effects, such as the extensive run-off of low salinity, sediment-laden water into the Gulf of Honduras are more difficult to quantify in the short-term (Kramer and Kramer, 2000).

Shipping and offshore effects

Heyman and Kjerfve (2001) state that industrial shipping is one of the largest and potentially most environmentally damaging industries in the Gulf of Honduras. Puerto Cortés, on the western coast of mainland Honduras, is one of the largest ports in the region and a spill from one of the many petroleum or chemical vessels could be catastrophic.

This combination of threats to reef health underscores the need to control land-based sources of stress through better land-use planning and environmental management.

2.3 Utila

Utila is the smallest of the three main Bay Islands and is 11 km long and 5 km wide with almost two-thirds of its area covered by swamp. Two small hills on the eastern side of the island, Stuart's Hill and Pumpkin Hill, are of volcanic origin. Almost all Utilans (population approximately 2000) live in East Harbour on the south side of the island. On the southwest side of the island lie 12 small islands, referred to as the Cays. The Cays are home to approximately 400 people, mostly on Suc-Suc and Pigeon Cay.

As recently as 1992, Utila was a quiet island community that relied mainly on local industries such as fishing and farming as it's main source of income. Also, for many years the men-folk of Utila have worked overseas on ships and oil rigs, sending their salaries home to their families. However, the community has developed rapidly over recent years as a fledgling tourism industry has expanded into a major aspect of the island's economy. Many tourists visit Utila to get SCUBA certifications and it is now known as the cheapest place in the world to learn to dive. Approximately 14 dive shops supply training facilities to thousands of international travellers who visit the island each year to learn to dive and enjoy the island's reefs, bars, restaurants and night-clubs. Whilst this industry brings additional income into the local economy and provides livelihoods for many islanders, it has had an impact upon the 'traditional' way of life.

2.4 Aims and objectives

During work on Utila, CCC developed a programme of surveys, training and conservation education aimed at assessing the status of local reefs and improving environmental awareness amongst neighbouring communities (Harborne *et al*., In press). The primary aims of the project were to: map the benthic and fish communities; provide data on reef health and threats to current reef health; continue the monitoring programme of Project Utila; generate basic fish and coral species lists; provide basic socio-economic data on diving pressure; providing training opportunities for local counter-parts and environmental awareness programmes (Table 1).

Table 1. Main aims, objectives and anticipated outputs of the *Bay Islands 2000* project in Utila.

AIM	OBJECTIVE	ANTICIPATED OUTPUTS
➲ Resource assessment.	❶ Undertake a scientific survey of Utila's reefs to document the benthic and fish communities. ❷ Conduct studies on climatic, oceanographic and anthropogenic variables affecting the reefs. ❸ Provide management tools and recommendations.	🗎 Baseline database and description of reef communities. 🗎 Documentation of gross climatic, oceanographic and anthropogenic variables. 🗎 Habitat map using aerial photography. 🗎 Management recommendations.
➲ Reef health assessment.	❶ Undertake 'Reef Check' surveys to quantitatively assess benthic and fish communities and anthropogenic impacts. ❷ Establish a Reef Check database for Utila. Provide data for the global Reef Check databases. ❸ Continue monitoring the sites established by 'Project Utila'. ❹ Provide management tools and recommendations.	🗎 Quantitative assessment of reef health. 🗎 Data set for comparison with future surveys. 🗎 Information on the change of benthic communities over time. 🗎 Management recommendations.
➲ Taxonomy.	❶ Complete a basic biodiversity assessment by generating fish and coral species lists	🗎 Quantitative assessment of reef biodiversity. 🗎 Data set for comparison with future surveys.
➲ Socio-economics.	❶ Undertake a basic assessment of diving pressure around Utila. ❷ Provide management tools and recommendations.	🗎 Quantitative assessment of diving pressure. 🗎 Data set for comparison with future surveys. 🗎 Management recommendations.
➲ Training and conservation education.	❶ Provide scientific and SCUBA training for CCC volunteers and local counterparts. ❷ Heighten awareness of marine resources, their use and protection. ❸ Begin to develop a sense of community stewardship in managing the coastal zone.	🗎 Trained project members. 🗎 Advice on coastal zone management issues around Utila. 🗎 Increased awareness amongst local communities.

The results of CCC's work in Utila are documented in a series of reports. This report is concerned with the benthic and fish community data, used for habitat mapping, gathered during the 'Resource assessment' component of the fieldwork.

3. METHODS

3.1 Volunteer training

Efficient and effective training is a vital component of any volunteer programme in order that participants quickly gain the required identification and survey skills that allow them to collect accurate and useful data. During the *Bay Islands 2000* project, CCC used an intensive 11-day training programme, which is outlined in Table 2. The programme was designed to provide volunteers, who may have no biological knowledge, with the skills necessary to collect useful and reliable data. The primary aim of the lecture programme was to give volunteers the ability to discern the specific identification characteristics and relevant biological attributes of the species that they would encounter during their diving surveys. The training programme was co-ordinated by the Project Scientist (PS) and Science Officer (SO) and involved two lectures and two dives each day along with de-briefings and evening audio-visual presentations. Volunteers were also encouraged to snorkel and utilise identification guides to ensure a thorough understanding of the information provided in the lectures.

An important component of the training schedule was a series of testing procedures to ensure that each volunteer had reached a minimum acceptable standard. Hence the training programme concluded with a series of tests, which ensured that the volunteers had reached an acceptable standard of knowledge. These tests used both 'flash-cards' and in-water identification exercises for corals and fish. Furthermore, to assess the quality of data collected by CCC volunteers during actual survey work, two validation exercises were undertaken. The benthic validation exercise used a test transect survey set up and thoroughly surveyed by the PS and SO to collate a reference data set. Test transects were conducted in buddy pairs with one person recording coral and the other soft corals, invertebrates and algae (as performed by Divers 3 and 4 during surveys; Section 3.3). Data were then transferred to recording forms and entered into a spreadsheet where the results from each pair were compared to the reference using the Bray-Curtis similarity coefficient (Equation 1; Bray and Curtis, 1957).

Equation 1:

$$\text{Bray - Curtis Similarity, } S_{jk} = \left[1 - \frac{\sum_{i=1}^{p} \left| X_{ij} - X_{ik} \right|}{\sum_{i=1}^{p} \left(X_{ij} + X_{jk} \right)} \right]$$

Where X_{ij} is the abundance of the *i*th species in the *j*th sample and where there are *p* species overall.

Since it is impossible to compare volunteer fish data to a reference, validation of fish surveys were conducted by measuring the consistency between pairs of surveyors. It is then assumed that if surveyors are consistent they are also accurate. Therefore, both divers within a buddy pair independently survey the whole fish list and each surveyor fills out their own survey form and enters it onto a spreadsheet. As with the benthic validation, the pairs of results were compared using the Bray-Curtis similarity coefficient. These assessments were similar to the critical assessment conducted by CCC in 1993 to test the accuracy of volunteer divers conducting baseline transect surveys (Mumby *et al*., 1995).

Table 2. Science training week timetable for CCC volunteers in Utila. ID = identification.

	Day +1 (Fri)	Day +2 (Sat)	Day +3 (Sun) No scuba day	Day +4 (Mon)	Day +5 (Tue)	Day +6 (Wed)	Day +7 (Thr)	Day +8 (Fri)	Day +9 (Sat)	Day +10 (Sun) No scuba day	Day +11 (Mon)
⇩AM		**Lecture 2** ▶Dangerous animals! procedures **Practical** ▶Orientation dive	**Practical** ▶ID - coral life forms (snorkel) **Review** ▶Coral life forms	**Lecture 5** ▶Intro to coral biology ▶Soft corals/fire coral ID **Practical** ▶Hard & soft coral ID (scuba 18m)	**Lecture 7** ▶Coral ID - species **Practical** ▶Coral ID – Families (scuba-28m) **Review** ▶Coral ID – Families	**Lecture 9** ▶Intro to fish & families **Practical** ▶Fish ID – families (scuba-18m) **Review** ▶Fish ID – target species	**Lecture 11** ▶Fish ID - pt. 2 **Practical** ▶Fish ID (scuba-18m) **Review** ▶Fish ID	**Lecture 13** ▶Invert ID – pt.1 ▶CCC ordinal scales **Skills Validation** ▶Benthic validation (scuba-28m) **Review** ▶Benthic validation	**Lecture 15** ▶Habitat types **Skills Validation** ▶Fish (scuba-18m) **Review** ▶CCC ordinal scale	**Review** ▶ID – hard & soft corals	**Practical** ▶CCC survey (scuba-20m)
⇩PM	**Transfer to site**	**Practical** ▶Orientation dive	**Lecture 4** ▶ CCCs Honduran partners	**Lecture 6** ▶Major hard coral grps ▶Additional species info. **Practical** ▶Hard/soft coral ID (scuba 16m) **Review** ▶Hard/soft coral ID	**Lecture 8** ▶Coral ID – species **Practical** ▶Coral ID – target species (scuba-16m) **Review** ▶Coral ID – target species **Self-revision** ▶Coral ID	**Lecture 10** ▶Fish ID – pt. 1 **Practical** ▶Fish ID (scuba-16m)	**Lecture 12** ▶Fish ID – pt..3 **Practical** ▶Fish ID (scuba-16m)	**Lecture 14** ▶CCC survey methods **Practical** ▶Practice survey (scuba-16m)	**Lecture 16** ▶Review of CCC survey methods ▶Survey forms **Examination** ▶Hard & soft corals – coral trail (scuba-16m)	**Skills tests** ▶Emergency procedures **Practical** ▶Marine ID skills (ID trail – snorkel only) ▶GPS use **Lecture 18** ▶GPS use **Lecture 19** ▶Ropes & knots	**Practical** ▶CCC survey (scuba-18m)
Eve	**Lecture 1** ▶Roatan & Honduras ▶Local culture & customs **Review** ▶ Training schedule			**Review** ▶Coral ID	**Review** ▶Coral ID **Examination** ▶Coral ID	**Review** ▶Fish ID	**Review** ▶ID – coral & fish (slides) **Lecture 12** ▶Marine plants & algae	**Examination** ▶Fish ID	**Lecture 17** ▶Invert ID – pt.2 **Practical** ▶Optional night-dive (12m)	**Lecture 20** ▶Use of CCC data **Lecture 21** ▶CCC data validation	**Examination** ▶Re-takes (if required) **Lecture 22** ▶Other survey methods (e.g. ReefCheck)

3.2 Study areas

Data were collected within individual ‘study areas’ (Figure 2) which were defined *a priori* to assist structuring the survey work. Furthermore, this facilitated data analysis at the scale of both the whole island and by individual study areas to examine different spatial patterns.

3.3 Baseline transect technique

The habitat mapping component of the *Bay Islands 2000* project utilised the standard baseline survey techniques developed by CCC for the rapid assessment of biological and physical characteristics of reef communities by trained volunteer divers. Following an intensive training programme, CCC’s techniques have been shown to generate precise and consistent data appropriate for baseline mapping (Mumby *et al*., 1995). All surveys were co-ordinated by the PS and SO to ensure accurate and efficient data collection.

CCC’s standard baseline transect survey technique utilised a series of plot-less transects, perpendicular to the reef, starting from the 28 metre contour and terminating at the reef crest or in very shallow water. Stony corals and fish were recorded to species level. Sponges and octocorals were recorded in various life form categories. Seaweeds were classified into three groups (green, red and brown algae) and identified to a range of taxonomic levels such as life form, genera or species.

Since most transects require two or more dives to complete, transect surveys were usually divided up into sections (or ‘sub-transects’) with surveys of each sub-transect carried out by a team of four trained divers divided into two buddy pairs (A and B) as shown in Figure 3. At the start point of each sub-transect, Buddy Pair B remained stationary with Diver 3 holding one end of a 10 m length of rope, whilst Buddy Pair A swam away from them, navigating up or along the reef slope in a pre-determined direction until the 10 m line connecting Diver 1 and 3 became taught. Buddy Pair A then remained stationary whilst Buddy Pair B swam towards them. This process was repeated until the end of the planned dive profile, when a surface marker buoy (SMB) carried by Diver 2 was deployed to mark the end of that sub-transect. The SMB acted as the start point for the next survey team and this process was repeated until the entire transect was completed. The positions of the SMB at the start and end of each dive were fixed using a Global Positioning System (GPS).

Diver 1 was responsible for leading the dive, taking a depth reading at the end of each 10m interval, and documenting signs of anthropogenic impact such as broken coral or fishing nets. Diver 1 also described the substratum along the sub-transect by recording the presence of five substrate categories (dead coral, bedrock, rubble, sand and mud). Divers 2, 3 and 4 surveyed fish, hard corals, sponges and gorgonians and algae and invertebrates respectively. All divers surveyed an area of approximately 2.5 metres to either side of the line.

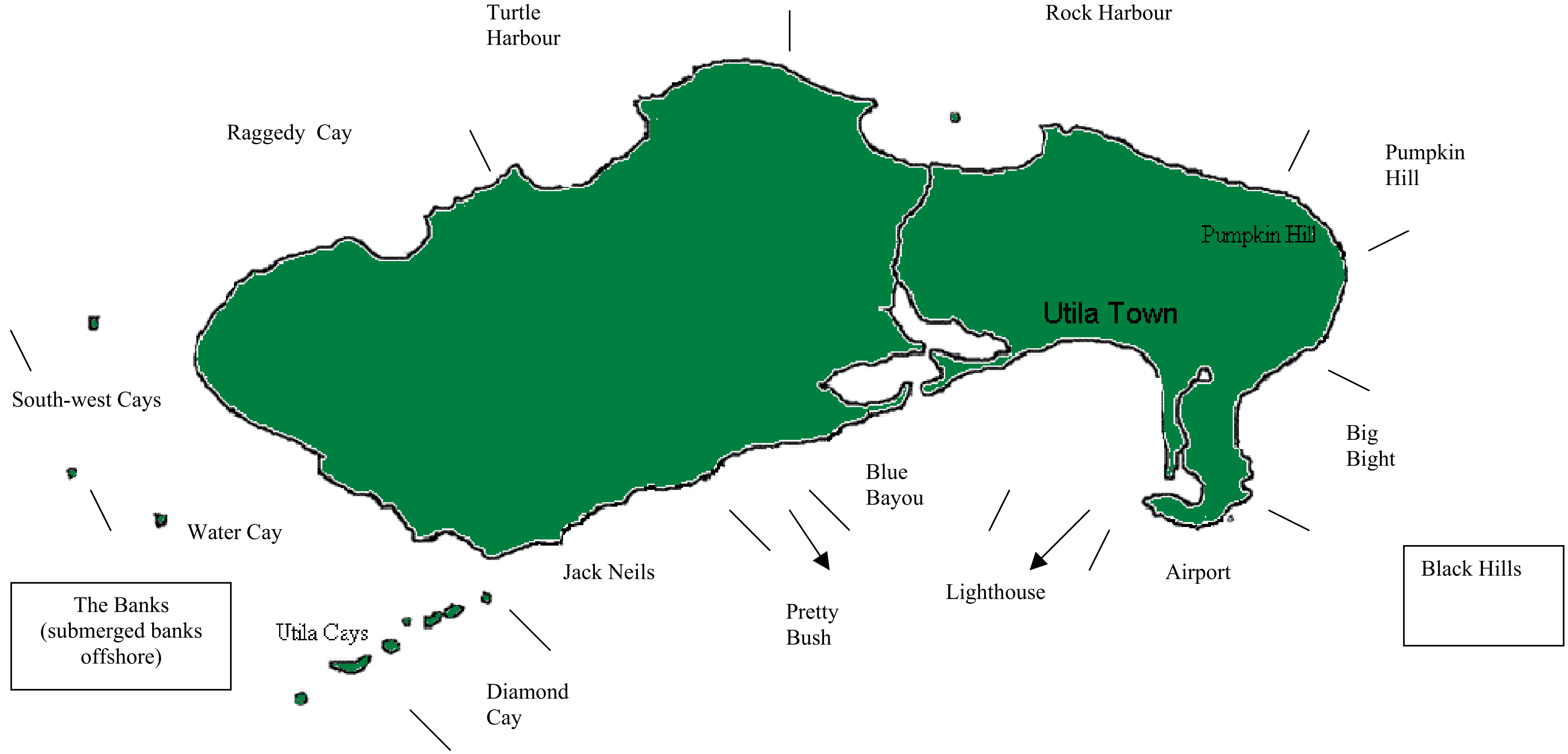

Figure 2. Map of Utila showing the location of the study areas around the island.

