Coral Reef Ecology

Background
Coral reefs are the most diverse, productive marine communities and create the biggest, most spectacular structures made by living organisms. Local communities exploit their high productivity and tourists admire their beauty and uniqueness - for these very reasons they need to be used sustainably.

What are coral reefs?
A coral reef is a living system built by hard corals, comprising of a symbiosis between the coral animal (polyp) and plant (zooxanthellae). Many polyps aggregate forming colonies that secrete calcium carbonate, creating a collective limestone "skeleton". Successive generations of polyps build on top of previous generations' "skeletons" leading to reef formation. As such, reef-building (hermatypic) corals are the basis of life in reef communities.

Where are coral reefs found?
Coral reefs are present in the waters of over 100 countries. These are warm (18-29°C), shallow, sunny regions primarily between the Tropics of Cancer and Capricorn. They support over 25% of all known marine fish species whilst only representing 0.25% of the marine environment.

Critical environmental variables affecting Coral Reefs
Reef survival requires temperature, light, depth, water clarity, salinity and water movement to remain within narrow limits.

How long have coral reefs been around for?
Reef structures have been around for 450 million years although the major reef building species has changed from blue-green algae to sponges and corals. Coral reefs as we know them date back 195 million years. Reefs have survived many mass extinctions, the most recent 136 million years ago, prior to which many more hermatypic corals were present (of 7500 known coral species, around 5000 are now extinct).

Coral Reef Conservation

Why conserve coral reefs?
Coral reefs and their associated habitats have an almost unimaginable and hugely underappreciated value to mankind, providing billions of people with a source of food and income. Their biological richness comes close to that of tropical forests. This is why coral reefs have been dubbed the ‘rainforests of the sea’. Some of the key ecological and economic services provided by coral reefs are highlighted below.
ECOLOGICAL

1) Biodiversity
Reef systems are home to an estimated one million species. There are more species per unit area of coral reef than in any other ecosystem. The level of specialisation has been pushed to extremes, adapting to specific diets, cryptic habitats and highly evolved defence mechanisms. It is estimated that less than 10% of the Earth's reef organisms are known to science.

2) Coastal protection
Reef systems provide a natural buffer against waves, storm surge and floods for more than 100,000km of coastline. During storms they are a key factor in preventing the loss of life, property and erosion. They contribute to the formation of sandy beaches and sheltered harbours.

ECONOMIC

1) Medicines
Recent research has linked compounds found in coral reef species with treatments for heart disease, cancer, HIV, arthritis, human bacterial infections, viruses, and other diseases. Research in this field suggests that coral reefs will increasingly become an important resource for medical treatments, nutritional supplements, pesticides, cosmetics, and other commercial products. Cone snails are thought to contain more chemicals useful to medical research than any other group of organisms on the planet.

2) Tourism
The billions of dollars spent each year on diving tours, recreational fishing trips, hotels, restaurants, and other businesses based near reef ecosystems create livelihoods for an enormous number of people worldwide. An economic valuation conducted in Tobago by the World Resource Institute concluded that the value of coral reefs for 2007 was more than half of the island's annual GDP!

3) Fisheries
Coral reefs provide a wide range of harvestable species, including fish, molluscs and crustaceans. For generations, many developing coastal communities have depended on them as a primary food source. In addition, reef ecosystems are vital in providing nutrients and breeding grounds for many oceanic commercial species, as well as the reef dependent species which we commonly think of.

4) Building
Coral reefs are a source of raw materials in many parts of the world. Extraction practices can have immediate consequences on the reef and
nearby beaches, such as high levels of siltation resulting in coral reef mortality and coastal erosion. This leads to destabilization of the coast and collapse of buildings.

5) Nutritional
Coral reefs provide the main source of animal protein for 1 billion people in Asia alone.

6) Aquarium trade
It is estimated that 2-2.5 million people around the world keep marine aquaria. If managed properly, aquarium species could become a high value source of income in coastal zones with limited resources. The problem with this form of exploitation is the destructive techniques used, and the lack of quantitative data to measure its environmental impact. Huge numbers of vulnerable reef organisms are removed from the reefs every year to supply the burgeoning aquarium trade, upsetting the ecological balance of the systems.

The ecological and economic qualities of coral reefs are conventionally used to quantify their value but increasingly other factors, such as their intrinsic and cultural value, are being recognised. Some of the very uses that make coral reefs economically viable have led to their exploitation and today around the world corals are severely threatened.

How Are Coral Reefs Threatened?

Things are not looking good for coral reefs. According to the 2008 Status of Coral Reefs of the World report, our planet has effectively lost nearly 20% of its coral reef area over the assuming a ‘business as usual’ scenario, another 45% will be lost within the next 40 years if urgent measures are not taken to reduce both local and global impacts to coral reefs.

There is still room for optimism however. 46% of the world’s reefs are regarded as being relatively healthy and not under any immediate threats of destruction. There is still time to take action and join the effort to preserve the some of the richest and beautiful natural habitats our planet has to offer.

