SUMMARY OF CORAL CAY CONSERVATION'S OCEANOGRAPHIC, CLIMATE AND ANTHROPOGENIC IMPACT DATA FROM UTILA, HONDURAS

- Prepared by -

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***This report is part of a series of documents detailing CCC's science programme in Utila (1999-2000).
The series is also available on CD-Rom.***

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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 oceanographic, climate and anthropogenic data collected by the *Bay Islands 2000* project.
- Data were collected during standard transects and were divided into individual 'study areas' to facilitate data analysis at a range of spatial scales.
- Data were collected on: temperature, salinity, wind, currents, visibility, natural and anthropogenic impacts, boat activity and biological and aesthetic impressions.
- CCC survey teams completed a total of approximately 600 dives (169 individual transects) from around the whole of Utila.
- The data collected during this study were generally qualitative and, therefore, it is not possible to discern detailed trends and patterns. However, the data can be used to show gross patterns amongst the variables that were monitored.
- Oceanographic and climatic parameters showed conditions to be generally typical during this study: sea surface temperatures were approximately 28.5°C and peaked during the warm wet season (May to September); prevailing winds were easterly and there was some evidence of counter-clockwise current flow.
- Surface salinity showed the expected trend of decreasing significantly during the wet season although the mean value (25.2‰) was lower than expected, but this is almost certainly partly caused by equipment inaccuracies.
- Water visibility (a measure of suspended material in the water column) is a key influence on coral health. Visibilities varied around the island and were generally lower close to Utila Town, possibly indicating anthropogenic influences and threats to coral health, and higher to the north and on offshore banks.
- Surface litter, which is aesthetically unpleasant and can affect a range of animals, was present on 15.7% of surveys. Other surface impacts were uncommon.
- Underwater impacts were generally uncommon but there was generic 'coral damage' on 11.1% of surveys. Evidence of reef sedimentation was found close to human populations. There was only limited evidence of coral bleaching and disease.
- Boat activity was higher along the southern side of Utila, with numerous dive boats at popular dive sites. Fishing boats were commonest to the south-west, where fisherman living on the Utila Cays fish on the south-west banks.
- The 'Black Hills' area (an offshore bank) had the highest dive quality rating. Areas along the south coast, which are heavily used by the dive industry, were generally attractive to divers. Ratings were surprisingly low in the Turtle Harbour Wildlife Refuge. Topographically complex escarpments and spur and groove areas were of most interest to divers.
- This study led to nine recommendations:
  - One or more agencies should continue to collect basic oceanographic, climatic and impacts data to monitor temporal changes.

- The oceanographic data, particularly for currents, should be extended to allow analysis of how coral and fish larvae are entrained and circulated around the island.
- Data on water visibility (turbidity) should be extended to include studies researching the impacts of sedimentation on reef health.
- Establish a code of practise for people living and working on Utila regarding sewage and waste disposal. Provide a standard environmental awareness briefing for all visitors to the dive resorts.
- Maintain and extend the excellent system of mooring buoys to minimise anchor damage.
- If any sites show evidence of diver impacts, dive schools should be encouraged to utilise other areas of the island.
- 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.
- The ‘Black Hills’ reef (east of Utila) appears to be an appropriate site for a marine reserve because of its attractiveness to divers and anthropogenic impacts are limited.
- A marine reserve along the south coast would help to maintain the health of this heavily used reef area and should be situated to the west to minimise influences from Utila Town and other coastal developments.

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ABBREVIATIONS

ANOVA - Analysis of Variance
BICA - Bay Islands Conservation Association
CCC - Coral Cay Conservation
COHDEFOR - Coorporación Hondureña de Desarrollo Forestal
IUCN - World Conservation Union
NGO - Non Government Organisation
p - Probability value of a statistical test.
PMAIB - Programa Manejo Ambiental Islas de la Bahía
PS - Project Scientist
SD - Standard Deviation
SO - Science Officer
SST - Sea Surface Temperature
UNAH - Universidad Nacional Autonoma de Honduras
UNEP - United Nations Environment Programme

FIGURES AND TABLES

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 fishing pressure, 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.

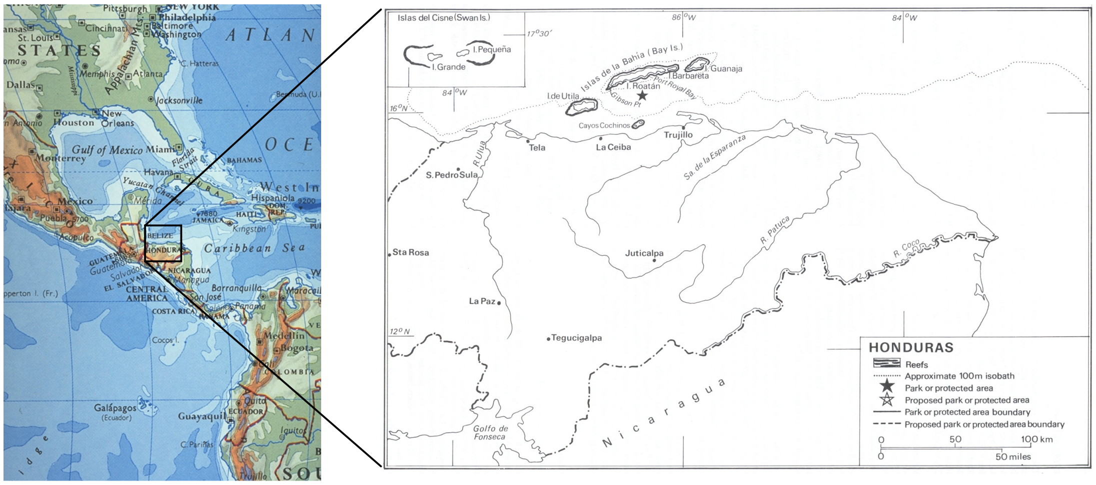


Figure 1. The location of (a) Honduras and (b) the locations of the Bay Islands (Utila, Roatán and Guanaja).

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 oceanographic, climate and anthropogenic 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*., 1998). 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 climatic, oceanographic and anthropogenic impact data gathered during the 'Resource assessment' component of the fieldwork.

3. METHODS

3.1 Surveyors

All data presented in this report were collected by CCC volunteers between June 1999 and September 2000 during standard transects to assess reef habitat types (see Raines *et al*., 1992 and Harborne *et al*., 2001 for full details of the methodology). Volunteers underwent a week of intensive science training and testing (see Harborne *et al*., 2001) which enabled them to implement the survey protocols, including measuring given parameters and identifying species precisely and consistently (Mumby *et al*., 1995). Volunteer divers in Utila were co-ordinated by a Project Scientist (PS) and Science Officer (SO). The primary responsibilities of the PS and SO were to train CCC volunteers in marine life identification, survey techniques and other supporting skills. The PS and SO also co-ordinated and supervised the subsequent surveys and data collection.

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 Temperature and salinity

Temperature readings (±0.5°C) were taken from the survey boat using a bulb thermometer at the sea surface. The survey team also took the temperature at the maximum survey depth (i.e. at the start of the survey). Similarly, the salinity was recorded from a water sample taken from both the surface and the maximum survey depth using either a hydrometer or electronic meter.

3.4 Wind

The strength and direction of the wind at each survey site was qualitatively assessed by volunteers on the survey boat. Direction was recorded as one of eight compass points (direction wind was blowing from) and strength was assessed using the Beaufort Scale.

3.5 Currents

The strength and direction of the current at each survey site was qualitatively assessed by the survey divers. Direction was recorded as one of eight compass points (direction current was flowing towards) and strength was assessed as being ‘None’, ‘Weak’, ‘Medium’ or ‘Strong’.

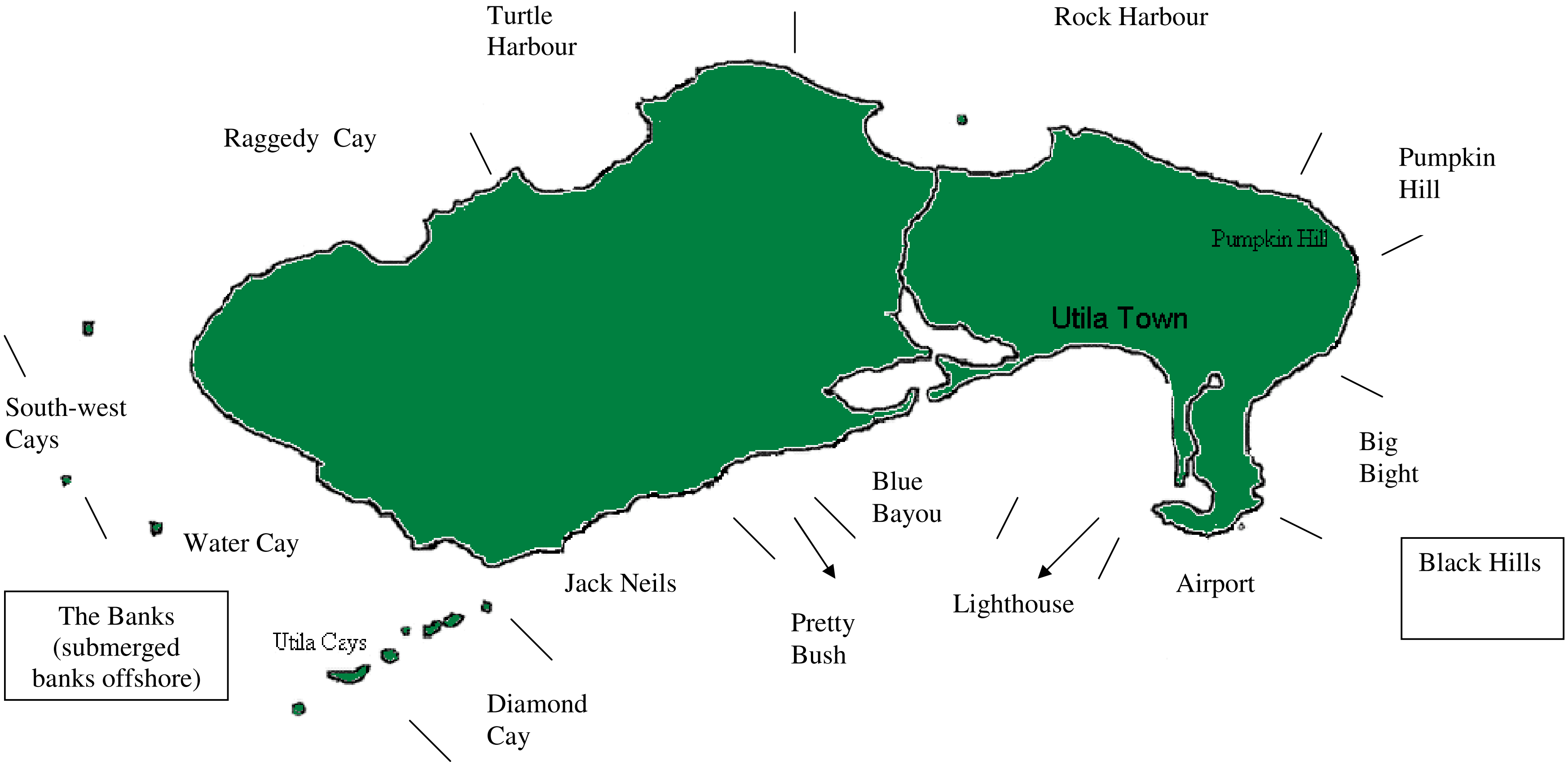


Figure 2. Map of Utila showing the location of the study areas around the island.