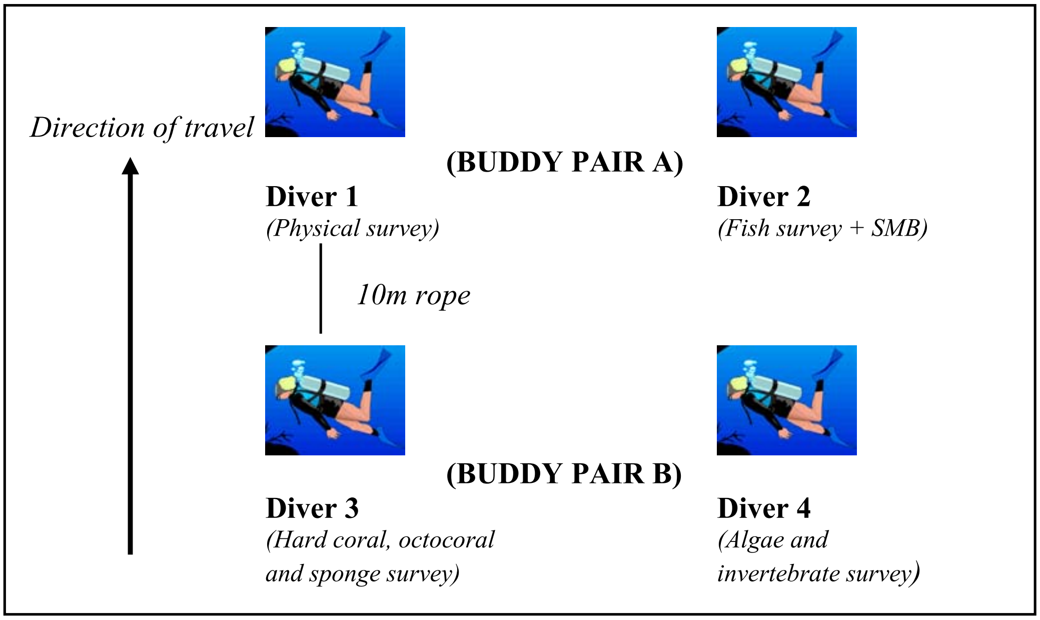

Figure 3. Schematic diagram of a baseline survey dive team showing the positions and data gathering responsibilities of all four divers. Details of the role of each diver are given in the text.

During the course of each sub-transect survey, divers may have traversed two or more apparently discrete habitat types, based upon obvious gross geomorphological (e.g. forereef, escarpment or lagoon) or biological differences (e.g. dense coral reef, sand or rubble; Figure 4). Data gathered from each habitat type were recorded separately for subsequent analysis.

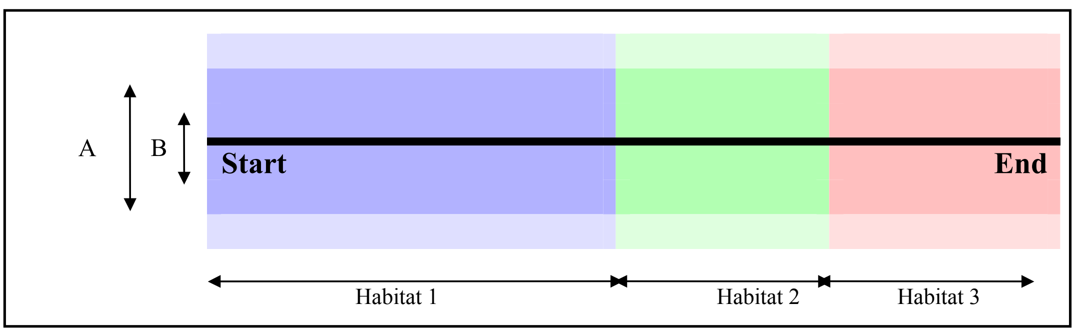

Figure 4. Schematic diagram (aerial aspect) of an example of a reef area mapped by divers during a sub-transect survey. Solid line represents imaginary sub-transect line. Dashed lines and shaded areas represent areas surveyed (A = 5m wide swathe surveyed by Divers 1, 2 and 4; B = 2 m wide swathe surveyed by Diver 3). Benthic data from habitats 1, 2 and 3 (e.g. reef, sand and rubble) are recorded separately.

Each species, life form or substratum category within each habitat type encountered was assigned an abundance rating from the ordinal scale shown in Table 3.

Table 3. Ordinal scale assigned to life forms and target species during baseline surveys.

Abundance rating	Coral and algae	Fish and invertebrates (number of individuals)
0	None	0
1	Rare	1-5
2	Occasional	6-20
3	Frequent	21-50
4	Abundant	51-250
5	Dominant	250+

During the course of each survey, certain oceanographic data and observations on obvious anthropogenic impacts and activities were recorded at depth by the divers and from the surface support vessel. The methods used for these parameters, and the resulting data are presented in a separate report (Cadbury *et al*., 2001).

3.3 Data analysis

Note on statistical conventions: during this report the results of statistical tests are given by showing the 'p' (probability) value of the test. Under statistical conventions, a p value of less than 0.05 is regarded as 'significant' (the error of the test is less than 1 in 20) and a p value of less than 0.01 is regarded as 'very significant'.

3.3.1 Benthic data

In order to describe the reefal habitats within the project area, benthic and substratum data were analysed using multivariate techniques within PRIMER (Plymouth Routines in Multivariate Ecological Research) software. Data from each Biological Form (which represents a 'snap-shot' of the benthic community from either part or all of a habitat type distinguished by the survey team) are referred to as a Site Record. Multivariate analysis can be used to cluster the Site Records into several groups, which represent distinct benthic classes. Firstly, the similarity between benthic assemblages at a subset of 250 Site Records was measured quantitatively using the Bray-Curtis Similarity coefficient without data transformation (Equation 1; Bray and Curtis, 1957). This coefficient has been shown to be a particularly robust measure of ecological distance (Faith *et al.*, 1987).

Agglomerative hierarchical cluster analysis with group-average sorting was then used to classify field data. Cluster analysis produces a dendrogram grouping Site Records together based on biological and substratum similarities. Site Records that group together are assumed to constitute a distinct benthic class. Characteristic species or substrata of each class were determined using Similarity Percentage (SIMPER) analysis (Clarke 1993).

To identify characteristic features, SIMPER calculates the average Bray-Curtis similarity between all pairs of intra-group samples (e.g. between all Site Records of the first cluster). Since the Bray-Curtis similarity is the algebraic sum of contributions from each species, the average similarity between Site Records of the first cluster can be expressed in terms of the average contribution from each species. The standard deviation provides a measure of how consistently a given species contributes to the similarity between Site Records. A good characteristic species contributes heavily to intra-habitat similarity and has a small standard deviation. The univariate summary statistics of median abundance of each species, life form and substratum category were also used to aid labelling and description of each benthic class, following the classes described in Mumby and Harborne (1999). Data points not included in the sub-set of clustered data were assigned to a benthic class via a discriminant function (Hand, 1981).

Finally, the benthic class of each Site Record was combined with the geomorphological class assigned during the survey to complete the habitat label. The combination of a gemorphological class and benthic class to produce a habitat label follows the format described by Mumby and Harborne (1999).

3.3.2 Fish and invertebrate data

Fish and invertebrate data were summarised graphically and via univariate statistics, along with more detailed examination of the data using Kruskal-Wallis (KS) and ANalysis Of SIMilarity (ANOSIM, a routine within PRIMER). ANOSIM tests for differences between groups of community samples, defined *a priori*, using randomisation methods on a similarity matrix produced by cluster analysis. Data were either summarised for the whole project area or for each of the five reef complexes as appropriate. Note that the ordinal scores for fish and invertebrates cannot be standardised for transect length.

3.4 Habitat map production

Once each Site Record had been assigned to a habitat type, they were combined with aerial photography to produce a habitat map. The aerial photographs were obtained from PMAIB and consist of a series of three, over-lapping colour images with minimal cloud cover. To facilitate maximum resolution of benthic habitats, habitat boundaries (‘polygons’) were delineated by eye onto acetate sheets from hard copies of these images. These acetate sheets were then scanned and joined within Adobe Photoshop. This digital file was then imported into ESRI Arc/Info Geographic Information System (GIS) software for editing, cleaning and building polygons.

Both the aerial photographs and polygon coverage were then geometrically corrected with Arc/Info GIS software. Geometric correction is achieved using a series of Ground Control Points (GCPs) which are the correct co-ordinates, collected either via GPS in the field or from an accurate chart, of obvious features such as island headlands. These GCPs are located on the aerial photographs or polygon coverage and the computer is then able to correct the whole file so that every area has the correct co-ordinates.

When the aerial photographs and polygon coverage had been geocorrected, the location of each Site Record was overlaid within the GIS using the GPS co-ordiantes collected during each survey. Polygons were then classified using a spatial join procedure within the GIS. Note that if a given polygon contained differently classified Site Records the most common classification was used. For example, if a polygon contained three Site Records classified as ‘Forereef + Sparse massive and encrusting corals’ and one Site Records classified as ‘Forereef + Dense massive and encrusting corals', the polygon was classified 'Forereef + Sparse massive and encrusting corals'. Finally, unclassified polygons (i.e. polygons that were not surveyed by CCC volunteers) were assigned a label using a combination of study of the aerial photographs, adjacent areas that were surveyed and anecdotal information. Finally, contextual editing was undertaken by the authors to classify additional polygons where the habitat was known but no actual survey data were available.

4. RESULTS

4.1 Volunteer training

The results of the tests and validation exercises that concluded the science training weeks during the *Bay Islands 2000* project are shown in Table 4. Table 4 shows that the volunteers achieved a high standard in the tests and validation exercises.

Table 4. Summary of test and validation results for CCC volunteers in Utila. 181 volunteers and staff members undertook science training. Figures in parentheses show standard deviation.

Test	Mean scores
Coral Test - % passed	87.9
Coral Test - mean score (%)	89.5 (10.0)
Coral Re-test - % passed	100.0
Coral Re-test – mean score (%)	90.6 (7.4)
Coral Trail - % passed	60.0
Coral Trail - mean score (%)	78.7 (17.8)
Mean similarity coefficient for benthic validation exercise (%)	65.6 (11.8)
Fish Test - % passed	47.2
Fish Test – mean score (%)	75.5 (18.3)
Fish Re-test - % passed	76.2
Fish Re-test – mean score (%)	84.0 (3.2)
Mean similarity co-efficient for fish validation exercise (%)	62.1 (14.5)

4.2 Surveys completed

During the *Bay Islands 2000* project in Utila a total of 592 dives were completed, which resulted in 169 baseline transects within the 16 study areas (Figure 2). These dives generated 784 Biological Forms including over 39,000 individual records of species or life form abundance and location. The locations of each Site Record are shown in Figure 5.

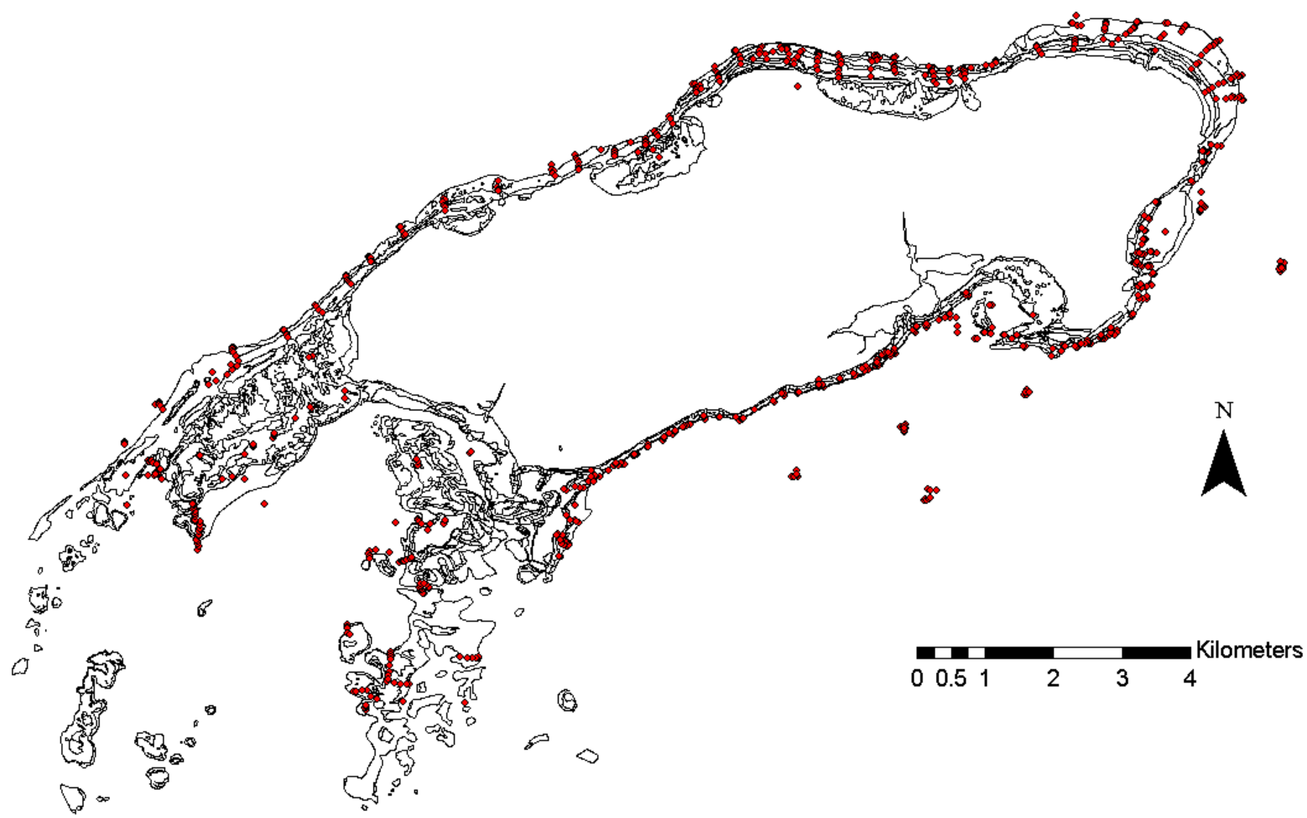

Figure 5. Locations of Site Records (red circles) completed during CCC surveys around Utila. Lines show the polygons that were delineated from the aerial photographs.

4.3 Benthic data

The dendrogram resulting from cluster analysis of the baseline survey data discriminated nine major benthic classes, each with a minimum of three Site Records. The dendrogram resulting from cluster analysis of the 163 records is shown in Figure 6. The remaining 87 records (34.8%) were discarded because the dendrogram showed that they represented either erroneous data or extremely rare habitats i.e. they did not cluster with any other site records.

Using the characteristics of the benthic class defined by SIMPER and univariate analysis (Table 5 and Appendix 1), the nine benthic classes were labelled as shown in Table 6.

Figure 6. Dendrogram from cluster analysis of CCC baseline survey data from Utila. Each line represents benthic and substratum data from each Site Record (one completed Biological Form). The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray-Curtis coefficient (%).

Table 5. Major characteristics of the nine benthic classes discriminated during the *Bay Islands 2000* project in Utila. Figures in parentheses indicate median abundances derived from 0-5 ratings assigned during surveys. A full list of all medians is provided in Appendix 5. The most characteristic species, life forms or substratum categories (greater than 5% contribution to cluster similarity as highlighted by SIMPER analysis) are in bold.

BENTHIC CLASS	SUBSTRATUM	HARD CORALS	OCTOCORALS	SPONGES	ALGAE / SEAGRASS
1	**Sand (4.6)**	Rose (0.5)	-	-	***Thalassia* (4.1)**, ***Syringodium* (2.7)**, *Rhipocephalus* (1.2), *Dictyota* (1.1)
2	**Sand (4.6)**	Cavernous Star (0.5), Leaf (0.4), Mountainous Star (0.4)	Branching Plume (0.7)	Encrusting (0.4)	***Dictyota* (1.0)**, ***Rhipocephalus phoenix* (0.9)**, ***Halimeda tuna* (0.4)**
3	**Bedrock (4.1)**	**Elliptical Star (1.1)**, Mountainous Star (1.1)	**Common Sea Fan (1.0)**, Branching Plume (1.3)	Encrusting (0.4)	***Dictyota*** (2.3)
4	**Sand (3.1)**, **Bedrock (2.8)**	**Smooth Brain (2.1)**, Smooth Starlet (1.6), Elliptical Star (1.6)	**Branching Plume (2.3)**, Branching Rod (2.0)	Encrusting (1.2)	***Dictyota* (2.6)**
5	Dead coral (1.3), Bedrock (1.0)	**Mountainous Star (2.8)**, Cavernous Star (2.4)	**Branching Rod (2.9), Branching Plume (2.8)**	Tube (1.3)	***Dictyota* (2.6)**, *Halimeda goreaui* (1.8)
6	**Sand (2.8), Bedrock (2.3)**	Mountainous Star (1.4), Mustard Hill (1.2), Smooth Brain (1.0)	Branching Rod (1.2)	Encrusting (1.0)	***Dictyota* (1.9)**, *Halimeda goreaui* (1.0), *Lobophora variegata* (1.1)
7	**Bedrock (2.7)**	Leaf (1.3), Branching Fire (1.3), Smooth Brain (1.2), Mustard Hill (1.2)	Branching Rod (2.0), Branching Plume (1.9)	Encrusting (1.7), Tube (1.0)	***Dictyota* (2.2)**, ***Lobophora variegata* (2.1)**
8	**Bedrock (2.1)**	Mountainous Star (1.6), Leaf (1.5), Cavernous Star (1.1)	**Branching Rod (1.2), Branching Plume (1.4)**	Encrusting (1.0), Tube (1.0)	***Lobophora variegata* (2.9)**, ***Dictyota* (2)**
9	Bedrock (2.0), Dead Coral (1.8)	Mountainous Star (2.2), Mustard Hill (1.8), Leaf (1.7), Cavernous Star (1.5)	Branching Plume (2.0), Branching Rod (1.8)	Encrusting (1.1), Vase (1)	***Lobophora variegata* (2.8)**, ***Dictyota* (2.5)**, *Halimeda goreaui* (1.9)

Table 6. The benthic classes discriminated by cluster and discriminant analysis and labelled using SIMPER and univariate statistics.

Benthic class	Number of Site Records	Label
1	28	Seagrass
2	92	Sand with sparse algae
3	7	Bedrock / rubble and sparse gorgonians
4	54	Bedrock / rubble and dense gorgonians
5	37	Dense massive and encrusting corals
6	89	Bedrock / sand and gorgonians
7	49	Fleshy brown algae and sparse gorgonians
8	90	Sparse massive and encrusting corals
9	163	Medium density massive and encrusting corals
Unknown	175	
Total	**784**	**-**

When combined with the geomorphological habitats, a total of 50 habitats were delineated in Utila. The commonest of these habitats are listed in Table 7.

Table 7. Habitat types delineated by baseline transect data during the *Bay Islands 2000* project in Utila. Unknown records and habitat types with less than 1% of Site Records are omitted for clarity.

Habitat type	Number of Site Records	Percentage of Site Records
Back Reef + Bedrock / sand and gorgonians	13	2.1
Back Reef + Fleshy brown algae and sparse gorgonians	7	1.1
Escarpment + Dense medium and encrusting corals	14	2.3
Escarpment + Fleshy brown algae and sparse gorgonians	8	1.3
Escarpment + Medium density massive and encrusting corals	34	5.6
Escarpment + Sparse massive and encrusting corals	23	3.8
Forereef + Bedrock / rubble and dense gorgonians	44	7.2
Forereef + Bedrock / sand and gorgonians	54	8.9
Forereef + Dense medium and encrusting corals	10	1.6
Forereef + Fleshy brown algae and sparse gorgonians	31	5.1
Forereef + Medium density massive and encrusting corals	102	16.7
Forereef + Sand with sparse algae	73	12.0
Forereef + Seagrass	7	1.1
Forereef + Sparse massive and encrusting corals	60	9.9
Reef Crest + Medium density massive and encrusting corals	7	1.1
Shallow lagoon + Seagrass	18	3.0
Spur & groove + Bedrock / sand and gorgonians	10	1.6
Spur & groove + Medium density massive and encrusting corals	12	2.0

4.4 Fish data

4.4.1 Fish communities within the whole project area

Analysis of individual fish species (all surveys combined) showed that the most obvious feature of fish populations in the project area was the abundance of small reef associated species. For example, the most abundant species was the bicolor damselfish (median abundance 1.3). Similarly, the blue chromis, foureye butterflyfish, bluehead wrasse and blue tang also had abundances of > 0.4.

Table 8. The median abundance from all baseline surveys of the 10 commonest fish species recorded around Utila.

Fish species	Median abundance
Bicolor damselfish (*Stegastes partitus*)	1.29
Blue chromis (*Chromis cyanea*)	0.62
Foureye butterflyfish (*Chaetodon capistratus*)	0.52
Bluehead wrasse (*Thalassoma bifasciatum*)	0.44
Blue tang (*Acanthurus coeruleus*)	0.42
Ocean surgeonfish (*Acanthurus bahianus*)	0.40
Stoplight parrotfish (*Sparisoma viride*)	0.36
Yellowtail damselfish (*Microspathodon chrysurus*)	0.35
Fairy basslet (*Gramma melacara*)	0.32
Barred hamlet (*Hypoplectrus unicolor*)	0.31

4.4.2 Population variations between habitat types

ANOSIM between the fish communities (the most abundant 125 of the 183 species) in each benthic class showed that there was an overall significant difference ($r = 0.204$, $p<0.01$) i.e. there were different fish communities in each benthic class. Eleven relatively abundant ecologically and economically important fish species from different trophic levels were then selected for more detailed analysis. These were: foureye butterfly fish (*Chaetodon capistratus*); blue tang (*Acanthurus coeruleus*); barjack (*Caranx ruber*); schoolmaster (*Lutjanus apodus*); blue striped grunt (*Haemulon sciurus*); yellowtail damselfish (*Microspathodon chrysurus*); coney (*Cephalopholis fulvus*); stoplight parrotfish (*Sparisoma viride*); spanish hogfish (*Bodianus rufus*); bluehead wrasse (*Thalassoma bifasciatum*) and Black durgon (*Melichthys niger*). Firstly, these species were assessed using Kruskal-Wallis analysis for variation in abundance between the nine benthic classes distinguished by the baseline transects. All 11 species showed significant differences in abundances between benthic classes ($p<0.05$).

Figure 7 shows the abundance of each target species in each benthic class. Figure 7 clearly shows that fish abundances were lower in sand dominated habitats ('Seagrass' and 'Sand with sparse algae') compared to coral and gorgonian dominated areas. It was also clear that some species exhibit particular habitat preferences. For example, the foureye butterflyfish was commonest in coral rich benthic classes ('Dense medium and encrusting corals' and 'Medium density massive and encrusting corals'). In contrast, bluehead wrasse appeared to favour areas with abundant gorgonians ('Bedrock / rubble and dense gorgonians', 'Bedrock / sand and gorgonians' and 'Fleshy brown algae and sparse gorgonians'). The herbivorous blue tang, yellowtail damselfish and stoplight parrotfish were relatively abundant in all benthic classes. Commercially important species, particularly barjack, schoolmaster snapper, blue striped grunts, coney and spanish hogfish were generally less abundant than the other species in each benthic class.

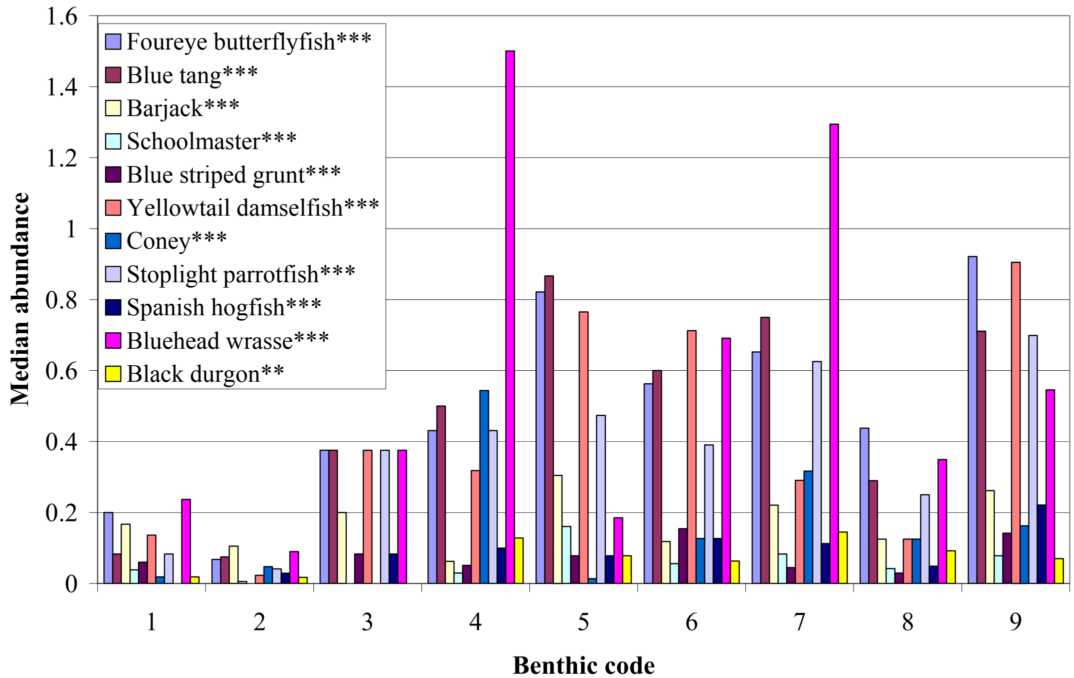

Figure 7. Abundance of each target fish taxa in each benthic class delineated during baseline surveys. Key to benthic codes: 1 = Seagrass; 2 = Sand with sparse algae; 3 = Bedrock / rubble and sparse gorgonians; 4 = Bedrock / rubble and dense gorgonians; 5 = Dense medium and encrusting corals; 6 = Bedrock / sand and gorgonians; 7 = Fleshy brown algae and sparse gorgonians; 8 = Sparse massive and encrusting corals; 9 = Medium density massive and encrusting corals. Asterixes in legend refer to results of Kruskal-Wallis tests: * = $p<0.1$; ** = $p<0.05$, *** = $p<0.01$. See Table 6 for sample sizes.

4.4.3 Population variations between study areas

In order to examine spatial variations in fish abundances within the project area, comparisons were made between the 16 study areas. In order to control for variations between benthic classes, this analysis was restricted to the most abundant benthic class ('Medium density massive and encrusting corals' which had 163 replicates). Removing variation between benthic classes is vital because, for example, lower fish abundances in study area A compared to study area B may simply be caused by a higher proportion of habitat that is unattractive to many fish species (e.g. sand). By restricting the analysis to one benthic class, these differences are removed and any remaining patterns can be attributed to factors such as differential fishing pressure.

ANOSIM analysis showed that there was an overall significant difference between the fish communities in each study area ($r = 0.133$, $p<0.05$). Kruskal-Wallis tests were then used to test for variations between study areas of populations of the same eleven relatively abundant ecologically and economically important fish species that were tested for differences between habitat types. Three of the 11 target species showed significant variations ($p<0.05$) of abundances between study areas. The abundances of these species are shown in Figure 23 (non-significant species are omitted for clarity). Figure 8 shows that blue tang exhibited only minor variations between study areas but this species appeared more abundant in the Jack Neils and Turtle Harbour study areas (median abundances > 0.7). Similarly, stoplight parrotfish were most abundant in two study areas (Big Bight and Raggedy Cay; median abundance > 0.6). Yellowtail damselfish were abundant in the Pretty Bush study area but were also common in Big Bight, Diamond Cay, Jack Neils and Airport (median abundance > 0.6).