3.6 Visibility

Water visibility, a surrogate of turbidity, was measured both vertically and horizontally. A secchi disc was used on the survey boat to measure vertical visibility through the water column (Figure 3). Secchi disc readings were not taken where the water was too shallow to obtain a true reading. Horizontal visibility through the water column was measured by divers' estimates while underwater.

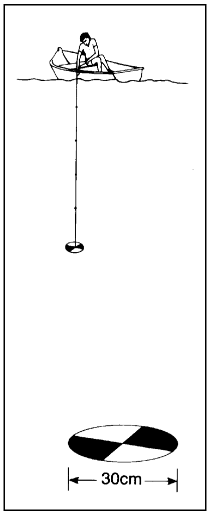


Figure 3. The use of a secchi disc, which assesses vertical water clarity. The secchi disc is lowered into the water until the black and white quarters are no longer distinguishable. The length of rope from the surveyor to the disc is then recorded. *Source*: English *et al.* (1997).

3.7 Natural and anthropogenic impacts

Natural and anthropogenic impacts were assessed both at the surface from the survey boat and by divers during each survey. Surface impacts were classified as 'Litter', 'Sewage', 'Driftwood', 'Algae', 'Fishing nets' and 'Other'. Sub-surface impacts were categorised as 'Litter', 'Coral damage', 'Sewage', 'Line nets', 'Fish traps', 'Sediment', 'Disease', 'Bleaching' and 'Other'. All information was assessed as presence / absence and hence was then converted to binary data for analysis.

3.8 Boats

Any boats seen from the boat during a survey were recorded, along with information on the number of occupants and its activity. The activity of each boat was categorised as 'diving', 'fishing', 'pleasure' or 'commercial'. Effort was made to not record the same boat twice when completing concurrent surveys within an area.

3.9 Biological and aesthetic impressions

The divers during each survey recorded a general impression of the survey location. These ratings were completed for biological (e.g. benthic and fish community diversity and abundance) and aesthetic (e.g. topography) parameters. Both parameters were ranked as 5 (excellent), 4 (very good), 3 (good), 2 (average) or 1 (poor).

3.10 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'.

Oceanographic, climatic and anthropogenic impact data were generally summarised graphically and via univariate statistics. However, more detailed examination of the data was undertaken using Analysis of Variance (ANOVA) and subsequent least significant difference multiple range tests (parametric data) and Kruskal-Wallis tests (non-parametric data). Normal and non-normal variables were assessed using the Kolmogorov-Smirnov goodness of fit test. Data were either summarised for the whole of Utila or for each of the study areas as appropriate.

4. RESULTS

By September 2000, CCC survey teams had completed a total of approximately 600 dives to assess reef habitat types. These dives provided data from 169 individual transects from around Utila. Hence the oceanographic, climatic and anthropogenic data summarised in this report represent a thorough spatio-temporal investigation of conditions around the island.

4.1 Temperature and salinity

4.1.1 Temperature

The sea surface temperature (SST) data from Utila shows that the overall mean temperature during 1999 and 2000 was 28.5°C (n = 577; standard deviation (SD) = 1.5°C). However, there was some temporal variation as shown in Figure 4, which shows the mean daily SST during the study period. Figure 4 shows that there was a clear decrease in SST temperatures between December 1999 and March 2000, reaching a minimum of 25.0°C in February 2000. The temperatures then gradually rose and appeared to be at their highest, approximately 28-30°C, from May until September in both 1999 and 2000. There is some evidence that the temperatures during 1999 were slightly above those in 2000.

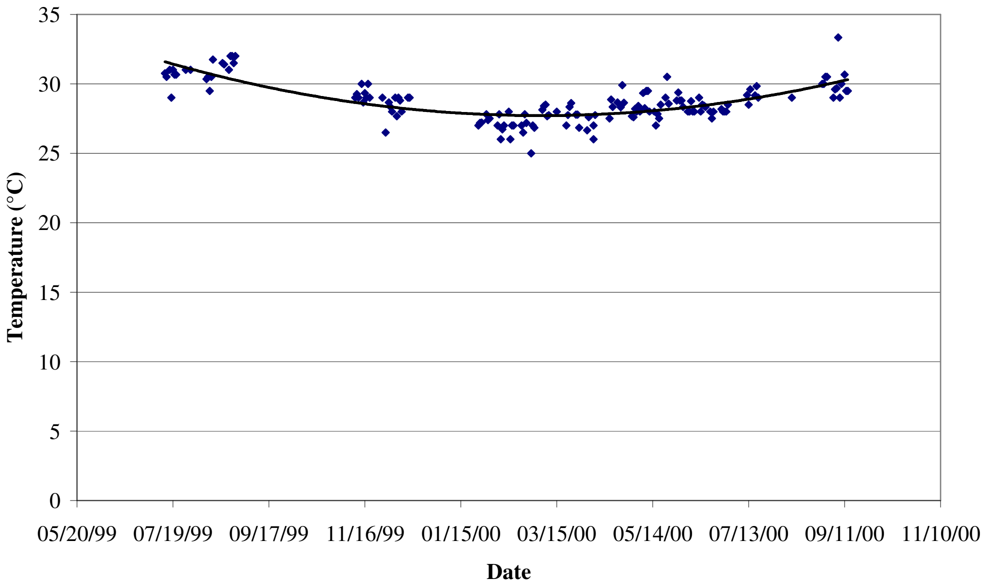


Figure 4. Mean daily sea surface temperature around Utila between June 1999 and September 2000. Trendline represents a second order polynomial fit.

Water temperatures collected by the survey teams at the maximum survey depths were then summarised in 5 m classes (0.1-5 m; 5.1-10 m; 10.1-15 m; 15.1-20 m; 20.1-25 m and 25.1-30 m) and the results are shown in Figure 5. Figure 5 shows that there was some variability in temperature within the water column, the lowest temperatures occurred between 20.1 and 25 m depth.

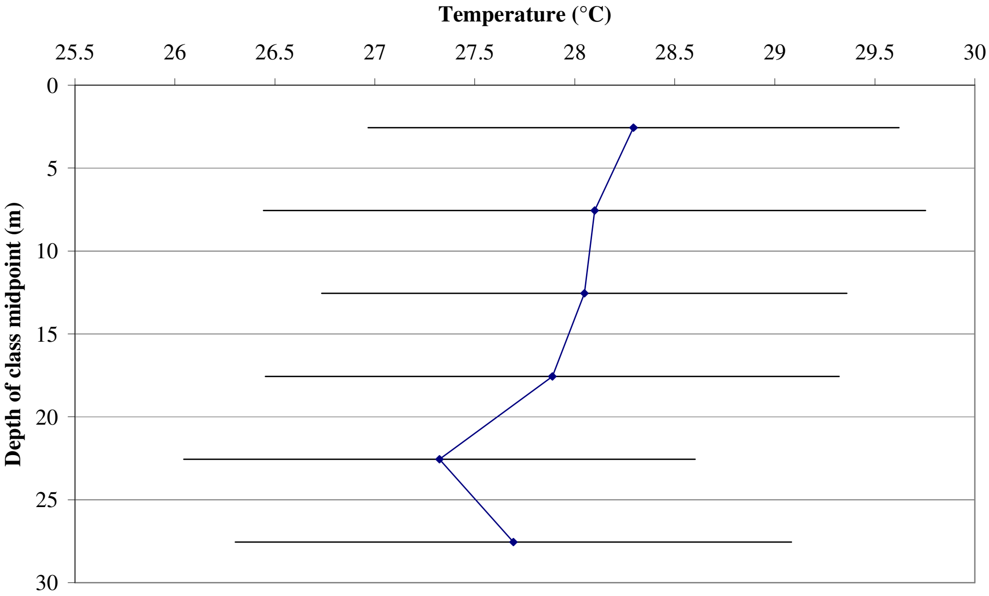


Figure 5. Mean water temperatures, for all surveys in the project area, in 5 m depth classes throughout the water column. Bars represent standard deviation. Sample sizes: 0.1-5 m = 46; 5.1-10 m = 92; 10.1-15 m = 73; 15.1-20 m = 117; 20.1-25 m = 108; 25.1-30 m = 115.

4.1.2 Salinity

The mean surface salinity around Utila during the study period was 25.2‰ (n = 539; SD = 6.5). However, there was considerable temporal variation as shown in Figure 6, which shows the mean daily salinity during the study period. The main feature of this temporal variation is the dramatic decrease of salinity between May and July 2000, from about 30‰ to less than 15‰.

Table 2 shows the mean values for each of the study areas, which varied significantly (ANOVA, $p < 0.0001$). The lowest surface salinity value was 17.8‰ at South-west Cays and the highest (34.2‰) was at Pretty Bush. Furthermore, within each study area, salinities collected by the survey teams at the maximum survey depths were summarised in 5 m classes (0.1-5 m; 5.1-10 m; 10.1-15 m; 15.1-20 m; 20.1-25 m and 25.1-30 m). These results are shown in Figures 7 (a) and (b).