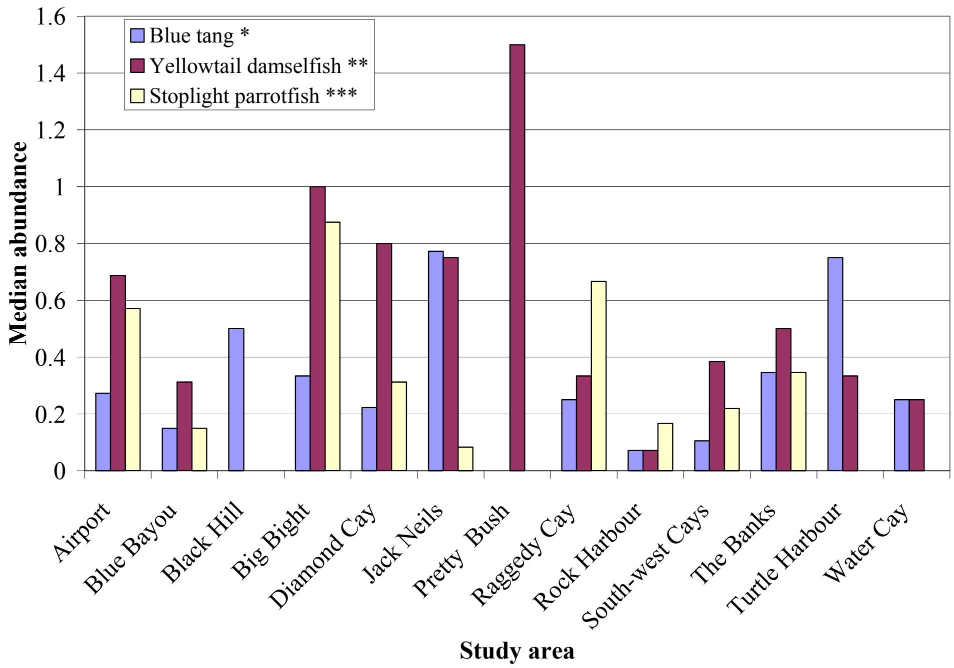

Figure 8. Fish abundances of significant target species within the benthic class 'Medium density massive and encrusting corals' in the different study areas around Utila. Asterixes in the legend refer to the results of the Kruskal-Wallis tests: * = p<0.1; ** = p<0.05, *** = p<0.01. Sample sizes: Airport = 17; Blue Bayou = 13; Black Hill = 2; Big Bight = 5; Diamond Cay = 13; Jack Neils = 28; Pretty Bush = 2; Raggedy Cay = 15; Rock Harbour = 8; South-west Cays = 23; The Banks = 22; Turtle Harbour = 5; Water Cay = 3. Lighthouse and Sandy Cay were omitted because the benthic class was not present and Pumpkin Hill was omitted as the target species were not present.

4.4.4 Population variation between fish and coral species richness

The final analysis of fish data collected during the baseline transects was an investigation of the link between coral and fish species richness. This was achieved via regression analysis between the number of coral species in each habitat ('Site Record') delineated by the survey teams and the number of target fish species. This relationship was significantly correlated ($p<0.001$; $R^2 = 0.37$) and is shown in Figure 9. Note that R^2 is the correlation coefficient that varies from –1 (strong negative correlation) to 1 (strong positive correlation).

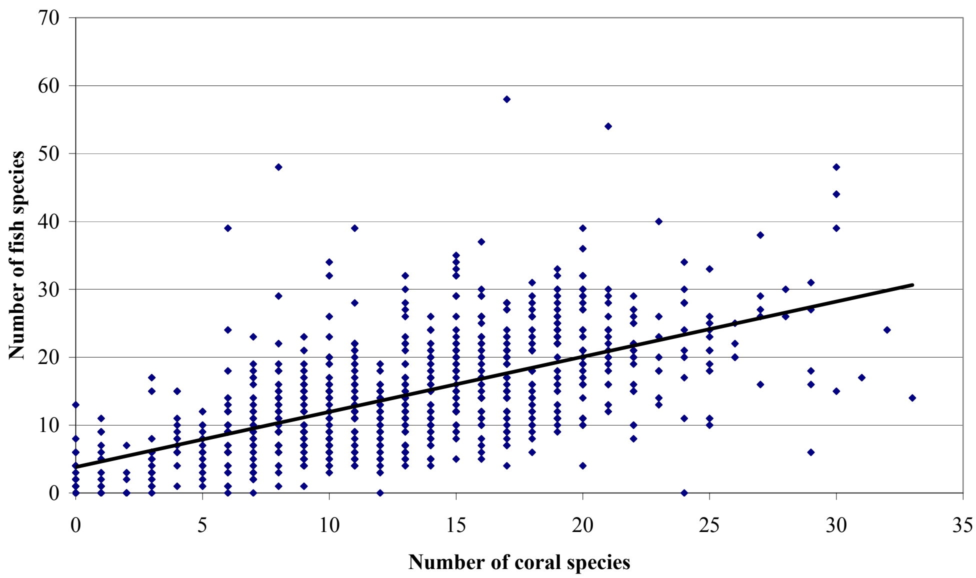

Figure 9. Relationship between the number of target fish and coral species seen during baseline transect surveys. Trendline shows linear relationship via regression analysis.

4.5 Invertebrate data

4.5.1 Invertebrate community within the whole project area

Analysis of individual invertebrate taxa[1] (all surveys combined) showed that the most obvious feature of invertebrate populations in the project area was the abundance of polychaete worms. For example, the two most abundant taxa were the 'feather duster' and 'Christmas tree' worms (median abundance > 0.45). Echinoderms were also relatively common, with urchins, brittle stars and feather stars all being among the 10 most abundant taxa.

Table 9. The median abundance from all baseline surveys of the 10 commonest invertebrate taxa recorded around Utila.

Invertebrate taxa	Median abundance
Feather duster worm (Sabellidae)	0.59
Christmas tree worm (*Spirobranchus giganteus*)	0.46
Tunicates (Ascidiacea)	0.28
Reef urchin (*Echinometra lucuter*)	0.26
Shrimp (Natantia)	0.21
Brittle star (Ophiuroidea)	0.18
Feather star (Crinoidea)	0.17
Hermit crab (*Diognidae*)	0.15
Long-spined sea urchin (*Diadema antillarum*)	0.14
Topshell (Prosobanchia)	0.13

[1] For the purposes of this report 'invertebrate' refers to invertebrates not included in the multivariate cluster analysis i.e. taxa other than hard corals, gorgonians and sponges.

4.5.2 Population variations between habitat types

ANOSIM between the invertebrate communities (all 51 taxa; not including corals, octocorals or sponges which are analysed during cluster analysis in Section 4.2.3) in each benthic class showed that there was an overall significant difference ($r = 0.091$, $p<0.05$) i.e. there were different invertebrate communities in each benthic class, although this pattern is only weak. Six relatively abundant ecologically and economically important invertebrate species, genera or families were then selected for more detailed analysis. These were: spiny lobster (Palinuridae); banded coral shrimp (*Stenopus hispidus*); queen conch (*Strombus gigas*); octopus (Octopoda); long-spined sea urchin(*Diadema antillarum*); sea cucumber (Holothuroidea). Firstly, these species were assessed using Kruskal-Wallis analysis for variation in abundance between the seven benthic classes distinguished by the baseline transects. Only three of the six target taxa showed significant differences in abundances between benthic classes ($p<0.05$): queen conch, long-spined urchins (*Diadema*) and sea cucumbers.

Figure 10 shows the abundance of each target taxa in each benthic class. Figure 10 shows that there was some evidence that invertebrate abundances were lower in sand dominated habitats (‘Seagrass’ and ‘Sand with sparse algae’) compared to coral and gorgonian dominated areas. A clear exception was for queen conch, which were most abundant in the ‘Seagrass’ benthic class. Banded coral shrimps, octopus and sea cucumbers were infrequently recorded. Long-spined sea urchins (*Diadema*) were the most abundant target taxa and appeared to prefer ‘Bedrock / rubble and dense gorgonians’ and ‘Bedrock / sand and gorgonians’ benthic classes.

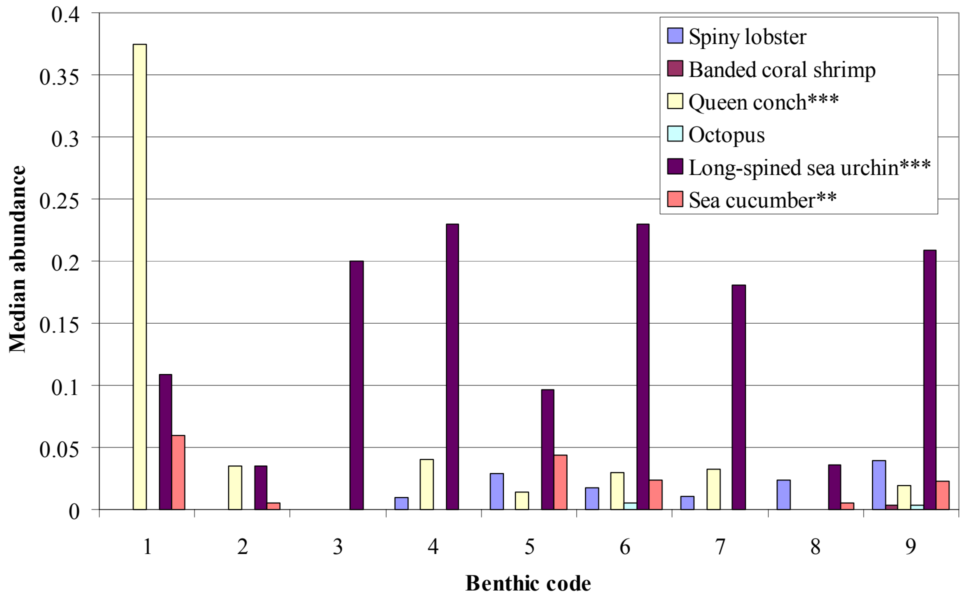

Figure 10. Abundance of each target invertebrate taxa in each benthic class delineated during baseline surveys. Key to benthic codes: 1 = Seagrass; 2 = Sand with sparse algae; 3 = Bedrock / rubble and sparse gorgonians; 4 = Bedrock / rubble and dense gorgonians; 5 = Dense medium and encrusting corals; 6 = Bedrock / sand and gorgonians; 7 = Fleshy brown algae and sparse gorgonians; 8 = Sparse massive and encrusting corals; 9 = Medium density massive and encrusting corals. Asterixes in legend refer to results of Kruskal-Wallis tests: * = $p<0.1$; ** = $p<0.05$, *** = $p<0.01$. See Table 6 for sample sizes.

4.5.3 Population variations between study areas

In order to examine spatial variations in invertebrate abundances within the project area, comparisons were made between the 16 study areas. In order to control for variations between benthic classes, this analysis was restricted to the most abundant class (‘Medium density massive and encrusting corals’ which had 163 replicates). Removing variation between benthic classes is vital because, for example, lower abundances in study area A compared to study area B may simply be caused by a higher proportion of habitat that is unattractive to many fish species (e.g. sand). By restricting the analysis to one benthic class, these differences are removed and any remaining patterns can be attributed to factors such as differential fishing pressure.

ANOSIM analysis showed that there was an overall significant difference between the invertebrate communities in each study area ($r = 0.114$, $p<0.05$). Kruskal-Wallis tests were then used to test for variations between reef complexes of populations of the same six relatively abundant ecologically and economically important invertebrate species, genera or families that were tested for differences between habitat types. Only one of the six target taxa showed significant variations ($p<0.05$) of abundances between reef complexes (banded coral shrimp). Similarly to the data between benthic classes, lobster, queen conch, octopus and sea cucumber were rare in each study area with the ‘Medium density massive and encrusting corals’ benthic class. Long-spined sea urchins (*Diadema*) were more abundant were commonest in the Diamond Cay and Pretty Bush study areas.

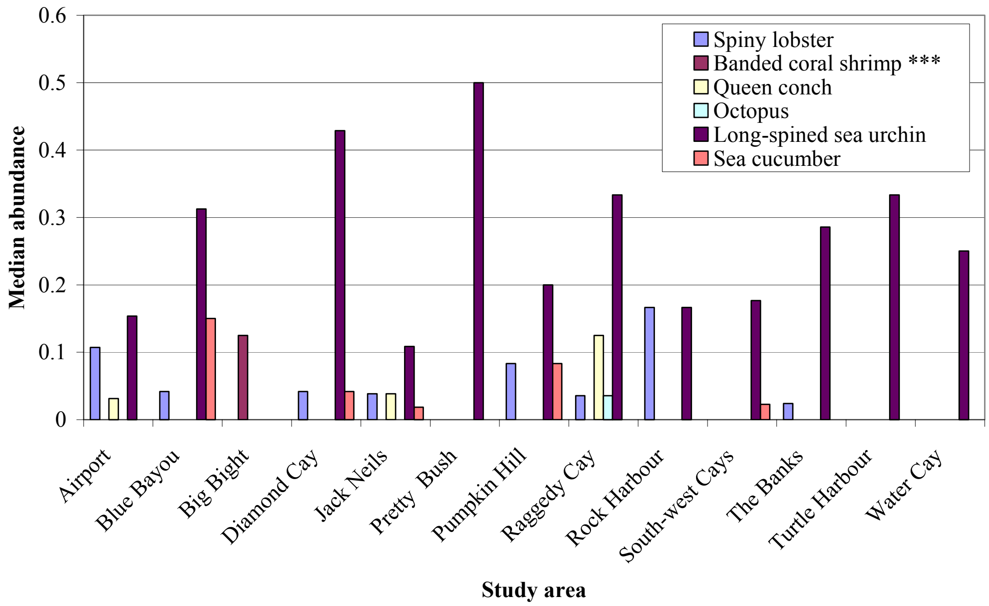

Figure 11. Invertebrate abundances of target species within the benthic class 'Medium density massive and encrusting corals' at the different study areas around Utila. Asterixes in the legend refer to the results of the Kruskal-Wallis tests: * = $p<0.1$; ** = $p<0.05$, *** = $p<0.01$. Sample sizes: Airport = 17; Blue Bayou = 13; Big Bight = 5; Diamond Cay = 13; Jack Neils = 28; Pretty Bush = 2; Pumpkin Hill = 7; Raggedy Cay = 15; Rock Harbour = 8; South-west Cays = 23; The Banks = 22; Turtle Harbour = 5; Water Cay = 3. Sandy Cay was omitted because the benthic class was not present and Black Hills and Lighthouse were omitted as the target species were not present.

4.6 Habitat map production

Figure 12 shows the results of classification of the PMAIB aerial photographs for Utila. Since the full habitat map is relatively small-scale, as an example, the area including the Turtle Harbour Wildlife Refuge is expanded in Figures 13 and 14. Note that not all of the habitat types discriminated from the data (Table 7) are shown in the habitat map because they were not distinguishable on the photographs.

Note that the offshore banks, including ‘Black Hills’, which is popular with divers, is not represented on the habitat map as they were either not within the boundaries of the aerial photographs or were too deep to be seen. However, these areas were surveyed by CCC volunteers and are known to have relatively healthy fish and benthic communities. For example, the Black Hills has a gradually sloping forereef composed of small patches of bedrock, rubble and dead coral with a good diversity of hard coral. The forereef culminated in a relatively flat top at approximately 12 m with abundant gorgonians and the substratum dominated by bedrock and dead coral. Hard coral cover was similar in diversity to that of the deeper forereef but a lower abundance was observed.