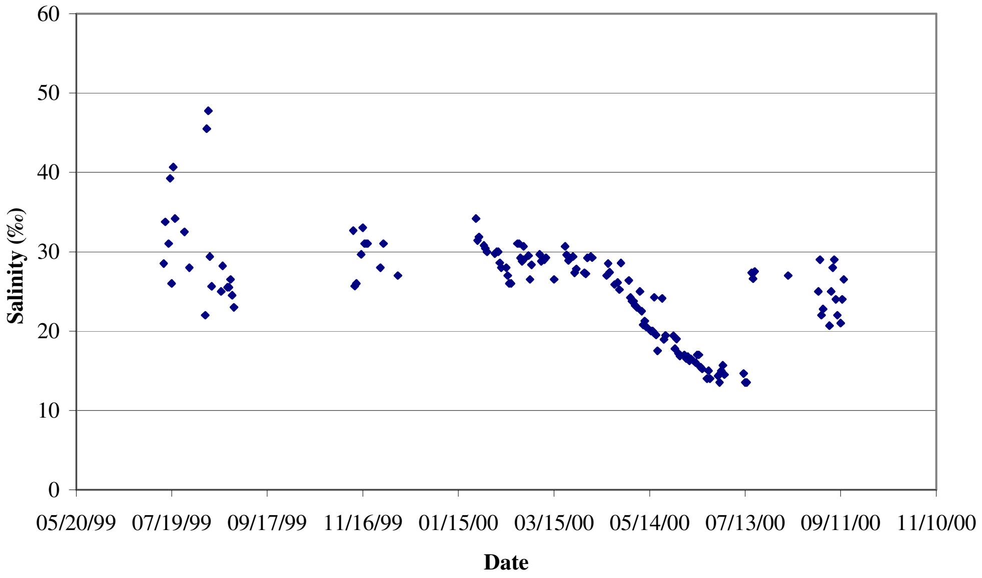
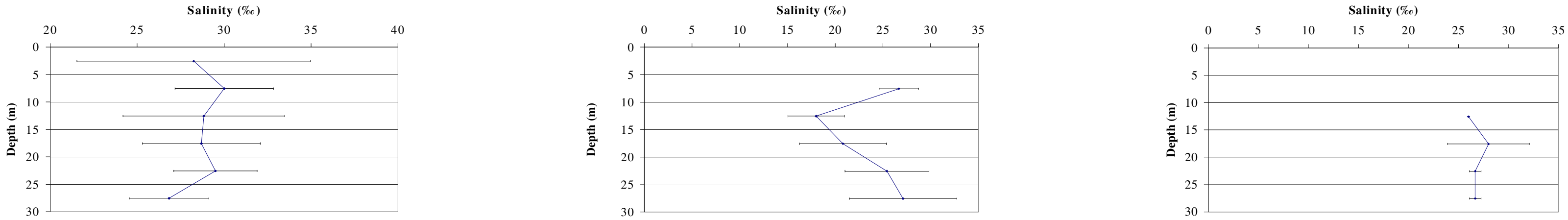


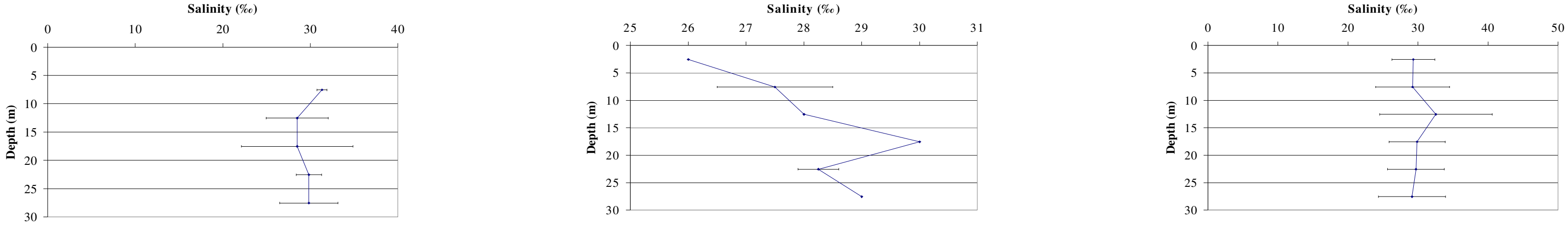
Figure 6. Surface salinity at Utila over the study period.

Table 2. Sea surface salinity at different study areas around Utila. See Figure 2 for locations of study areas.

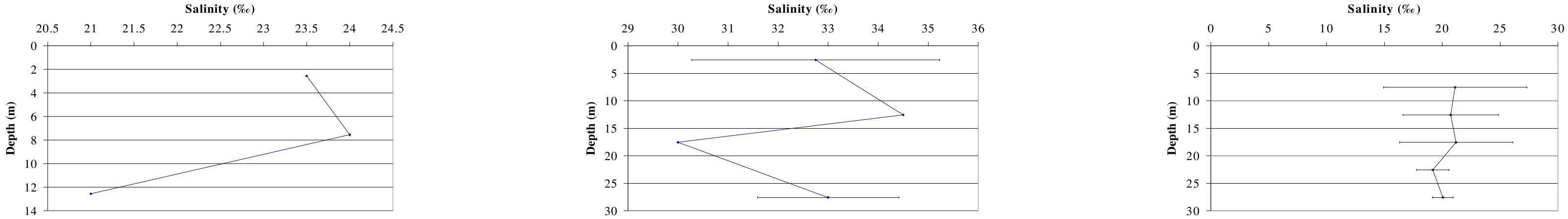
Study area	Sample size	Mean surface salinity (‰)	Standard deviation (‰)
Airport	50	28.3	6.0
Blue Bayou	33	23.4	5.2
Black Hills	11	27.6	2.4
Big Bight	24	30.6	2.6
Diamond Cay	18	28.6	1.3
Jack Neils	69	30.9	5.5
Lighthouse	4	21.0	0.0
Pretty Bush	6	34.2	0.3
Pumpkin Hill	56	20.1	4.1
Raggedy Cay	52	26.6	5.4
Rock Harbour	62	27.4	3.5
South-west Cays	47	17.8	2.7
The Banks	64	21.5	5.7
Turtle Harbour	68	28.6	5.3
Water Cay	27	18.2	4.8



Airport n=50 Blue Bayou n=33 Black Hills n=11

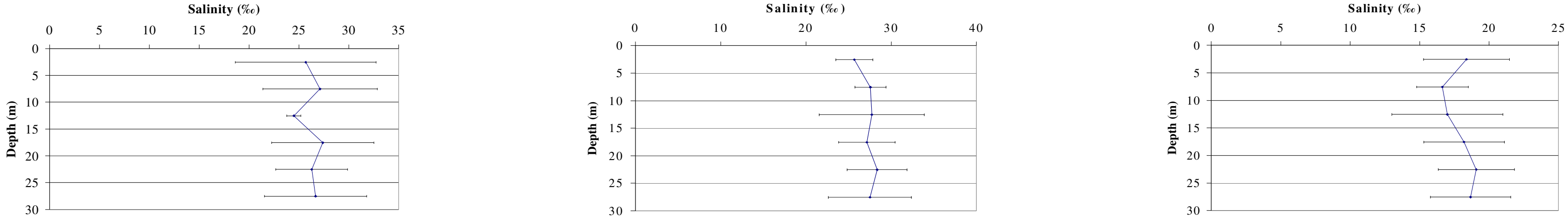


Big Bight n=24 Diamond Cay n=18 Jack Neils n=69

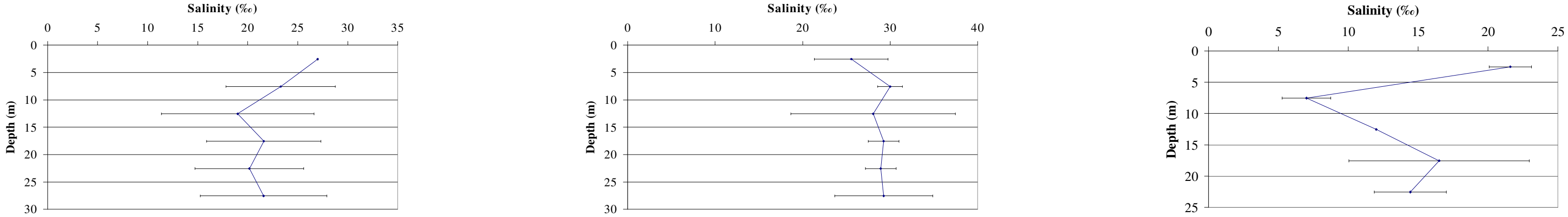


Lighthouse n=4 Pretty Bush n=6 Pumpkin Hill n=56

Figure 7(a). Mean water salinities, for study areas around Utila, in 5 m depth classes throughout the water column. Bars represent standard deviation. See Figure 2 for locations of study areas.



Raggedy Cay n=52 Rock Harbour n=62 South-west Cays n=47

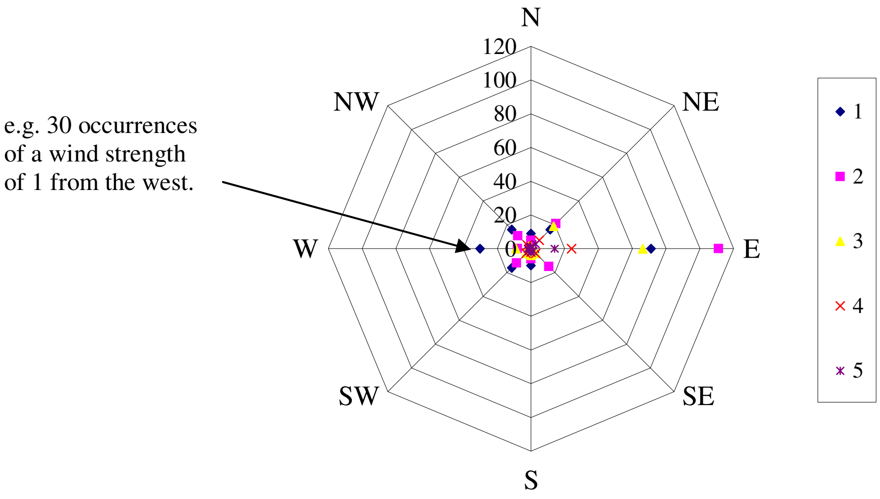


The Banks n=64 Turtle Harbour n=68 Water Cay n=27

Figure 7(b). Mean water salinities, for study areas around Utila, in 5 m depth classes throughout the water column. Bars represent standard deviation. See Figure 2 for locations of study areas.

4.2 Wind

Prevailing winds during the study period on Utila were summarised as a 'radar diagram' (Figure 8). Prevailing winds were recorded on 91.4% of surveys and hence it was still (0 on the Beaufort scale) during 8.6% of surveys. From Figure 8 it can be seen that the winds were generally from the east and most frequently observed to be a strength of 1-3 on the Beaufort scale (equivalent to a light or gentle breeze).



e.g. 30 occurrences of a wind strength of 1 from the west.

Figure 8. A radar diagram showing the prevailing winds recorded during the study period on Utila. Points represent the frequency of occurrence of combinations of wind direction and strength. Colours represent wind strength on the Beaufort scale.

4.3 Currents

The currents around Utila are illustrated using 'radar diagrams' for each study area (Figure 9). Surveyors on a total of 285 surveys (48.1%) recorded no perceptible currents. When currents were present, the strongest currents appear to have occurred on the north-east edge of Utila. The south and western sides of the island, in comparison had mostly just weak or medium currents. Currents on the northern side appeared to flow in a north-easterly direction, whilst along the southern edge the currents appeared to flow in a more easterly direction. To demonstrate these patterns more clearly, the predominant direction of the current was represented by an arrow in Figure 10. Note that the predominant direction was defined as the compass point with the greatest combined number of occurrences (irrelevant of strength) in each study area.

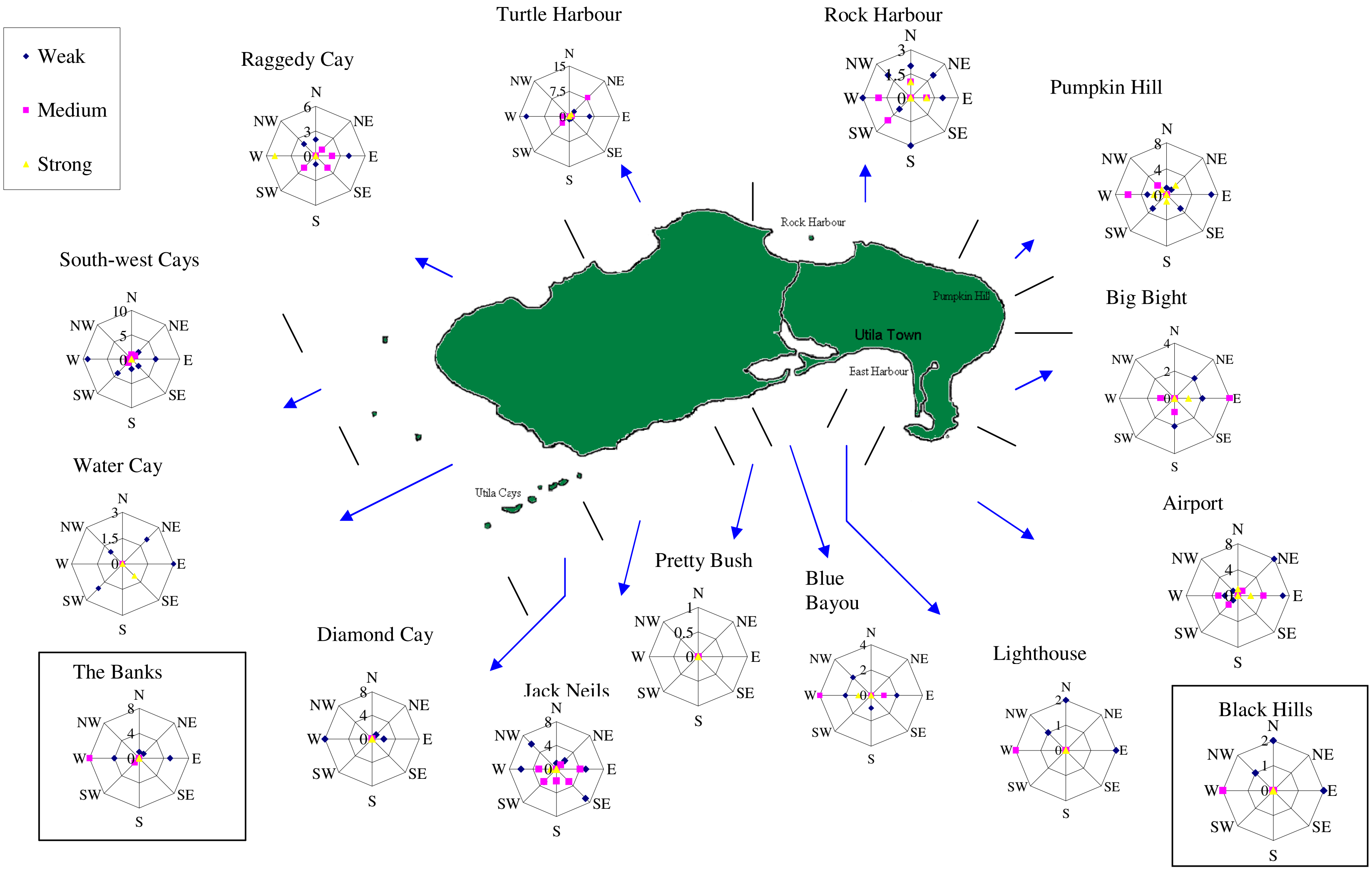


Figure 9. Radar diagrams showing current patterns in each study area. Points represent frequency of occurrence and the colours represent strength.

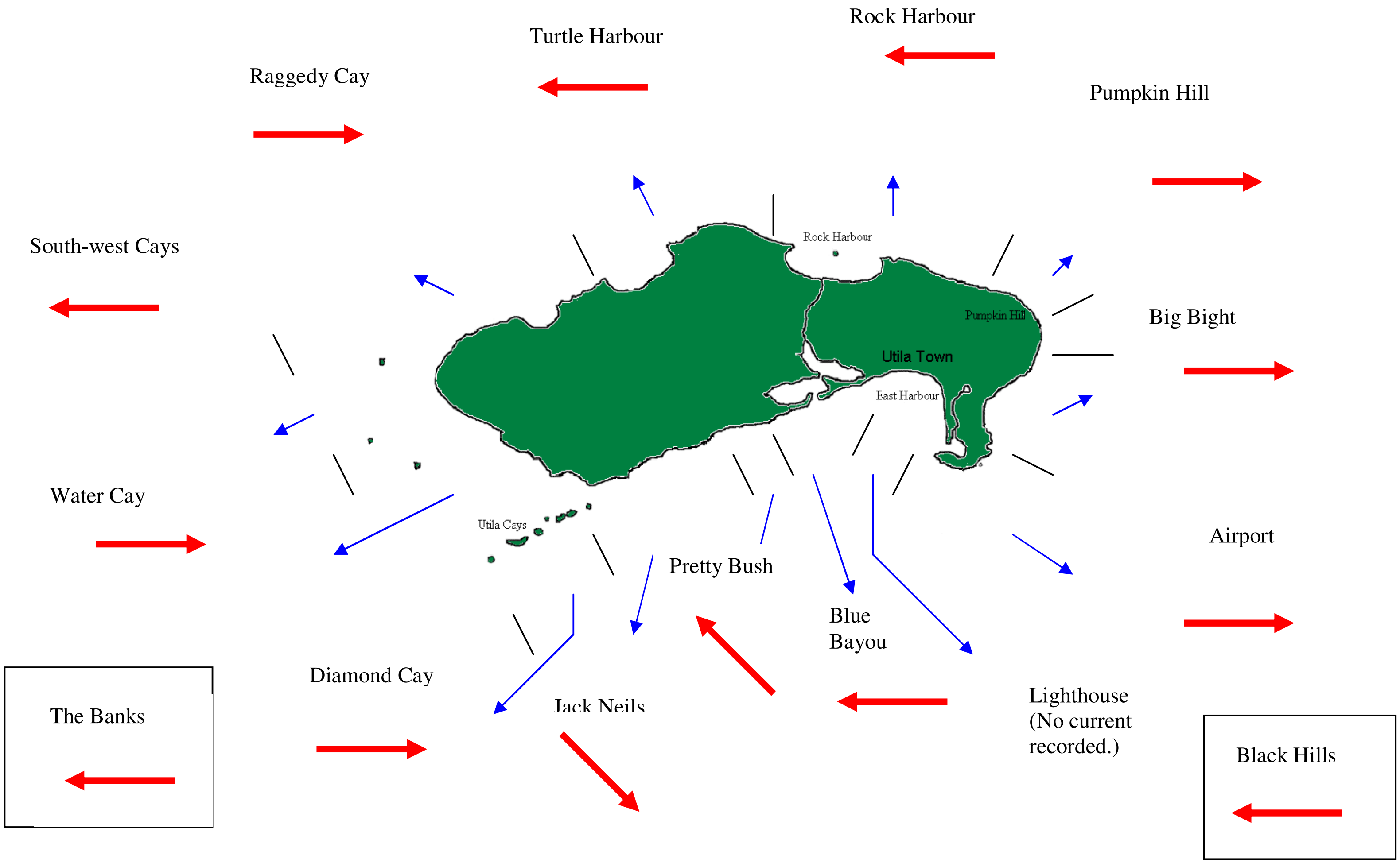


Figure 10. The predominant current direction (red arrow) in each study area.

4.4 Visibility

Water visibility is a surrogate of turbidity (the amount of suspended material within the water column), which is a key influence on coral health. For example, corals can be smothered and killed in areas with high turbidity because of changes in land use and increased erosion. The turbidity during surveys around Utila appeared to fluctuate slightly over the study period (Figure 11). Figure 11 shows a small decrease in visibility from July to September. The overall means for visibility across the whole survey period were 17.2 m for horizontal (n = 781; SD = 6.1) and 16.5 m for vertical (n = 563; SD = 5.6).