Since the classified habitat map is held within a GIS, it is possible to quantify the area covered by each benthic class (Table 10) and habitat type (Table 11).

Table 10. The aerial coverage of each benthic class on the reefs around Utila.

Benthic class	Area (km^2)	Percentage of total area of all benthic classes
Bedrock / rubble and dense gorgonians	3.4	12.7
Bedrock / sand and gorgonians	2.6	9.6
Dense massive and encrusting corals	0.1	0.3
Fleshy brown algae and sparse gorgonians	1.0	3.7
Medium density massive and encrusting corals	2.6	9.8
Sand with sparse algae	1.2	4.3
Seagrass	6.4	23.9
Sparse massive and encrusting corals	1.3	4.8
Unknown	8.4	31.0
Total (all benthic classes)	**26.9**	**100.0**

Table 11. The aerial coverage of each habitat type on the reefs around Utila.

Habitat type	Area (km^2)	Percentage of total area of all habitat types
Back Reef + Bedrock / sand and gorgonians	0.1	0.2
Back Reef + Fleshy brown algae and sparse gorgonians	0.1	0.3
Back Reef + Sand with sparse algae	0.4	1.5
Back Reef + Seagrass	0.1	0.3
Escarpment + Medium density massive and encrusting corals	0.0	0.1
Escarpment + Sparse massive and encrusting corals	0.1	0.2
Forereef + Bedrock / rubble and dense gorgonians	3.3	12.3
Forereef + Bedrock / sand and gorgonians	2.4	9.0
Forereef + Dense massive and encrusting corals	0.1	0.3
Forereef + Fleshy brown algae and sparse gorgonians	0.9	3.2
Forereef + Medium density massive and encrusting coral	1.5	5.5
Forereef + Sand with sparse algae	0.6	2.2
Forereef + Sparse massive and encrusting corals	1.2	4.6
Forereef + Unknown	0.1	0.2
Patch reef + Bedrock / sand and gorgonians	0.1	0.3
Reef Crest + Bedrock / rubble and dense gorgonians	0.1	0.4
Reef Crest + Bedrock / sand and gorgonians	0.0	0.1
Reef Crest + Medium density massive and encrusting corals	0.1	0.4
Sh. lagoon + Fleshy brown algae and sparse gorgonians	0.0	0.2
Sh. lagoon + Sand with sparse algae	0.2	0.6
Sh. lagoon + Seagrass	6.3	23.5
Sh. lagoon + Unknown	0.0	0.1
Spur & groove + Medium density massive and encrusting	1.0	3.8
Spur & groove + Unknown	0.0	0.1
Unknown	8.3	30.7
Total (all habitats)	**26.9**	**100.0**

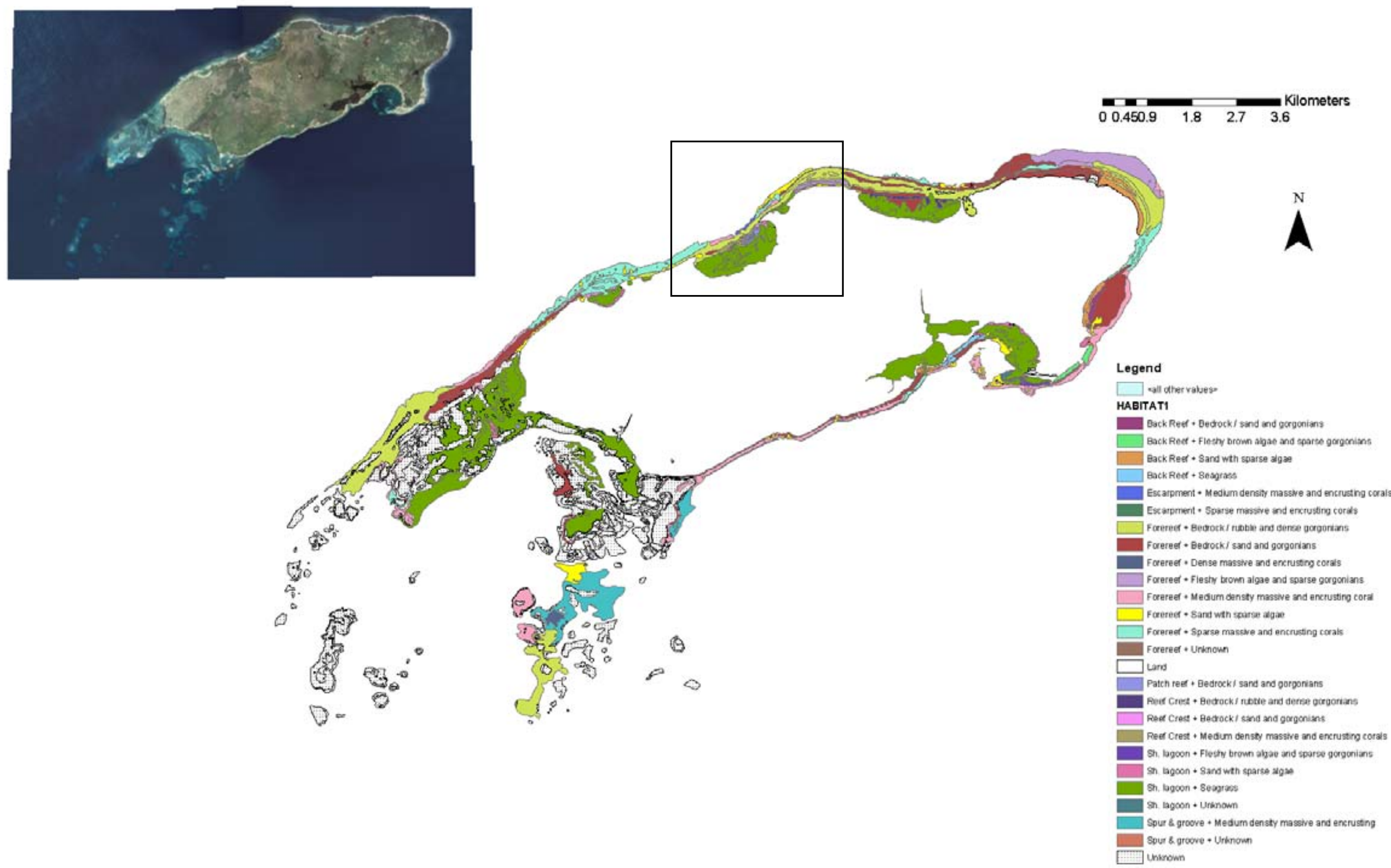

Figure 12. The classified habitat map for Utila. The aerial photos from which the map was made are also shown for orientation. The box shows the approximate area of the Turtle Harbour Wildlife Refuge that is expanded in Figures 13 and 14.

Figure 13. An aerial photograph of the approximate area of the Turtle Harbour Wildlife Refuge. The locations of the CCC Site Records used to classify this area are shown by the red circles.

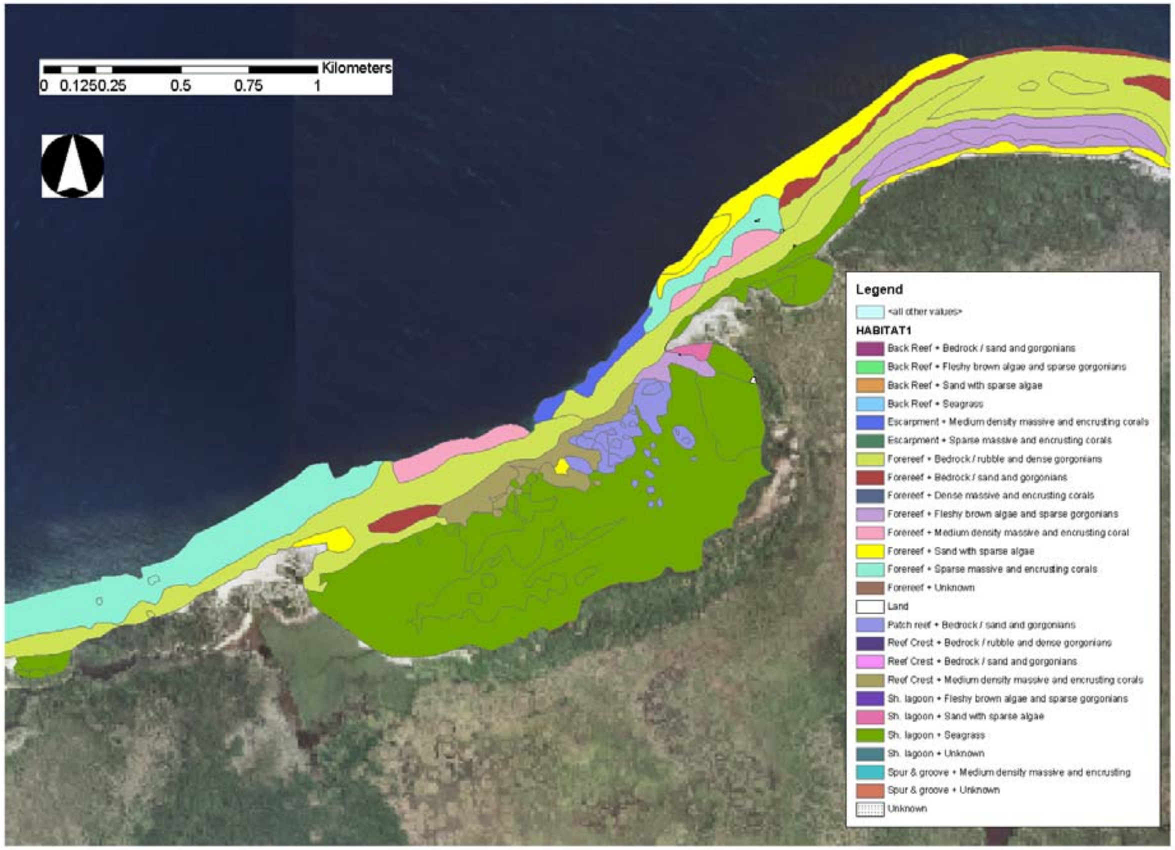

Figure 14. An aerial photograph of the approximate area of the Turtle Harbour Wildlife Refuge with the reefal area replaced with the classified polygons from the habitat map.

5. DISCUSSION

CCC volunteers collected all the data used in this report and the training programme used in Utila proved to be appropriate for volunteer survey work. For example, the results in the tests and in-water validation exercises were excellent and, therefore, the data collected during survey work are likely to be accurate and consistent. In addition to the data being accurate, surveys were also completed around the whole of Utila. Baseline transects discriminated nine benthic and six geomorpholgical classes and since these classes are derived from over 784 'Site Records' from across a wide geographical range they are likely to cover all the major habitats present on the reefs surveyed. However, there may be additional habitat types in very shallow water around the whole of Utila. These habitats are generally too shallow to survey with divers but snorkellers, using similar baseline transects, could collect the requisite data. Furthermore, it is possible that resurveys would highlight additional habitats contained within the areas surveyed by Site Records currently classified as 'unknown'. However, even with the current data set, it seems that Utila has a high habitat ('beta') diversity. Habitat diversity is important since the number of habitat types has been shown to be a good surrogate of species biodiversity.

The nine benthic classes that were distinguished were all relatively coral poor, with most coral species having a median abundance of less than 2. The health of Caribbean coral reefs is known to be declining significantly (Hughes, 1994 and many others). The factors that cause these problems are complex and can vary over space and time but include pollution, fishing pressure, hurricanes and coral bleaching events. Furthermore, there have been major changes in reef ecology at a regional scale since the 1980s. The major change has been a 'phase shift' towards algal dominated reefs, driven by the mass mortality of *Diadema* urchins in the early 1980s because of disease (reviewed by Lessios, 1988). The effects of losing this major herbivore have been exacerbated by the removal of herbivorous fish by fishing and the increase of nutrients in the water column. All these factors are present in Utila (Harborne *et al.*, 2001) and, for example, coral cover has obviously declined significantly over the last thirty years. However, these changes have been exacerbated by the combination of Hurricane Mitch and coral bleaching events in 1995 and 1998.

In 1998, Hurricane Mitch had significant effects on the marine resources of Honduras, particularly as it occurred shortly after a mass coral bleaching event. Kramer *et al.* (2000) report losses in coral cover of 15-20% across the Central American region and damage to 50-70% of corals in parts of Honduras, although recent mortality was only moderately high (<25%). Physical damage (broken, knocked over and abraded colonies) from the hurricane's direct action was approximately 11% of corals on shallow reefs and 2% on deep reefs in Honduras (Kramer and Kramer, 2000). Damage was particularly severe in the Bay Islands as the hurricane slowed and stalled close to Guanaja for two days. Secondary effects, such as the extensive run-off of low salinity, sediment-laden water into the Gulf of Honduras are more difficult to quantify but may have significantly disturbed shallow reef communities (Kramer and Kramer, 2000).

Coral bleaching events occur during occasional periods when climate conditions raise seawater temperatures and solar irradiance (summarised in Westmacott *et al.*, 2000). Coral bleaching, the paling of coral tissue from the loss of symbiotic zooxanthellae, has presumably occurred previously in Honduras but evidence of severe events prior to the mid-1990s is sparse. However, a mass bleaching event was recorded in 1995 by Guzmán and Guevara (1998) which affected 73% of scleractinians along with over 90% of all hydrocorals, zoanthids and octocorals. More detailed information is available for the more severe mass bleaching event in 1998 when high sea-surface temperatures affected Honduras in September and October. The effects of bleaching were severe, leading to an average regional coral mortality of 18% on shallow reefs and 14% on forereefs along with subsequent increases in the prevalence of diseases and will have long-term ecological consequences (Kramer *et al*., 2000; Kramer and Kramer, 2000).

Damselfish (Pomacentridae) were the most abundant reef associated fish recorded during baseline transect surveys, particularly the bicolor damselfish and blue chromis. This is not unusual as on most reefs this family constitutes a major part of the fish community. Particularly common were site attached herbivores, such as the yellowtail damselfish, and the blue chromis, which feed on zooplankton. It was noticeable that none of the ten most abundant species are targeted by fisherfolk. Commercially important fish are naturally large and less common than, for example, damselfish but abundances of whole families such as groupers would normally be expected to be much higher in unfished systems.

A recurring pattern in the baseline transect data was the greater abundance and diversity of fish in coral rich classes, which reflects a commonly observed phenomenon. For example, analysis of all the survey sites showed that there was a clear correlation between coral and fish species richness. The increased spatial complexity of coral rich habitats provides a larger variety of niches that support greater diversities of fish at the family and species level (Luckhurst and Luckhurst, 1978) via additional food sources (Thresher, 1983) and hiding places (Roberts and Ormond, 1987). Indeed species of butterflyfish that are obligate corallivores have been proposed as indicators of reef health because this link is so clear (e.g. Crosby and Reese, 1996).