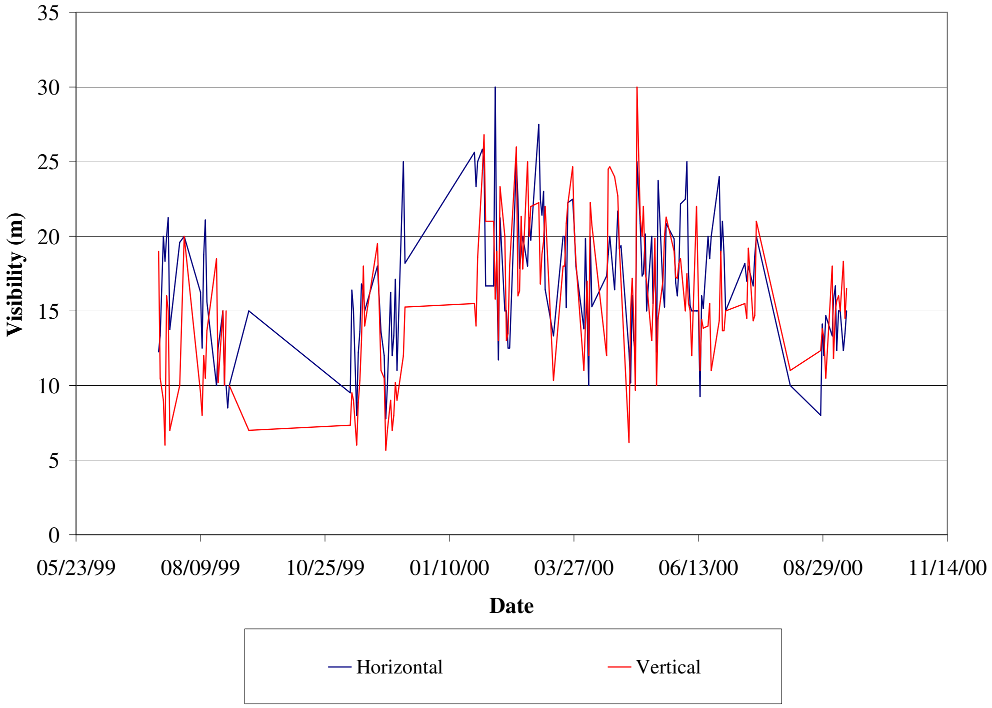


Figure 11. Horizontal and secchi disc (vertical) daily readings of water column visibility throughout the study period.

Table 3 shows the mean horizontal and vertical visibilities in each study area. Table 3 shows that the water at Lighthouse was particularly turbid (visibility < 8 m) for both vertical and horizontal visibility. In contrast, Black Hills and Rock Harbour had the highest vertical and horizontal visibilities. The differences between the study areas were significant (ANOVA; $p < 0.00001$). Subsequent multiple range tests on the means for each study area showed which pairs of study areas were significantly different (Table 4). Table 4 shows that the vertical visibility at Lighthouse was significantly lower than all others. Black Hills had the greatest vertical visibility and analysis showed this to be significantly greater than at all the other study areas around the island (Table 4). The water at Turtle Harbour was also significantly clearer than all study areas except Black Hills, Rock Harbour and Pumpkin Hill.

Table 3. Mean horizontal and secchi disc (vertical) water column visibilities in each study area.

Study area	Horizontal (m)			Vertical (m)		
	n	Mean	SD	n	Mean	SD
Airport	72	15.9	6.0	45	14.1	6.2
Blue Bayou	51	15.4	10.3	33	14.3	4.9
Black Hills	14	19.9	2.5	10	26.8	3.1
Big Bight	40	15.7	5.0	24	12.8	4.1
Diamond Cay	26	16.5	5.8	18	17.3	6.0
Jack Neils	93	16.1	5.7	61	12.8	5.3
Lighthouse	5	7.8	3.9	2	5.0	0.0
Pretty Bush	8	25.6	4.2	6	15.5	6.3
Pumpkin Hill	65	19.4	4.9	56	18.8	4.0
Raggedy Cay	67	17.1	6.3	47	17.1	5.1
Rock Harbour	85	20.3	5.0	63	21.0	5.6
South-west Cays	54	15.6	3.1	46	15.2	3.9
The Banks	75	16.4	3.9	64	15.0	3.0
Turtle Harbour	88	19.9	4.8	62	19.9	4.5
Water Cay	37	13.8	5.6	25	13.7	4.0

Table 4. Results of multiple range tests of mean vertical turbidity between each pair of study areas. Study areas are ordered from the least turbid to the most turbid and the star indicates a significant difference between a pair. 1 = Airport; 2 = Blue Bayou; 3 = Black Hills; 4 = Big Bight; 5 = Diamond Cay; 6 = Jack Neils; 7 = Lighthouse; 8 = Pretty Bush; 9 = Pumpkin Hill; 10 = Raggedy Cay; 11 = Rock Harbour; 12 = South-west Cays; 13 = The Banks; 14 = Turtle Harbour; 15 = Water Cay.

	7	4	6	15	1	2	13	12	8	10	5	9	14	11	3
7															
4	*														
6	*														
15	*														
1	*														
2	*														
13	*	*	*												
12	*	*	*												
8	*														
10	*	*	*	*	*	*	*								
5	*	*	*	*	*	*									
9	*	*	*	*	*	*	*	*							
14	*	*	*	*	*	*	*	*	*	*	*				
11	*	*	*	*	*	*	*	*	*	*	*	*			
3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	

4.5 Natural and anthropogenic impacts

4.5.1 Surface Impacts

Surface impacts are summarised for the whole of Utila in Table 5 and shown by study area in Figure 12. ‘Algae’ and ‘Litter’ were the most frequent impacts recorded and were found to be present at almost all the study areas around the island. ‘Driftwood’ was recorded infrequently (7.4% of surveys) and ‘Nets’ were not recorded at any of the surveys. ‘Sewage’ was recorded at just 0.5% of the surveys with only two of the study areas being affected (Water Cay and Turtle Harbour). Water Cay appeared to be the study area with the highest frequency of impacts observed, with particularly high levels of ‘Algae’, ‘Litter’ and ‘Driftwood’ present.

Table 5. Percentage of surveys, across the whole project area, affected by each category of surface impact. n=591.

	Litter	Sewage	Driftwood	Algae	Nets	Other
Surveys affected (%)	15.7	0.5	7.4	17.1	0.0	2.4

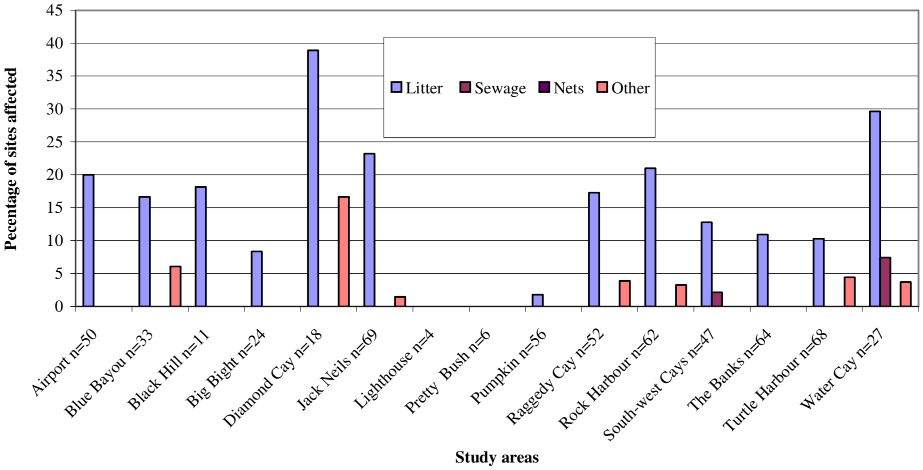


Figure 12. Proportion of surveys within each study area affected by each surface impact category. Driftwood and algae are excluded for clarity. See Figure 2 for locations of study areas.

4.5.2 Underwater impacts

Impacts seen by divers during surveys are summarised for the whole of Utila in Table 6 and shown by study area in Figure 13. The most frequently observed underwater impact was ‘Coral damage’ which was recorded as present at 11.1% of surveys and was present around the whole island. ‘Sediment’ and ‘Coral bleaching’ were also found at most of the study areas around the island with 9.6% and 6.6% of surveys affected respectively. ‘Litter’ was observed along 3.9% of the surveys and appeared at several study areas, most notably Water Cay. ‘Traps’ were absent and ‘Nets’ were rarely found (only at Blue Bayou). Underwater ‘Sewage’ was only observed at Diamond Cay. The incidence of ‘Disease’ on coral colonies was low (2.7% of surveys affected) but recorded at several different study areas. Big Bight was the most affected study area with ‘Coral damage’ and ‘Coral bleaching’ being the most frequently recorded impacts. Water Cay and The Banks also had particularly high levels of impacts recorded, with ‘Sediment’ and ‘Coral damage’ as the most frequent of the impacts in both areas.

Table 6. Percentage of surveys, across the whole project area, affected by each category of underwater impact. n=591.

	Litter	Coral damage	Sewage	Line Net	Fish trap	Sediment	Disease	Bleach	Other
Surveys affected (%)	3.9	11.1	0.2	0.2	0.0	9.6	2.7	6.6	1.5

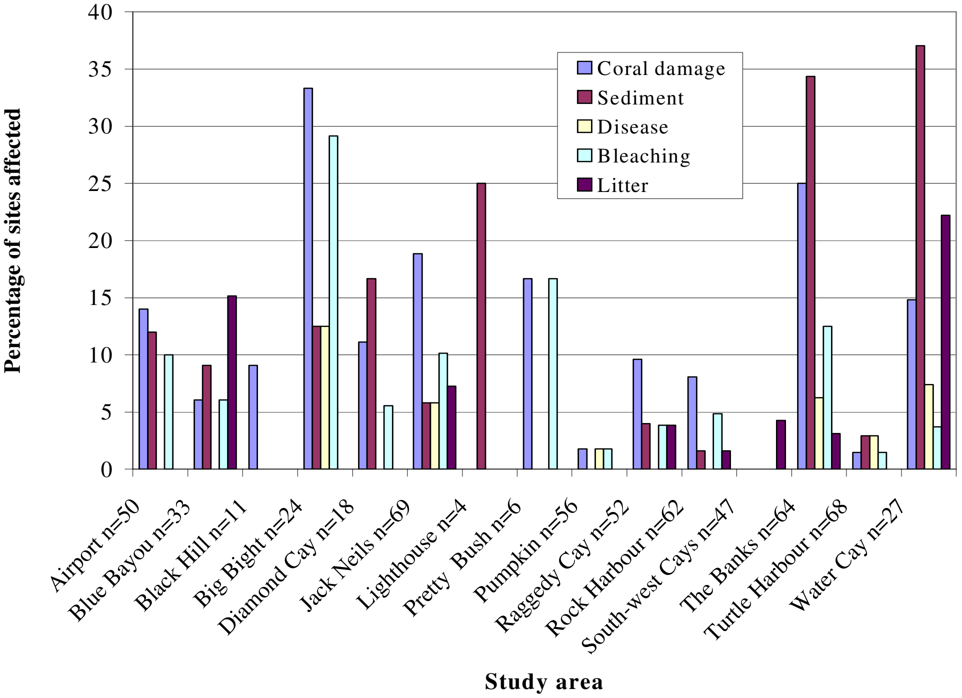


Figure 13. Proportion of surveys within each study area affected by each underwater impact category. Categories with <2% presence recorded omitted for clarity.