Similarly, at the fish community level, the variation between benthic classes (all target species) was not surprising with sandy benthic classes generally containing fewer fish than those with more abundant bedrock and coral. However, although the link between fish abundance and coral cover was clear, not all species were necessarily most abundant in the most coral rich areas. For example, parrotfish feed on the algae growing on hard substrates in coral rich areas, or in areas of shallow bedrock that support significant algal biomass. Their distribution is linked to surge (low to moderate), food availability (high algal productivity in shallow-medium depths >5m, <30m) and shelter availability (needed for nocturnal hiding from predator fish) (Bouchon-Navarro and Harmelin-Vivien, 1981; Hay, 1981). Similarly, within this study, bluehead wrasse appeared to favour areas with abundant gorgonians. Such preferences support the need for marine protected areas to include representative examples of every habitat type (for example Salm, 1984; Gray, 1997). This requirement is made even more important by ontogenetic shifts of habitat and prey preference within individual species (for example Eggleston *et al*., 1998) and the role of mangrove creeks, seagrass beds and sand-rubble zones as nursery habitats (Sedberry and Carter, 1993).

Within the relatively coral rich 'Medium density massive and encrusting corals' benthic class there was an overall significant difference in the fish communities seen in each survey area, but this trend was very weak. This might be expected since the majority of species are not affected by fishing or other anthropogenic impacts and, therefore, will be found wherever there is suitable habitat. However, analysis of individual commercially and ecologically important taxa highlighted some variation. Some of this variation may be caused by the patchiness of some species since, for example, blue tang are a shoaling species and their abundance will rely, to some degree, on whether a shoal is encountered during a survey or not. Furthermore, some of the sample sizes of individual study areas were low. However, since all three significant species were herbivores it seems likely that the variations in abundances may be linked to algal abundance.

Invertebrates were generally uncommon during baseline surveys and this is partly because many of them are cryptic, and often nocturnal, and hence are missed by divers (e.g. squid and octopi). Therefore, the relative abundance of obvious tunicates, polychaetes, and echinoderms was expected. More specialised survey techniques and taxonomic expertise are required to fully inventory the invertebrate communities of the project area. However, the low abundance of commercially important invertebrates, such as lobster and conch, was noticeable and provides evidence of significant fishing pressure. The abundances of many invertebrate taxa were correlated with coral cover but this trend was weaker than for fish species. Furthermore, as expected, the queen conch was most common on areas characterised by the benthic class 'Seagrass'. *Diadema* were the most abundant target species and appeared to be less abundant in 'Seagrass' and 'Sand and sparse algae' benthic classes. The distribution of densities of this echinoid could be linked to aggregative behaviour (Pearse and Arch, 1969), abundance of complex habitat for shelter (Carpenter, 1984), or reduction in predation pressure from invertivores such as triggerfish (McClanahan, 2000).

Although, data collected during this study facilitate the description of habitat types, and their associated fish and invertebrate communities, around Utila, one of the major planned outputs of the *Bay Islands 2000* project was a marine habitat map. Coastal habitat maps are a fundamental data requirement in establishing coastal management plans (Cendrero, 1989). In the context of conserving reef diversity, habitat maps provide an inventory of habitat types and their statistics (Luczkovich *et al*., 1993; Spalding and Grenfell, 1997), the location of environmentally sensitive areas (Biña, 1982), allow representative networks of habitats to be identified (McNeill, 1994), identify hotspots of habitat diversity, permit changes in habitat cover to be detected (Loubersac *et al*., 1989), and allow boundary demarcation of multiple-use zoning schemes (Kenchington and Claasen, 1988). Furthermore, the conservation of marine habitats may serve as a practicable surrogate for conserving other scales of diversity including species and ecosystems (Gray, 1997). In essence, coastal habitats are manageable units and large-scale maps allow managers to visualise the spatial distribution of habitats, thus aiding the planning of networks of marine protected areas and allowing the degree of habitat fragmentation to be monitored. As Gray (1997) states, a mosaic of marine habitats must be protected if complete protection of biodiversity is to be achieved.

Habitat maps are generally created using remotely sensed imagery, such as satellite images or aerial photography, in combination with field data. Despite limitations such as cloud cover and limited water penetration (typically <25 m), remotely sensed imagery has the advantage of facilitating the cost-effective extrapolation of field data to large spatial scales. Readers are referred to Green *et al*. (2000) for further information on remote sensing for tropical coastal management.

The habitat map presented within this report is intended to be an indication of the distribution of habitat types around Utila. Further data would improve the classification of the map and, now that it is available, it would be worth revisiting these areas and assigning habitat labels to the 'Unknown' polygons, which are generally in the complex seagrass beds and submerged banks to the south-west of the island. However, the current version of the map is appropriate for assessing, for example, the locations of coral rich areas and patterns of zonation. Hence, both current and future versions of the habitat map should provide a framework for all information gathered for the project area and GIS technology will allow detailed spatial analysis of all existing data sets. For instance, patterns of fish abundance can be overlaid on existing fishing pressure to assess areas of conflict. Such analysis is vital for conservation, especially for discussing the location of marine protected areas. Knowledge of the accuracy of marine habitat maps is also import (Green *et al*., 2000) but unfortunately there was insufficient time to gather the independent data set required for a true accuracy assessment. However, since (a) the image was cloud free and taken at the same time as the fieldwork (b) there was a large amount of field data and (c) there were a limited number of benthic classes, it seems likely that the accuracy is approaching that found for other studies with aerial photography (summarised in Green *et al*., 2000). Hence the accuracy of the preliminary habitat map is likely to be between 50 and 70%.

Assuming that the map is reasonably accurate and that most of the unclassified polygons are sand and seagrass dominated, the estimates of areal extents of each benthic class and habitat type are instructive. For example, there is only approximately 27 km^2 of reefal habitats around Utila. Furthermore, the area supporting the most coral rich benthic classes ('Sparse / medium density / dense massive and encrusting corals') is only approximately 4 km^2 (15%). These statistics both highlight the damage caused by the bleaching event and Hurricane Mitch and other anthropogenic impacts and the need to conserve remaining coral rich areas.

If stakeholders in Utila decide to create further reserves, where should they be sited? Although protection of any reefal area will improve its health, there is substantial existing and current research on maximising reserve efficacy by placing them in optimal positions. For example, it is important to try to protect a range of reef and habitat types, including mangroves and seagrass beds, in order to conserve the biodiversity of any given area (Salm and Clarke, 1989; Gray, 1997). For this reason, it appears that the Turtle Harbour Wildlife Refuge is well placed since this areas includes a wide range of habitat types. However, placement of reserves in Utila should favour relatively coral rich habitats over sand dominated areas. Furthermore, case studies indicate that a series of small reserves may be easier to establish, spread the risk of a catastrophic impact to one area and provide a network of protection to species with widespread dispersal phases in their life history (e.g. many fish larvae travel large distances before settling on the reef).

6. RECOMMENDATIONS

The habitat descriptions and habitat map presented in this report are derived from a large data set but the accuracy of the map should be assessed and the currently 'Unknown' polygons should be classified via further data.

Recommendation 1: One or more agencies should collect additional ground-truthing data from around Utila to facilitate both classification of currently 'Unknown' polygons and an accuracy assessment of the map.

Since all the data collected by the Bay Islands 2000 project are spatially referenced, they could be integrated, within a GIS, with other information available for the area and future data sets. The habitat map shown in this report should be the basis of this GIS.

Recommendation 2: Establish an integrated GIS and associated meta-database for Utila, including data from the *Bay Islands 2000* project.

Recommendation 3: Examine the potential of using data collected by the *Bay Islands 2000* project as the basis of national habitat classification scheme and subsequent national habitat map.

Similarly to most reefs in Central America, there are a suite of threats to reef health in Utila and pressure from, for example, fishing, development and diving, combined with effects from natural events such as coral bleaching, are likely to increase. One or more marine protected areas around Utila would help to maintain reef health. Such reserves would also provide additional ecological and economic benefits, such as increased fish catches and income for local communities (Clark, 1996). The importance of marine reserves in Utila is exemplified by the area supporting the most coral rich benthic classes being only approximately 4 km^2.

Recommendation 4: Continue to aim to establish one or more additional multiple use marine protected areas around Utila, with an integrated monitoring programme to measure their efficacy, and strengthen the enforcement of regulations in the Turtle Harbour Wildlife Sanctuary. Establish regulations, and enforce existing legislation, to minimise the detrimental effects of coastal development on reef health.

Recommendation 5: Additional marine reserves in Utila should integrate factors such as the preference of many fish species for coral rich habitats and the protection of areas incorporating a range of habitat types, including mangroves and seagrass beds, in order to allow for nursery areas, ontogenetic shifts and species that rely on non-coral rich habitats. The corollary of the preference of fish species for coral rich habitats is to protect coral cover within the reserves.

With the damage caused to reefs in Utila by Hurricane Mitch and coral bleaching, a site on the south coast of Utila would be a good candidate for protection as this area is more sheltered and may be less prone to future hurricane damage.

Recommendation 6: The reef on the south coast of Utila appears to be a good candidate for protection because it is relatively sheltered from storm and hurricane damage.

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APPENDIX 1

Median abundances of substratum categories, biological life forms and species (algae, gorgonians, sponges, invertebrates, corals and fish) found in each of the nine major benthic classes identified during the *Bay Islands 2000* project:

1 = All surveys combined; 2 = Seagrass; 3 = Sand with sparse algae; 4 = Bedrock / rubble and sparse gorgonians; 5 = Bedrock / rubble and dense gorgonians; 6 = Dense medium and encrusting corals; 7 = Bedrock / sand and gorgonians; 8 = Fleshy brown algae and sparse gorgonians; 9 = Sparse massive and encrusting corals; 10 = Medium density massive and encrusting corals.

Note that because of the complex taxonomy and difficult identification of tropical marine fauna and flora, a combination of species, genera, life forms and higher taxonomic classifications are used with both Latin and common names.

(A) Substratum categories

Category	Benthic Class									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Dead coral	0.94	0.08	0.08	0.38	0.63	1.25	1.39	0.29	0.89	1.82
Mud	0.02	0.02	0.05	0.00	0.00	0.00	0.02	0.01	0.02	0.02
Rubble	0.62	0.17	0.17	0.67	0.79	0.38	1.06	0.38	0.42	1.05
Sand	1.85	4.57	4.62	0.67	3.13	0.64	2.80	0.48	0.90	1.40
Bedrock	2.11	0.24	0.44	4.08	2.77	0.95	2.30	2.66	2.07	1.96

(B) Algae and marine plants

Taxa	Benthic Class									
	1	2	3	4	5	6	7	8	9	10
Acetabularia spp.	0.02	0.11	0.05	0.00	0.02	0.01	0.01	0.01	0.00	0.01
Anadyomene spp.	0.01	0.00	0.00	0.00	0.03	0.01	0.02	0.04	0.01	0.00
Anotriclum barbatum	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01
Asparagopsis taxiformis	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Avrainvillea spp.	0.05	0.64	0.08	0.00	0.10	0.01	0.06	0.08	0.05	0.02
Blue-Green Filamentous Algae	0.04	0.00	0.02	0.00	0.04	0.03	0.09	0.06	0.04	0.04
Botryocladia pyriformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bryopsis penrata	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Bryothamnion triquetrum	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Caulerpa cupressoides	0.01	0.08	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00
Caulerpa paspaloides	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Caulerpa prolifera	0.01	0.02	0.03	0.00	0.03	0.01	0.01	0.00	0.01	0.01
Caulerpa spp.	0.05	0.06	0.08	0.00	0.03	0.04	0.07	0.04	0.01	0.04
Centroceras clavulatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceramium sp.	0.01	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.01	0.01
Chaetomorpha	0.01	0.02	0.03	0.00	0.02	0.00	0.00	0.00	0.01	0.00
Chondria littoralis	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Cladocephalus luteofuscus	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Cladophora prolifera	0.02	0.04	0.01	0.00	0.07	0.03	0.01	0.03	0.01	0.02
Cladosiphon occidentalis	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Codium repens	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Codium sp.	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Coelothrix irregularis	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Dasya harveyi	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Dasya spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dictyospaeria cavernosa	0.14	0.20	0.09	0.08	0.05	0.16	0.10	0.06	0.09	0.29
Dictyota spp.	2.06	1.06	0.99	2.25	2.55	2.64	1.90	2.17	2.01	2.51
Digenea simplex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dockweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dogweed	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Dratoris	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01
Enteromorpha flexuosa	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Galaxaura sp.	0.32	0.20	0.14	0.00	0.62	0.58	0.37	0.41	0.20	0.45
Gelidium pusillum	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Glacilaria sp.	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green brush-like	0.19	0.04	0.11	0.20	0.66	0.03	0.29	0.91	0.15	0.12
Green Encrusting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Green filamentous algae	0.06	0.06	0.03	0.00	0.05	0.08	0.07	0.16	0.06	0.03
Green turf algae	0.25	0.06	0.24	0.08	0.21	0.08	0.62	0.92	0.19	0.18
Griffithsia globulifera	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Halicystis-Derbesia osterhoutii	0.04	0.04	0.02	0.00	0.11	0.03	0.06	0.07	0.01	0.04
Halimeda copiosa	0.39	0.24	0.22	0.08	0.19	0.88	0.18	0.24	0.64	0.82
Halimeda discoidea	0.14	0.08	0.09	0.20	0.07	0.14	0.15	0.29	0.17	0.16
Halimeda goreaui	1.03	0.17	0.22	0.67	0.29	1.80	1.03	0.75	0.88	1.89
Halimeda incrassata	0.06	0.43	0.11	0.08	0.01	0.16	0.04	0.02	0.01	0.05
Halimeda monile	0.02	0.20	0.01	0.00	0.01	0.00	0.02	0.00	0.02	0.01
Halimeda opuntia	0.27	0.11	0.07	0.38	0.18	0.47	0.45	0.34	0.19	0.40
Halimeda spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Halimeda tuna	0.67	0.14	0.40	0.38	0.23	0.19	1.10	1.18	0.44	1.15
Halophila decipiens	0.03	0.08	0.13	0.00	0.00	0.01	0.03	0.00	0.01	0.01