4.6 Boats

A total of 392 boats were seen during the surveys (246 diving, 94 fishing, 17 commercial and 35 pleasure). A summary of the number of boats per survey in each study area (Figure 14) shows the greatest density of boats was recorded at study areas Pretty Bush (2.2 boats per survey) and Jack Neils (1.5 boats per survey). Other study areas had a density of approximately 1 or less boat per survey. The activities of the boats that were recorded are shown in Figure 15 for each of the study areas. The vast majority of the boats observed were diving boats. South-west Cays and Water Cay, however, were both dominated by sightings of fishing boats. Pleasure boats were observed at the majority of study areas and most frequently at Diamond Cay and Pretty Bush. High proportions of commercial boats were observed at Diamond Cay and The Banks.

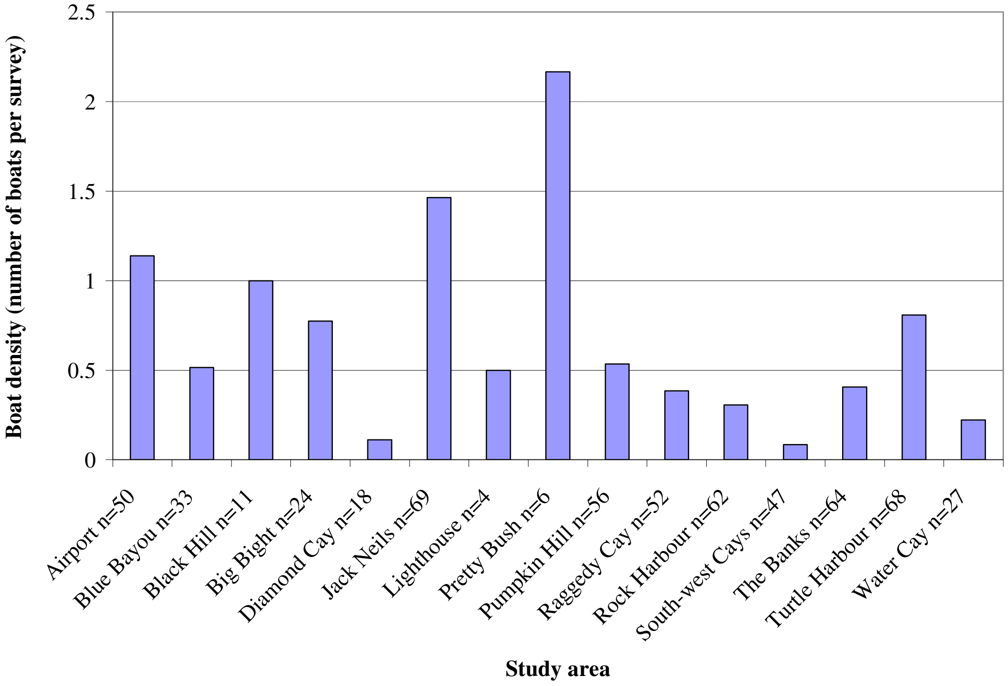


Figure 14. Comparative density of boats (all types) in each study area.

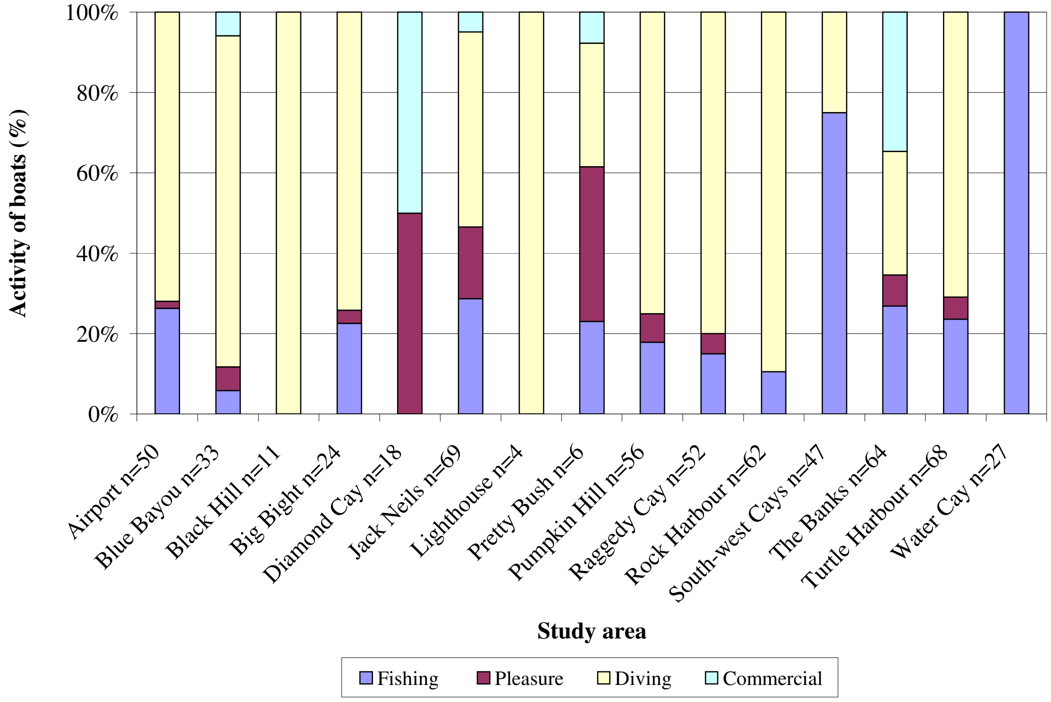


Figure 15. Summary of boat activities observed in each study area.

4.7 Biological and aesthetic impressions

A summary of the median ratings, from 1 ('poor') to 5 ('excellent'), assigned for biological values (e.g. abundance and diversity of the fauna and flora) and aesthetic values (e.g. topography) in each study area is presented in Figure 16. Analysis showed that the median biological values varied significantly between study areas (Kruskal-Wallis, $p < 0.0001$). The majority of study areas had a median value of between 1.5 and 3, which equates to biological ratings of 'average' to 'good'. Black Hills had the highest median rating, which was between 'good' and 'very good'. Airport and Water Cay had the lowest ratings, equivalent to a 'poor' biological value.

Similarly, the median aesthetic values varied significantly between sites (Kruskal-Wallis, $p < 0.0001$). There was some variation between the different sites but for most the median value was close to 2 ('average'). Black Hills had the highest median with a value of 3.3 which is equivalent to a rating of 'good' and Jack Neils, Pretty Bush, Raggedy Cay and The Banks also had medians above 2.5.

Figure 17 shows the same data analysed by reef zone. Both median biological and aesthetic values varied significantly between the different reef zones (Kruskal-Wallis, $p < 0.01$). From Figure 17 it can be seen that there is little variation in the biological values between the different reef zones as most were close to a value of 2 ('average'). Escarpment areas had a median of 2.7 ('good') and, therefore, appeared to have the highest biological quality. Aesthetically, the majority of reef zones were between 2 and 3, a value of 'average' to 'good'. The lagoonal zone was lower and had an aesthetic value that was 'poor', with a median below 1.5.

Finally, the aesthetic and biological values were combined produce an overall 'dive quality' index (Figure 18). All sites scored above 2 ('average') and Black Hills had the highest score of 3.3 ('good').

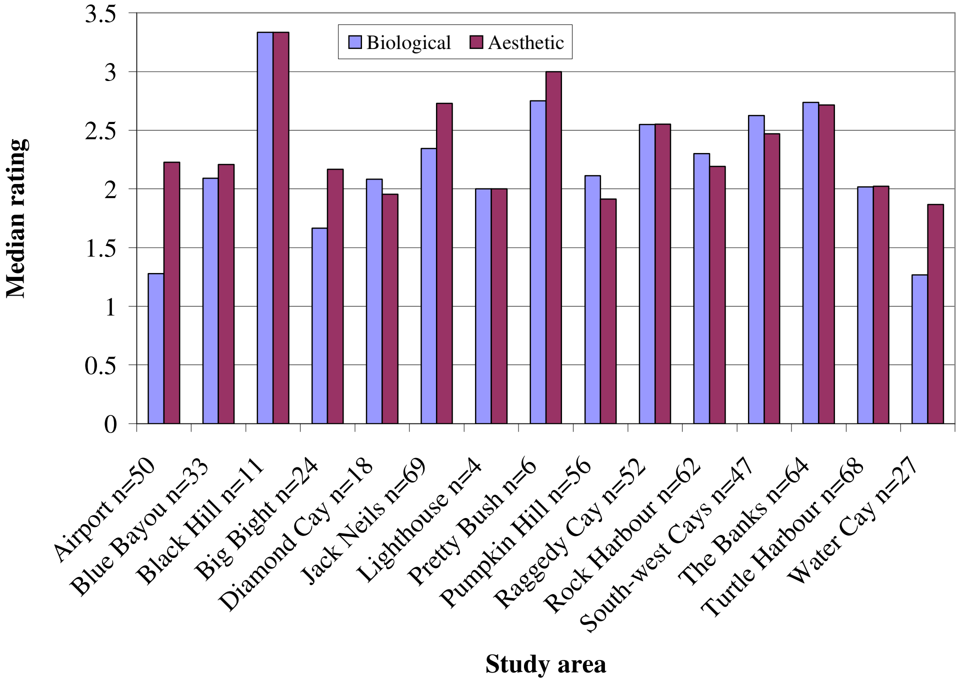


Figure 16. Summary of the ratings for biological and aesthetic values of survey sites in each study area. Categories are from 1 (poor) to 5 (excellent).

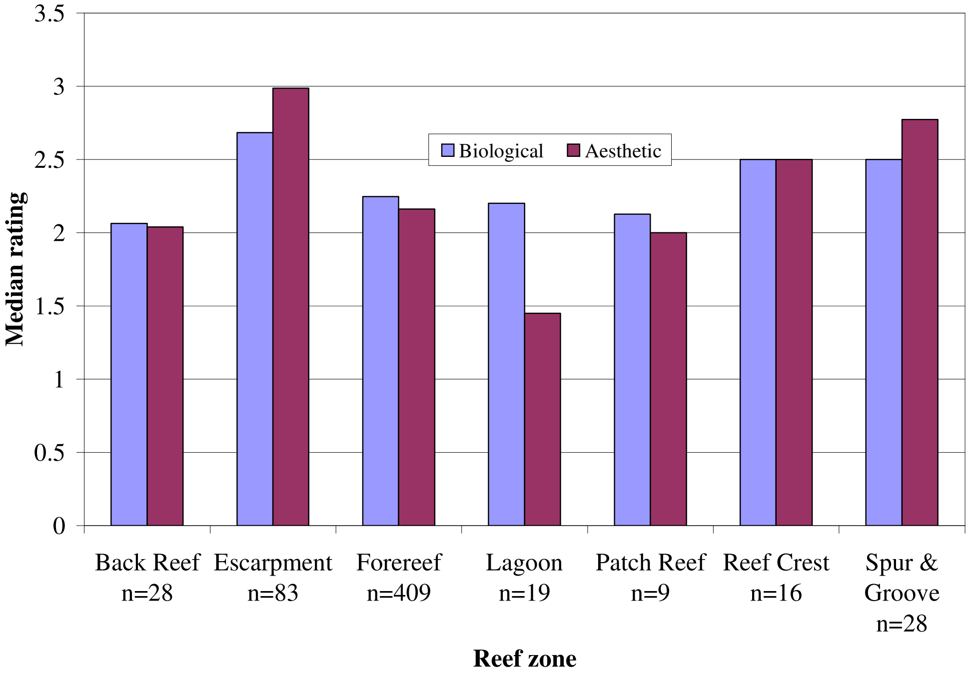


Figure 17. Summary of the ratings for biological and aesthetic values of survey sites in each reef zone. Categories are from 1 (poor) to 5 (excellent).

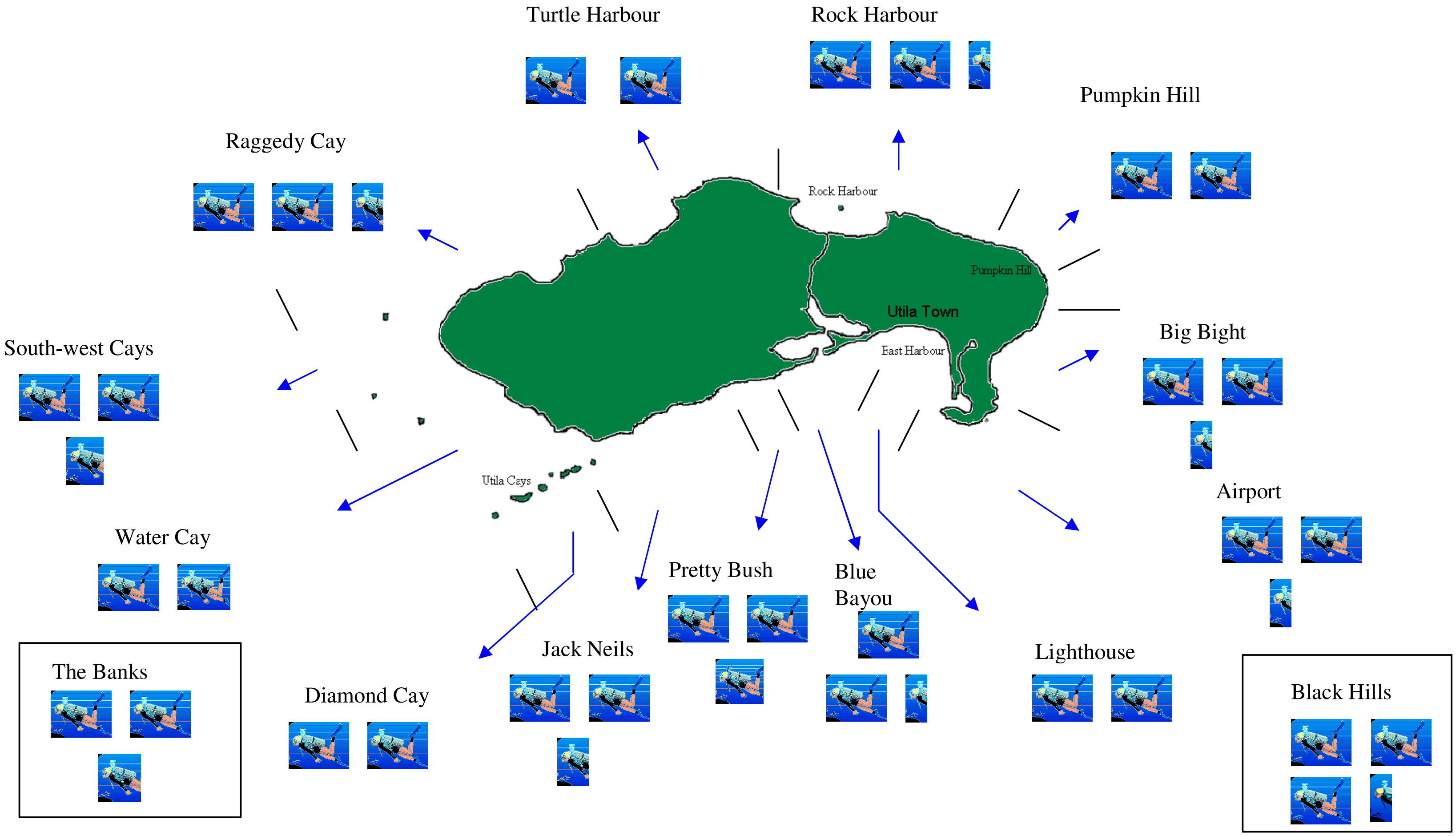


Figure 18. The overall ‘dive quality’ of each study area around Utila. Number of divers represents this ‘dive quality’ which ranges from 1 (poor) to 5 (excellent) based on the median of the combined biological and aesthetic values assigned to each site e.g 2 divers = rating of 2 (average).

5. DISCUSSION

5.1 Oceanography and climate

The oceanographic and climatic data collected by CCC, including during this study, is generally qualitative and, therefore, it is not possible to discern detailed spatio-temporal trends and patterns. However, the data can be used to show gross patterns amongst the variables that were monitored. Hence, the results summarised in this report provide a baseline for further, more detailed studies.

The climate of Honduras is subtropical, influenced by easterly trade winds that result in an eight month wet season and a cooler dry season from November to February (summarised in Harborne *et al.*, 2001). This pattern was reflected in the sea surface temperatures recorded over the study period in Utila. Hence, temperatures were found to peak from May to September, corresponding to the wet season when the climate is generally warmer along the Caribbean coast. Similarly, temperatures were lowest between January and March because of the counter-clockwise currents early in the year which affect the Bay Islands and are associated with coastal upwelling of cooler water (Brenes *et al.*, 1998). As typical in tropical waters, temperatures recorded at varying depths within the water column showed no obvious thermocline. These data indicate that the shallow waters (<30 m) around Utila were well mixed although there was evidence that the water temperature decreases with increasing depth, as might be expected because of attenuation of sunlight.

The slightly higher temperatures during 1999 compared to 2000 may be related to the El Niño event of 1998. El Niño is a disruption of the ocean-atmosphere system in the tropical Pacific which has important consequences for weather around the globe, including playing a role in mass coral bleaching events such as the one that occurred in Honduras in 1998 (Kramer and Kramer, 2000). Since coral bleaching is inextricably linked to seawater temperatures it is important to monitor these temperatures as only a small increase may cause coral bleaching to occur. Such detailed monitoring of sea temperatures, along with other oceanographic variables, would be best achieved with the use of digital monitoring meters. This equipment has the advantage that it can be moored on the reef and left at key locations to gain a more quantitative and consistent data set.

In contrast to seawater temperatures, the mean surface salinity of 25.2‰ was lower than expected, but this is almost certainly partly caused by the inaccuracy of the equipment used by CCC. Hayman and Kjerfve (2001) report that the salinity along the Honduras coast is generally about 37‰, although this is known to decrease significantly at the beginning of the wet season. Indeed this pattern was observed during this study, with surface salinity decreasing between May and July 2000. Furthermore, the raw data shows that 11 of the 15 study areas were being sampled during this period indicating that it was a seasonal factor rather than a statistical artefact related to a particular part of Utila. In addition, salinity data collected during the same time period at the nearby monitoring station on Cayos Cochinos also showed a decrease beginning in July, close to the start of the wet season. However, the decrease at Cayos Cochinos was smaller, possibly reflecting more sophisticated equipment and thus a less variable data set (Halley, 2001).

Around Utila, there was no clear evidence of haloclines within the water column but the mean surface salinity was lowest at the two study areas located to the west of the island: 'South-west Cays' and 'Water Cay'. This trend may indicate a particularly high amount of run-off from adjacent coastal areas, which could be natural and linked to groundwater movement on Utila. However, it could also be associated with significant development since, for example, clearing land of its natural vegetation can lead to rainwater not being absorbed as efficiently and flowing straight onto the reef. Decreased salinities are important because they can have an adverse effect on coral growth (Hubbard, 1997). Similarly to water temperatures, long-term monitoring of salinity patterns should be undertaken using moored digital monitoring meters.

The influence of the seasonal easterly trade winds was reflected in the wind data collected around Utila. Hence, the majority of winds recorded during surveys were easterly in direction. In contrast, there was significant variation in current directions in each study area. Currents are known to generally flow from the west to the east of Utila (summarised in Harborne *et al*., 2001) and this is consistent with data from the southern edge of the island. However, the predominant directions (directions that occurred the most times) from study areas on the northern side of the island appears to show westerly currents, possibly indicating some counter-clockwise flow around Utila. It should be noted, however, that the data are limited for several of the study areas and the sample sizes were too small to reliably represent the currents and further research is required. Accurately modelling water movement patterns is vital for conservation since fish and coral larvae are entrained by currents and moved between 'source' and 'sink' areas (e.g. Caley *et al*., 1996). Hence, for example, it is important to place marine reserves in areas that provide larvae (sources) via current flow to other local reefs and, therefore, can replenish fish stocks and regenerate benthic communities after degradation by anthropogenic impacts (Robert and Hawkins, 2000). As for currents and salinity, digital meters would be ideal for producing accurate and detailed current data for the reefs of Utila.

The final oceanographic parameter recorded for Utila was water visibility. Water visibility is a surrogate of turbidity (the amount of suspended material in the water column), which is a key influence on coral health. For example, corals can be smothered and killed in areas with high turbidity (low visibility) caused by changes in land use and subsequent increased erosion. However, it is important to note that CCC did not collect any data on sedimentation rates onto the reefs of Utila and hence can only infer links between water visibility and coral health (i.e. low visibility is likely to have negative effects on coral cover).

During this study, turbidity was highly variable, which may part be partly caused by the use of basic equipment (secchi discs) and divers estimates. However, the gross patterns were as expected and, like temperature and salinity, turbidity varied seasonally. Rainfall and wind action may be expected to cause the water to become more turbid and indeed visibility was reduced between about July and September, when higher rainfall during the wet season increases freshwater and sediment runoff to the sea. In contrast, visibility increased from November to February as rainfall decreased during the dry season.