Haloplegma duperreyi	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Halymenia floresia	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.02	0.00	0.01
Jarnia sp.	0.19	0.11	0.14	0.00	0.18	0.01	0.28	0.64	0.13	0.20
Kallymenia limminghii	0.03	0.00	0.02	0.00	0.02	0.00	0.02	0.04	0.04	0.02
Lobophora variegata	1.16	0.24	0.53	0.20	1.50	0.63	1.08	2.08	2.89	2.82
Martensia pavonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesophyllum mesomorphum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Microdictyon sp.	0.01	0.00	0.01	0.00	0.03	0.03	0.01	0.02	0.01	0.00
Ochtodes secundiramea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Octodes sp.	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
Padina spp.	0.13	0.11	0.05	0.08	0.50	0.21	0.16	0.27	0.13	0.08
Penicillus capitatus	0.02	0.24	0.05	0.00	0.00	0.00	0.02	0.01	0.00	0.01
Penicillus dumetosus	0.01	0.14	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.01
Penicillus pyriformis	0.02	0.14	0.03	0.00	0.02	0.01	0.02	0.01	0.01	0.02
Penicillus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Polyphysa polyphysoides	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red calcified	0.22	0.14	0.07	0.20	0.54	0.10	0.23	0.41	0.16	0.33
Red coarse branched	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00
Red encrusting (calcified)	0.13	0.04	0.05	0.00	0.13	0.04	0.25	0.29	0.10	0.15
Red filamentous	0.11	0.08	0.08	0.00	0.07	0.10	0.09	0.32	0.10	0.12
Red fine branched	0.05	0.08	0.02	0.00	0.11	0.04	0.12	0.03	0.02	0.03
Red fine branched	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red fine branching	0.04	0.24	0.02	0.08	0.16	0.00	0.04	0.02	0.02	0.03
Red turf algae	0.16	0.04	0.10	0.00	0.14	0.06	0.20	0.34	0.17	0.20
Reef cement	0.28	0.04	0.11	0.08	0.25	0.12	0.47	1.20	0.30	0.33
Rhipocephalus phoenix	0.41	1.20	0.85	0.00	0.73	0.16	0.52	0.62	0.23	0.25
Sargassum hystrix	0.09	0.04	0.03	0.00	0.23	0.04	0.08	0.29	0.07	0.08
Sargassum spp.	0.04	0.02	0.08	0.00	0.07	0.06	0.04	0.03	0.06	0.03
Spyridia hypnoides	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Squirrel tail	0.31	0.06	0.17	0.08	1.80	0.12	0.37	1.15	0.33	0.28
Stypopodium zonale	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Syringodium filiforme	0.02	2.67	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.00
Thalassia testudinum	0.03	4.14	0.03	0.00	0.00	0.00	0.08	0.00	0.01	0.00
Titanoderma sp.	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Trichoglea sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Turbinaria spp.	0.05	0.04	0.03	0.00	0.40	0.03	0.03	0.18	0.02	0.02
Udotea cyathiformis	0.06	0.00	0.11	0.00	0.04	0.04	0.02	0.00	0.04	0.10
Udotea flabellum	0.05	0.06	0.11	0.00	0.05	0.03	0.06	0.01	0.03	0.03
Udotea occidentalis	0.03	0.11	0.05	0.00	0.02	0.00	0.02	0.01	0.02	0.03
Udotea wilsonii	0.01	0.00	0.01	0.00	0.02	0.00	0.02	0.01	0.01	0.00
Ulva spp.	0.02	0.00	0.02	0.00	0.03	0.00	0.05	0.03	0.01	0.02
Valonia	0.03	0.04	0.03	0.00	0.09	0.03	0.02	0.07	0.01	0.03
Ventricaria ventricosa	0.19	0.04	0.06	0.00	0.16	0.16	0.25	0.24	0.11	0.39
Wrangelia argus	0.08	0.02	0.03	0.08	0.19	0.04	0.12	0.16	0.05	0.07
Wrangelia penicilla	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00

(C) Gorgonians

Taxa	Benthic Class									
	1	2	3	4	5	6	7	8	9	10
Branching plume	1.64	0.38	0.70	1.33	2.29	2.90	1.08	1.86	1.43	1.97
Branching rod	1.51	0.38	0.50	0.67	2.02	2.83	1.17	1.96	1.24	1.80
Common sea fan	1.21	0.43	0.20	1.00	1.82	2.46	1.07	1.48	0.98	1.66
Corky sea finger	0.15	0.08	0.02	0.08	0.18	0.16	0.12	0.11	0.17	0.27
Deepwater fan	0.02	0.00	0.01	0.00	0.02	0.04	0.01	0.04	0.06	0.02
Encrusting soft coral	0.13	0.02	0.02	0.00	0.18	0.14	0.16	0.13	0.11	0.20
Flat sea whip	0.15	0.17	0.18	0.20	0.25	0.08	0.14	0.32	0.15	0.12
Grooved blade sea whip	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Red sea whip	0.01	0.00	0.01	0.08	0.01	0.03	0.01	0.02	0.02	0.01

(D) Sponges

Species	Benthic Class									
	1	2	3	4	5	6	7	8	9	10
Ball sponge	0.11	0.04	0.02	0.00	0.07	0.04	0.10	0.14	0.07	0.18
Barrel sponge	0.16	0.02	0.08	0.08	0.11	0.19	0.06	0.16	0.26	0.23
Boring sponge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Branching sponge	0.12	0.04	0.03	0.08	0.13	0.04	0.14	0.10	0.12	0.22
Encrusting sponge	0.93	0.14	0.35	0.38	1.17	0.56	1.02	1.67	0.98	1.07
Lumpy sponge	0.15	0.04	0.05	0.08	0.18	0.12	0.15	0.24	0.14	0.19
Plate sponge	0.02	0.00	0.00	0.00	0.03	0.01	0.02	0.04	0.01	0.03
Rope sponge	0.32	0.20	0.14	0.08	0.27	0.30	0.31	0.20	0.46	0.53
Tube sponge	0.72	0.17	0.29	0.20	0.46	1.31	0.32	1.00	0.94	0.96
Vase sponge	0.69	0.08	0.25	0.00	0.73	0.78	0.24	0.90	0.82	0.99

(E) Invertebrate taxa

Taxa	Benthic Class									
	1	2	3	4	5	6	7	8	9	10
Banded coral shrimp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bivalues	0.08	0.08	0.08	0.08	0.13	0.04	0.08	0.11	0.07	0.08
Brittle star	0.18	0.06	0.08	0.20	0.10	0.04	0.22	0.29	0.16	0.29
Bulb tunicate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Christmas tree worm	0.46	0.14	0.08	0.20	1.50	0.34	0.75	1.00	0.25	0.71
Clam	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Coral crab	0.01	0.00	0.01	0.00	0.03	0.00	0.00	0.01	0.00	0.02
Cowrie	0.05	0.00	0.02	0.00	0.13	0.06	0.04	0.08	0.02	0.05
Cushion sea star	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diatoms	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Donkey dung	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fan worm	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feather duster worm	0.59	0.32	0.24	0.20	0.75	0.53	0.67	0.44	0.50	0.81
Feather star	0.17	0.06	0.04	0.08	0.14	0.16	0.14	0.03	0.18	0.32
Fire worms	0.00	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01
Flamingo tongue	0.03	0.00	0.01	0.00	0.07	0.00	0.02	0.08	0.02	0.03
Gaudy Down Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Hermit crab	0.15	0.14	0.07	0.08	0.16	0.04	0.24	0.22	0.12	0.16
Infaunal Polychaetes	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jelly fish	0.03	0.06	0.05	0.00	0.02	0.04	0.03	0.02	0.03	0.03
Lettuce sea slug	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Long-spined sea urchin	0.14	0.11	0.03	0.20	0.23	0.10	0.23	0.18	0.04	0.21
Lugworm	0.02	0.00	0.02	0.00	0.02	0.01	0.03	0.02	0.02	0.01
Magnificent feather duster worm	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Mantis Shrimp	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Moon jellyfish	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Nudibranchs	0.01	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.01
Octopus	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Queen conch	0.03	0.38	0.03	0.00	0.04	0.01	0.03	0.03	0.00	0.02
Reef squid	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00
Reef urchin	0.26	0.11	0.09	0.20	0.29	0.06	0.84	0.24	0.08	0.42
Rock-boring urchin	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rough Fire Clam	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand dollar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sea cucumber	0.02	0.06	0.01	0.00	0.00	0.04	0.02	0.00	0.01	0.02
Sea star	0.01	0.17	0.01	0.00	0.02	0.00	0.01	0.01	0.01	0.00
Sea wasp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shrimp	0.21	0.20	0.17	0.00	0.29	0.04	0.18	0.32	0.19	0.28
Slate-pencil urchin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00
Spaghetti worm	0.05	0.11	0.02	0.00	0.05	0.03	0.11	0.04	0.04	0.02
Spider crab	0.01	0.00	0.01	0.00	0.02	0.01	0.01	0.02	0.01	0.01
Spiny lobster	0.03	0.00	0.00	0.00	0.01	0.03	0.02	0.01	0.02	0.04
Star horseshoe worm	0.02	0.00	0.02	0.00	0.03	0.00	0.03	0.02	0.04	0.02
Stocky cerith	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.01
Topshell	0.13	0.06	0.08	0.08	0.16	0.03	0.12	0.22	0.13	0.14
Tunicates	0.28	0.02	0.18	0.08	0.21	0.12	0.17	0.32	0.42	0.40
Upside-down jellyfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Variegated sea urchin	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
West Indian sea egg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wing Oyster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Yellowline arrow crab	0.10	0.06	0.08	0.08	0.11	0.04	0.09	0.14	0.08	0.14

(F) Coral species

Species	Benthic Class									
	1	2	3	4	5	6	7	8	9	10
Blade fire coral	0.79	0.11	0.03	0.20	0.37	0.10	0.34	0.27	0.05	0.23
Blue crust coral	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Blushing star	0.20	0.06	0.08	0.00	0.58	0.12	0.18	0.41	0.18	0.21
Branching fire coral	0.17	0.24	0.19	0.00	1.09	0.43	0.71	1.26	0.78	0.98
Butterprint brain	0.51	0.02	0.11	0.00	0.50	1.16	0.14	0.70	0.64	0.85
Cavernous star	1.09	0.08	0.48	0.75	1.38	2.35	0.86	1.15	1.05	1.46
Club finger	0.23	0.14	0.02	0.08	0.13	0.21	0.20	0.18	0.12	0.64
Eight-ray finger coral	0.04	0.04	0.02	0.00	0.00	0.06	0.02	0.03	0.04	0.07
Elkhorn	0.04	0.02	0.00	0.08	0.03	0.08	0.08	0.04	0.02	0.05
Elliptical star	0.57	0.17	0.17	1.13	1.60	0.55	0.66	1.03	0.55	0.49
Fat fungus	0.24	0.02	0.01	0.00	0.09	0.34	0.17	0.13	0.37	0.59
Finger	0.13	0.06	0.03	0.20	0.06	0.12	0.10	0.06	0.11	0.28
Flower	0.22	0.08	0.05	0.08	0.05	0.43	0.22	0.14	0.14	0.57
Fragile saucer	0.10	0.04	0.01	0.00	0.01	0.10	0.11	0.06	0.16	0.19
Fungus	0.26	0.02	0.03	0.08	0.11	0.88	0.20	0.18	0.21	0.53
Fused staghorn	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.01
Giant brain	0.30	0.08	0.05	0.00	0.13	0.56	0.31	0.32	0.21	0.79
Golfball	0.08	0.17	0.01	0.08	0.11	0.06	0.10	0.24	0.06	0.05
Green cactus	0.19	0.00	0.05	0.08	0.11	0.19	0.13	0.14	0.21	0.44
Grooved brain	0.43	0.20	0.05	0.08	0.29	1.11	0.37	0.62	0.33	0.88
Grooved fungus	0.04	0.02	0.01	0.00	0.00	0.10	0.04	0.04	0.04	0.07
Knobby brain	0.04	0.06	0.00	0.00	0.13	0.03	0.06	0.08	0.04	0.02
Large flower	0.06	0.02	0.00	0.00	0.04	0.10	0.02	0.02	0.05	0.14
Leaf	1.17	0.08	0.38	0.67	1.39	1.22	0.75	1.26	1.47	1.67
Massive leaf	0.09	0.02	0.01	0.00	0.02	0.19	0.18	0.02	0.06	0.17
Mountain-ous star	1.51	0.17	0.37	1.13	0.88	2.82	1.39	1.10	1.63	2.16
Mustard hill	1.14	0.43	0.16	0.38	1.30	1.64	1.17	1.21	0.96	1.77
Pillar	0.12	0.02	0.01	0.08	0.25	0.14	0.09	0.13	0.06	0.25
Purple leaf	0.04	0.02	0.02	0.08	0.04	0.08	0.01	0.04	0.04	0.09
Ribbon	0.36	0.04	0.10	0.67	0.10	0.64	0.54	0.18	0.19	0.88
Rose	0.06	0.50	0.05	0.00	0.04	0.03	0.06	0.10	0.02	0.07
Rough star	0.09	0.02	0.02	0.00	0.09	0.04	0.09	0.38	0.01	0.12
Rough starlet	0.43	0.17	0.18	0.67	0.83	0.85	0.49	0.73	0.42	0.46
Saucer	0.17	0.02	0.06	0.00	0.04	0.21	0.15	0.16	0.20	0.39
Scroll	0.02	0.00	0.01	0.00	0.02	0.04	0.02	0.00	0.04	0.03
Sheet	0.18	0.00	0.04	0.20	0.04	0.27	0.14	0.13	0.24	0.43
Sinous cactus	0.03	0.04	0.00	0.00	0.06	0.01	0.06	0.06	0.01	0.03
Smooth brain	0.89	0.14	0.11	1.13	2.05	1.00	1.02	1.20	0.35	1.17
Smooth starlet	0.84	0.20	0.13	0.00	1.55	1.09	1.01	1.19	0.77	0.95
Solitary disk	0.11	0.02	0.02	0.08	0.04	0.08	0.09	0.04	0.17	0.18
Staghorn	0.16	0.06	0.01	0.08	0.04	0.04	0.15	0.06	0.08	0.57
Thin finger coral	0.06	0.08	0.01	0.00	0.01	0.08	0.05	0.02	0.02	0.12
Thin fungus	0.16	0.02	0.03	0.00	0.02	0.30	0.12	0.07	0.17	0.36
Yellow pencil	0.10	0.00	0.02	0.00	0.02	0.16	0.04	0.03	0.05	0.28

(G) Fish species. Fish are ordered alphabetically by family (shown in parentheses).

Species	Benthic Class									
	1	2	3	4	5	6	7	8	9	10
Angelfish (Pomacanthidae)										
Cherubfish	0.01	0.00	0.01	0.00	0.00	0.03	0.01	0.02	0.01	0.01
French angelfish	0.02	0.00	0.00	0.08	0.02	0.04	0.02	0.03	0.03	0.03
Gray angelfish	0.07	0.00	0.05	0.08	0.07	0.06	0.02	0.03	0.08	0.09
Queen angelfish	0.06	0.00	0.01	0.08	0.07	0.12	0.06	0.11	0.07	0.07
Rock beauty	0.22	0.02	0.05	0.38	0.21	0.19	0.20	0.27	0.17	0.43
Barracuda (Sphyraenidae)										
Great barracuda	0.02	0.00	0.03	0.00	0.01	0.03	0.04	0.00	0.03	0.03
Blenny (Clinidae)										
Blenny	0.11	0.06	0.04	0.08	0.16	0.14	0.18	0.24	0.03	0.12
Palehead blenny	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Roughhead blenny	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Bigeye (Priacanthidae)										
Bigeye	0.01	0.00	0.00	0.00	0.07	0.00	0.01	0.01	0.00	0.01
Bone fish (Albulidae)										
Bone fish	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Bonnetmouth (Inermiidae)										
Boga	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.01	0.00
Boxfish (Ostraciidae)										
Honeycomb cowfish	0.01	0.00	0.00	0.00	0.02	0.01	0.00	0.03	0.00	0.02
Scrawled cowfish	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01
Smooth trunkfish	0.02	0.00	0.02	0.00	0.00	0.04	0.04	0.01	0.02	0.00
Spotted trunkfish	0.01	0.00	0.01	0.00	0.01	0.03	0.04	0.00	0.01	0.01
Trunkfish	0.01	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Butterfly fish (Chaetodontidae)										
Banded butterfly fish	0.10	0.02	0.01	0.00	0.37	0.19	0.12	0.13	0.03	0.13
Foureye butterfly fish	0.52	0.20	0.07	0.38	0.43	0.82	0.56	0.65	0.44	0.92
Longsnout butterfly fish	0.02	0.02	0.00	0.20	0.02	0.00	0.01	0.02	0.03	0.03
Reef butterfly fish	0.01	0.02	0.00	0.00	0.04	0.08	0.01	0.01	0.00	0.01
Spotfin butterfly fish	0.11	0.06	0.03	0.08	0.07	0.21	0.14	0.07	0.06	0.17
Cardinalfish (Apogonidae)										
Barred cardinalfish	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00
Belted cardinalfish	0.00	0.00	0.00	0.08	0.00	0.00	0.01	0.00	0.00	0.00
Flamefish	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Carpet shark (Rhincodontidae)										
Nurse shark	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chub (Kyphosidae)										
Bermuda chub	0.02	0.00	0.00	0.08	0.01	0.06	0.04	0.04	0.00	0.03
Damselfish (Pomacentridae)										
Beaugregory	0.11	0.04	0.03	0.00	0.04	0.10	0.14	0.08	0.13	0.20
Bicolor damselfish	1.29	0.20	0.48	0.88	1.95	1.21	1.17	1.54	1.23	1.63
Blue chromis	0.62	0.04	0.11	0.08	0.19	1.33	0.45	0.44	1.34	1.76

Brown chromis	0.06	0.00	0.01	0.00	0.03	0.10	0.06	0.08	0.04	0.12
Cocoa damselfish	0.07	0.04	0.01	0.00	0.05	0.12	0.15	0.03	0.04	0.07
Dusky damselfish	0.25	0.11	0.02	0.67	0.23	0.34	0.45	0.22	0.10	0.44
Longfin damselfish	0.05	0.02	0.01	0.00	0.02	0.12	0.11	0.07	0.02	0.07
Night sergeant	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00
Sergeant major	0.06	0.02	0.01	0.00	0.01	0.19	0.14	0.02	0.04	0.09
Sunshine-fish	0.01	0.02	0.00	0.00	0.03	0.01	0.01	0.03	0.01	0.01
Threespot damselfish	0.25	0.06	0.06	0.08	0.10	0.21	0.29	0.10	0.19	0.89
Yellowtail damselfish	0.35	0.14	0.02	0.38	0.32	0.76	0.71	0.29	0.13	0.91
Drum (Sciaenidae)										
Highhat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reef croaker	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Spotted drum	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.01
Eagle Ray (Myliobatidae)										
Spotted eagle ray	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01
Electric ray (Torpedinidae)										
Lesser electric ray	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flounder (Bothidae)										
Flounder	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Goatfish (Mullidae)										
Spotted goatfish	0.04	0.08	0.06	0.00	0.07	0.03	0.04	0.02	0.02	0.05
Yellow goatfish	0.02	0.02	0.03	0.00	0.01	0.03	0.02	0.00	0.01	0.03
Goby (Gobiidae)										
Cleaning goby	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Goby	0.22	0.08	0.14	0.00	0.37	0.30	0.21	0.41	0.09	0.30
Goldspot goby	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Neon goby	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Grouper / Seabass (Serranidae)										
Barred hamlet	0.31	0.02	0.08	0.38	0.07	0.19	0.20	0.10	0.55	0.75
Black grouper	0.01	0.00	0.01	0.00	0.01	0.03	0.00	0.01	0.00	0.01
Black hamlet	0.01	0.00	0.01	0.00	0.00	0.01	0.02	0.00	0.02	0.02
Blackcap basslet	0.01	0.02	0.01	0.00	0.03	0.04	0.01	0.02	0.00	0.01
Blue hamlet	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.01
Butter hamlet	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01
Candy bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chalk bass	0.02	0.02	0.03	0.00	0.02	0.03	0.03	0.00	0.00	0.02
Coney	0.13	0.02	0.05	0.00	0.54	0.01	0.13	0.32	0.13	0.16
Fairy basslet	0.32	0.06	0.05	0.08	0.16	1.00	0.34	0.22	0.37	0.60
Golden hamlet	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00
Graysby	0.11	0.00	0.04	0.00	0.04	0.19	0.08	0.13	0.18	0.20
Greater soapfish	0.01	0.00	0.00	0.00	0.05	0.03	0.02	0.02	0.02	0.01
Harlequin bass	0.07	0.00	0.02	0.00	0.13	0.14	0.05	0.06	0.02	0.14
Indigo hamlet	0.05	0.00	0.01	0.00	0.01	0.08	0.01	0.03	0.06	0.13
Jewfish	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lantern bass	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01
Marbled grouper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Masked hamlet	0.00	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00
Nassau grouper	0.01	0.00	0.01	0.00	0.02	0.01	0.00	0.00	0.02	0.02
Peppermint bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Red grouper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red Hind	0.03	0.02	0.01	0.00	0.06	0.01	0.02	0.03	0.03	0.04
Rock Hind	0.03	0.00	0.00	0.00	0.07	0.00	0.03	0.04	0.04	0.05
Shy hamlet	0.01	0.00	0.01	0.00	0.00	0.03	0.01	0.03	0.01	0.02
Tiger grouper	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01
Tobacco fish	0.03	0.04	0.06	0.00	0.02	0.03	0.05	0.03	0.01	0.03
Yellowbelly hamlet	0.02	0.04	0.00	0.00	0.00	0.01	0.05	0.06	0.02	0.02
Yellowfin grouper	0.01	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.01
Yellow-mouth grouper	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
Yellowtail hamlet	0.02	0.00	0.01	0.00	0.02	0.03	0.03	0.01	0.01	0.04
Grunt (Haemulidae)										
Black margate	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
Blue striped grunt	0.07	0.06	0.00	0.08	0.05	0.08	0.15	0.04	0.03	0.14
Caesar grunt	0.03	0.00	0.01	0.08	0.03	0.10	0.02	0.03	0.03	0.04
Cottonwick	0.01	0.00	0.00	0.00	0.00	0.04	0.01	0.01	0.01	0.02
French grunt	0.22	0.11	0.06	0.00	0.09	0.24	0.34	0.16	0.16	0.40
Margate	0.01	0.00	0.01	0.00	0.01	0.03	0.01	0.00	0.01	0.00
Porkfish	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.03	0.01	0.01
Sailors choice	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01
Small-mouth grunt	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Spanish grunt	0.01	0.00	0.00	0.08	0.01	0.03	0.01	0.02	0.02	0.00
Striped grunt	0.03	0.02	0.01	0.00	0.02	0.06	0.04	0.01	0.05	0.05
Tomtate	0.01	0.02	0.01	0.00	0.00	0.06	0.02	0.00	0.01	0.02
White grunt	0.07	0.04	0.02	0.20	0.05	0.10	0.04	0.06	0.06	0.11
Hawkfish (Cirrhitidae)										
Redspotted hawkfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Jack (Carangidae)										
Barjack	0.17	0.17	0.11	0.20	0.06	0.30	0.12	0.22	0.13	0.26
Blue runner	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horse-eye jack	0.01	0.00	0.01	0.00	0.01	0.03	0.00	0.00	0.01	0.01
Mackerel scad	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Palometa	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Permit	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Yellow jack	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.04
Jawfish (Opistognathidae)										
Jawfish	0.01	0.00	0.02	0.08	0.01	0.01	0.00	0.01	0.00	0.01
Lizardfish (Synodontidae)										
Bluestriped lizardfish	0.01	0.00	0.02	0.08	0.00	0.01	0.01	0.01	0.00	0.01
Sand diver	0.03	0.04	0.02	0.00	0.01	0.00	0.02	0.03	0.02	0.04
Mackarel (Scombridae)										
Cero	0.01	0.00	0.01	0.00	0.00	0.03	0.01	0.00	0.02	0.00
Mackerel	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Manta (Mobulidae)										
Atlantic manta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mojarra (Gerreidae)										
Mojarra	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Moray (Muraenidae)										
Chestnut moray	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goldentail moray	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00
Green moray	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00

Purplemouth moray	0.01	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Spotted moray	0.01	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.02
Needlefish (Belonidae)										
Needlefish	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Parrotfish (Scaridae)										
Blue parrotfish	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.01	0.00
Bucktooth parrotfish	0.02	0.04	0.00	0.00	0.02	0.01	0.02	0.01	0.01	0.02
Green-blotch parrotfish	0.02	0.02	0.01	0.00	0.00	0.03	0.02	0.00	0.01	0.04
Midnight parrotfish	0.01	0.00	0.01	0.00	0.01	0.04	0.01	0.01	0.02	0.02
Princess parrotfish	0.09	0.02	0.02	0.08	0.04	0.10	0.12	0.13	0.07	0.12
Queen parrotfish	0.01	0.00	0.00	0.00	0.00	0.03	0.01	0.03	0.01	0.02
Rainbow parrotfish	0.03	0.04	0.00	0.00	0.05	0.12	0.04	0.03	0.04	0.03
Redband parrotfish	0.12	0.00	0.03	0.20	0.06	0.10	0.14	0.07	0.04	0.23
Redtail parrotfish	0.04	0.00	0.01	0.00	0.07	0.04	0.02	0.03	0.02	0.06
Stoplight parrotfish	0.36	0.08	0.04	0.38	0.43	0.47	0.39	0.63	0.25	0.70
Striped parrotfish	0.20	0.02	0.05	0.08	0.13	0.14	0.28	0.08	0.16	0.45
Yellowtail parrotfish	0.05	0.00	0.01	0.08	0.09	0.04	0.04	0.08	0.03	0.08
Porgy (Sparidae)										
Saucereye porgy	0.05	0.02	0.05	0.00	0.04	0.03	0.06	0.02	0.04	0.08
Puffer / spiny (Tetraodontidae)										
Balloonfish	0.01	0.06	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.03
Bandtail puffer	0.02	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.01	0.04
Porcupine-fish	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01
Sharpnose puffer	0.08	0.06	0.03	0.00	0.06	0.10	0.13	0.03	0.07	0.13
Web burrfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Remora (Echeneidae)										
Remora	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Round Stingray (Urolophidae)										
Yellow stingray	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Scorpionfish (Scorpionidae)										
Scorpionfish	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00
Silverside (Atherinidae)										
Silverside	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Snapper (Lutjanidae)										
Cuberra snapper	0.01	0.04	0.00	0.20	0.00	0.04	0.01	0.01	0.00	0.01
Dog snapper	0.01	0.00	0.01	0.00	0.01	0.03	0.00	0.00	0.01	0.01
Glassy snapper	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.01
Gray snapper	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.02	0.01	0.02
Lane snapper	0.00	0.00	0.01	0.00	0.01	0.03	0.00	0.00	0.00	0.00
Mahogany snapper	0.01	0.00	0.01	0.00	0.01	0.06	0.01	0.00	0.02	0.01
Mutton snapper	0.01	0.04	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01
Schoolmaster	0.06	0.04	0.01	0.00	0.03	0.16	0.06	0.08	0.04	0.08
Yellowtail snapper	0.21	0.08	0.11	0.67	0.16	0.24	0.17	0.24	0.17	0.40
Snook (Centropomidae)										
Snook	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spadefish (Ephippidae)										
Atlantic	0.00	0.00	0.00	0.08	0.00	0.01	0.00	0.00	0.00	0.00

spadefish										
Squirrelfish (Holocentridae)										
Blackbar Soldierfish	0.01	0.00	0.01	0.00	0.02	0.01	0.00	0.04	0.01	0.01
Dusky squirrelfish	0.02	0.00	0.01	0.00	0.00	0.03	0.02	0.01	0.01	0.04
Longjaw squirrelfish	0.03	0.02	0.02	0.00	0.00	0.03	0.03	0.03	0.06	0.04
Longspine squirrelfish	0.25	0.06	0.11	0.08	0.73	0.12	0.18	0.52	0.32	0.25
Reef squirrelfish	0.02	0.00	0.01	0.00	0.01	0.01	0.02	0.01	0.03	0.02
Squirrelfish	0.19	0.00	0.06	0.00	0.34	0.19	0.18	0.32	0.14	0.25
Stingray (Dasyatidae)										
Southern stingray	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Surgeon fish (Acanthuridae)										
Blue tang	0.42	0.08	0.08	0.38	0.50	0.87	0.60	0.75	0.29	0.71
Doctor surgeonfish	0.16	0.04	0.11	0.20	0.19	0.16	0.22	0.27	0.10	0.20
Ocean surgeonfish	0.40	0.14	0.11	0.80	1.15	0.19	0.45	0.76	0.33	0.44
Tarpon (Elopidae)										
Tarpon	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tilefish (Malacanthidae)										
Sand tilefish	0.02	0.00	0.08	0.00	0.10	0.01	0.01	0.01	0.01	0.01
Toadfish (Batrachoididae)										
Toadfish	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Triggerfish (Balistidae)										
Black durgon	0.08	0.02	0.02	0.00	0.13	0.08	0.06	0.14	0.09	0.07
Ocean triggerfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Orangespotted filefish	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.02
Queen triggerfish	0.04	0.00	0.02	0.00	0.16	0.00	0.02	0.07	0.05	0.04
Scrawled filefish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
White-spotted filefish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trumpetfish (Aulostomidae)										
Trumpetfish	0.02	0.00	0.00	0.00	0.01	0.04	0.01	0.02	0.04	0.05
Wrasse (Labridae)										
Bluehead wrasse	0.44	0.24	0.09	0.38	1.50	0.19	0.69	1.29	0.35	0.55
Clown wrasse	0.03	0.02	0.01	0.00	0.07	0.04	0.04	0.06	0.02	0.05
Creole wrasse	0.12	0.00	0.05	0.08	0.05	0.24	0.09	0.13	0.12	0.16
Dwarf wrasse	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Green razorfish	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hogfish	0.02	0.02	0.01	0.08	0.02	0.04	0.01	0.03	0.02	0.02
Pudding-wife	0.01	0.00	0.00	0.08	0.01	0.00	0.02	0.02	0.01	0.01
Rosy razorfish	0.01	0.02	0.02	0.00	0.02	0.01	0.02	0.02	0.01	0.00
Slippery dick	0.07	0.14	0.03	0.00	0.13	0.06	0.12	0.08	0.04	0.07
Spanish Hogfish	0.11	0.00	0.03	0.08	0.10	0.08	0.13	0.11	0.05	0.22
Yellowhead wrasse	0.30	0.08	0.13	0.08	0.25	0.21	0.45	0.44	0.18	0.52