A comparison of visibilities within each study area also indicated that levels of turbidity were variable at different parts of the island. The lowest mean horizontal and vertical turbidity was found in the ‘Lighthouse’ study area (<10 m). This area is close to Utila Town and, therefore, it seems likely that the turbidity is linked to high levels of pollution (e.g. sewage) and coastal development. Further evidence of the influence of anthropogenic factors is shown by the relatively high turbidities in the study areas ‘Jack Neils’, ‘Water Cay’, ‘Airport’ and ‘Blue Bayou’. All these sites are along the more developed southern side of Utila and are influenced by pollution, coastal development and dredging.

‘Black Hills’, in comparison is situated well offshore and, therefore, less affected by anthropogenic impacts. This is reflected in this study area having the highest vertical and horizontal visibility (> 19 m). ‘Rock Harbour’ also had high water visibility, which is likely to be because of its position on the north side of the island where there is both little urban development and also greater flushing of the water because of the higher water depths and exposure. This hypothesis is supported by the high water visibilities in the ‘Turtle Harbour’ and ‘Pumkin Hill’ study areas, both of which are on the north side of Utila. More detailed turbidity comparisons are inappropriate since sites were not surveyed concurrently and turbidity are known to be affected by seasonal factors such as rainfall, which were not measured in this study.

At a regional scale, the overall means for visibility on Utila (horizontal 17.2 m and vertical 16.5 m) are both lower than those obtained by equivalent surveys during CCC’s work on Turneffe Atoll, Belize (horizontal 19.9 m and vertical 18.1 m; Turnbull and Harborne, 2000). However, this is expected since Turneffe Atoll has minimal development and is approximately 30 km from the mainland and hence receives very little pollution. Further data sets from elsewhere in Central America and the wider Caribbean region are required to assess sedimentation in Utila and more detailed research is needed to elucidate the influences of varying turbidity on reef health. Similarly, data on other important water quality parameters (e.g. nutrient and heavy metal loads) would be very useful to delineate anthropogenic stresses to the reefs.

5.2 Natural and anthropogenic impacts

The surface and underwater impacts recorded by CCC volunteers are highly qualitative (e.g. presence or absence) and are not collected systematically around the project area but the data sets are extensive and can be used to highlight apparent trends for future studies. For example, the most common surface impact was ‘Algae’ (a gross proxy for storm damage), recorded at 17.1% of surveys. ‘Litter’ was also present in the majority of study areas and 15.7% of surveys were affected overall. The proportion of sites where litter was present was particularly high at Diamond Cay and Water Cay. These two sites are located at the south-west edge of Utila close to the Utila Cays where there is a small settlement of people who may be the source of this litter. Litter in these areas may also be related to currents and run-off bringing it from other parts of the island. Litter is not considered a significant threat to reef health but is aesthetically unpleasant and may give a negative impression to tourists. Furthermore, large pieces of plastic rubbish pose a mechanical threat to turtles, dolphins and sea birds which may become entangled, maimed and possibly drowned (Pruter, 1987). Sea birds have also been shown to ingest small fragments of plastic, which could block their digestive tract. Litter may also be toxic to wildlife and chemicals leached from plastic may harm selected invertebrates.

'Nets' were not recorded at any of the study areas and, therefore, there is no evidence of 'ghost fishing' (fish trapped in lost nets) at the surface. Similarly, visible 'Sewage' was generally absent but such pollution requires more detailed monitoring of water quality parameters. Such monitoring is important because high levels of sewage can cause nutrient loading and increased abundance of algae to the detriment of corals and carry water borne diseases. 'Sewage' was only recorded on the south-west edge of the island, at Water Cay and South-west Cays, possibly because of the influence of the Utila Cay or the easterly currents moving it from Utila Town.

Underwater impacts were generally uncommon, with generic 'coral damage' most frequent (11.1% of surveys affected). Such coral damage may be caused by storms or anthropogenic impacts such as divers or anchors. The 'Big Bight' study area had the greatest proportion of sites affected by coral damage, which is likely to be because of its exposed position on the eastern side of the island and hence the increased wave energy. 'Jack Neils' and 'Pretty Bush' also had a high percentage of sites where coral damage was observed but in contrast to the wave damage at 'Big Bight' this may be related to their popularity as dive sites.

'Sediment' was found to be particularly prevalent at the 'Lighthouse' and 'Water Cay' study areas. This is consistent with the water visibility data that showed these two sites to have a high level of turbidity (sediment in the water column). These two study areas are both located close to human populations whose impacts on the land and the subsequent freshwater runoff may result in high sediment loads. Similarly to at the surface, some 'Litter' was seen, 'Sewage' was rare underwater and there was little evidence of 'ghost fishing' by lost nets. 'Coral bleaching' was also seen only on a small proportion of surveys (6.6%) but was generally limited to a few colonies and is certainly not indicative of another mass bleaching event (as in 1998). Since sea surface temperatures were approximately 28.5°C during this study, which is below the critical threshold for bleaching (approximately 30°C), these bleached corals presumably represent colonies that have very susceptible zooxanthellae or are subject to warm water micro-climates.

Coral disease is another important parameter to monitor the general reef health and also to indicate other sources of stress. For example, Green and Bruckner (2000) propose that the presence of coral disease may act as a bio-indicator of other anthropogenic stresses, based on an observed correlation between incidence of disease on Caribbean reefs and the presence of medium to high human impacts. During this study, coral disease was low with it being recorded on only 2.7% of surveys, distributed across several different study areas. A recent study carried out on the corals of Central America between March and June 1999, following Hurricane Mitch in 1998, reported that disease on coral reefs in the area was fairly prevalent (Kramer and Kramer, 2000). This study included several sites around Utila and showed disease on up to 20% of corals on the forereefs. It would appear, therefore, that the corals have recovered quickly or those affected have now died and further spread of disease has not occurred. However, coral diseases are notoriously difficult to identify accurately, even by trained researchers, and it is likely that the actual number of occurrences of diseases are underestimated by CCC volunteers.

The final anthropogenic impact recorded during this study was boat activity, which is a gross proxy of anthropogenic activity in any given area. The density of boats was generally fairly low (less than one per survey) but was higher at several study areas along the southern side of Utila. For example, boat density (diving and pleasure) was highest at the popular dive sites of 'Pretty Bush' and 'Jack Neils'. In contrast, at 'South-west Cays' and 'Water Cay' the majority of boats observed were fishing boats. This was likely to be because of the presence of fisherman living on the Utila Cays and fishing on the South-west banks.

5.3 Aesthetic and biological impressions

The biological and aesthetic ratings awarded on each survey were generally between 2 and 3, which is equivalent to a rating of between 'average' and 'good'. Although CCC volunteers receive more scientific training than most sport divers and the data are qualitative, their opinions represent an excellent objective data set from non-scientific divers with a wide range of previous experience. For example, some CCC volunteers have dived in many other locations around the world while others undertook their initial SCUBA training with CCC and hence have not seen other reefs for comparison. It should be noted, however, that observers using an ordinal scale are known to favour the middle category (Mumby *et al*., 1997), which is 'good' for these parameters.

As expected, there was a clear correlation between the medians for the aesthetic and biological values because, for example, a diverse reef community is aesthetically appealing. However, these parameters were combined to clearly demonstrate the quality of diving around Utila. The 'Black Hills' study area clearly had the highest dive quality rating (>3). Black Hills is located offshore, away from maximum fishing pressure, and is increasingly becoming a popular dive site because of its relatively high abundance of fish (D. Afzal, pers. comm.). Such qualities indicate that it would appear to be an ideal site for a no-take marine reserve that would protect the fish populations and be attractive to divers. The 'Lighthouse' study area, in comparison, had a low dive quality rating, probably because of its proximity to Utila Town and the associated anthropogenic impacts that decrease reef health.

Other study areas along the south coast, which are heavily used by the dive industry in Utila, were generally attractive to divers, including 'Blue Bayou', 'Pretty Bush' and 'Jack Neils'. The ratings were lower in 'Turtle Harbour', which was unexpected as this is also a popular dive site and a marine reserve. However, it is possible that this may be because results are averaged from both deep and shallow waters and the popular dive sites are in the deeper areas. The low rating for 'Pumpkin Hill' was more expected by its location on the exposed side of the island where there are poorly developed reefs.

The comparison between reef zones showed that the topographically complex escarpments and spur and groove areas were of most interest to divers (biological and aesthetic values >2.5). Shallow reef crests were also regarded as interesting dive sites. Lagoon areas support many fewer species than reefs and, therefore, were expected to have a lower biological rating than other reef zones (<1.5).

6. RECOMMENDATIONS

Analysis of CCC's oceanographic, climatic and natural and anthropogenic impact data from Utila has provided a baseline for future comparisons and indications of requirements for further research. These data, because they are generally qualitative and non-systematic, are only appropriate for highlighting gross trends and patterns. However, the results do lead to a number of recommendations.

Recommendation 1: One or more agencies should continue to collect basic oceanographic, climatic and impacts data to monitor temporal changes. These data will also provide important information on anomalous events, such as increased water temperatures that could led to another mass bleaching event.

Recommendation 2: The oceanographic data, particularly for currents, should be extended to allow analysis of how coral and fish larvae are entrained and circulated around the island. Such information is vital for ensuring that the main sources of larvae are conserved.

Recommendation 3: Data on water visibility (turbidity) should be extended to include studies researching the impacts of sedimentation on reef health.

There was evidence of anthropogenic effects, particularly along the more developed southern coast.

Recommendation 4: Establish a code of practise for people living and working on Utila regarding sewage and waste disposal. Provide a standard environmental awareness briefing for all visitors to the dive resorts.

Recommendation 5: Maintain and extend the excellent system of mooring buoys to minimise anchor damage.

Data from CCC volunteers showed that their biological and aesthetic impressions of the study areas and reef zones around Utila were similar.

Recommendation 6: If any sites show evidence of diver impacts, dive schools should be encouraged to utilise other areas of the island.

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).

Recommendation 7: 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.

<ins>Recommendation 8:</ins> The ‘Black Hills’ reef (east of Utila) appears to be an appropriate site for a marine reserve because of its attractiveness to divers and anthropogenic impacts are limited.

<ins>Recommendation 9:</ins> A marine reserve along the south coast would help to maintain the health of this heavily used reef area and should be situated to the west to minimise influences from Utila Town and other coastal developments.

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