Bleaching
Global warming and altered global climate patterns has increased the incidence of coral bleaching. Bleaching arises from abnormally high sea temperatures which induce the coral polyps to expel their zooxanthellae, removing the primary means of nutrient absorption and ultimately causing the death of the coral. Sometimes corals recover their zooxanthellae and survive the event. Prolonged stress from other factors such as salinity, ultraviolet light, sediment, or pollutants, means the corals are unable to cope, becoming susceptible to coral diseases and dying.
In 1998, 75% of reefs were affected by bleaching related to global climate change, 16% died. More recently in 2005, the Caribbean suffered over 20% loss in coral cover during one of the warmest summers on record.

**Oceanic Acidification**

Increased atmospheric carbon dioxide has further implications on coral growth as it affects structure and growth capabilities of hard corals. As the oceans soak up more carbon dioxide, the marine chemistry of the ocean changes. Dissolved in water, CO$_2$ becomes carbonic acid, reducing the amount of carbonate available to calcifying organisms such as reef building corals that need carbonate to create a calcium carbonate (limestone) skeleton. The predicted changes in seawater chemistry could have severe consequences for calcifying organisms, making it increasingly difficult for hard corals to maintain their limestone.

**Disease**

Stony coral diseases have increased significantly in the last decade causing widespread mortality of important hermatypic species. Studies have identified coral diseases are affecting greater numbers of coral species, increasing in frequency and distribution. Recently coral diseases with pathologies or tissue conditions not previously observed have emerged. Several of these have been recorded killing tissue at much faster rates.

**Marine pollution from commercial sea vessels**

Commercial shipping illegally dumps waste materials at sea. Ballast and fuel storage tanks are emptied at sea, releasing fuel, oil and other chemicals. Anti-fouling paints leach toxic chemicals.

**Sewage from land-based developments**

Tourist developments often have inappropriate water treatment and sanitation systems. Raw sewage is often dumped directly into the sea via outflow pipes that insufficiently long to prevent the sewage from being brought back to shore. Effluent release results in increased levels of nitrogen and phosphorous into the sea leading to eutrophication.

**Sedimentation**

Deforestation removes the root systems that anchor forest soils. Heavy rains erode unstable soil, which is transported by rivers and streams towards the sea. Mangrove removal leads to above normal levels of sedimentation smothering the reef system. Root mats hold 99% of rainforest nutrients. When a rainforest is burned or cut down the nutrients are removed from the system creating unproductive soil. The land is often abandoned and new areas cleared.
**Over fishing**

Natural predator and prey species are lost. Increasingly smaller fish are caught to meet a growing demand through a process known as ‘fishing down the food chain.’ Important reef grazers such as Parrotfish are often the first to be removed. Parrotfish play a vital role in keeping reefs healthy by scraping away the algae before they get a chance to outcompete the corals. The balance within the system is then lost, usually with detrimental effects.

**Destructive fishing practices**

Dynamite, cyanide and other illegal fishing methods destroy habitats and breeding sites. Larger fish are stunned and removed by fishers, but many smaller or less desirable fish die and are left amongst the broken coral.

**Coral mining**

Coral is often mined for use as a building material in coastal town and tourist resort development.

**Aquarium trade**

1,471 fish species are traded worldwide. Many juvenile 'aquarium sized' fish are captured, sedated and shipped in plastic bags within polystyrene boxes. Most do not survive the long journey. Future generations of potential breeding fish stocks are lost. Only 1-10% of fish and less than 1% of coral species can be bred in captivity. This perpetuates the demand for wild animals. Concern about over-exploitation has led the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to list many coral species on CITES Appendix II.

**Souvenirs**

Over 500 invertebrate species (other than coral) are traded as marine ornamentals. Estimates place the value of marine ornamental trade at US $200-330 million/year. Increased popularity of coral for use in jewellery is of particular concern as many are rare deep-water species. Extraction involves destructive trawls and tangle-net dredges causing immense damage to the reef.

**Predation**

There are increasingly predation epidemics by species like the Crown of Thorns Seastar, *Acanthaster planci*. The removal of the giant triton, *Charonia tritonis* (a major predator of the Crown of Thorns) harvested for its decorative shell may have contributed to population growth. Links between increased marine sewage and increased survival of Crown of Thorns larvae have also been identified.

**Commercial aquaculture**

Due to reduced fish stocks, fish farms are increasingly common. The restrictive areas used, combined with the large number of fish contained, increase disease and mortality. Widespread antibiotic use has led to increases in resistant strains of disease. Low sperm counts; hermaphrodites and absence of male cohorts are increasingly observed.
Anoxic water conditions

As fish within farms die through over-crowding or disease, their decay causes the accumulation of decomposing bacteria at the seabed. Bacteria consume large amounts of oxygen creating a layer of anoxic water. Anything entering anoxic zones, which is unable to escape quickly will die, further fuelling the bacteria and perpetuating the cycle.

Coastal Development

39% of the world’s population lives within 100 km of a coral reef. Worldwide coastal populations are expected to double by 2050. In addition, millions of tourists visit the tropics. Coral reefs provide nearly US $30 billion annually in net benefits in goods and services, including tourism, fisheries and coastal protection. They attract millions of SCUBA divers, yielding significant economic benefits. Dive tourism can damage and kill coral reef ecosystems by contact with fins, hands and knees. Anchor damage is also significant. Uneducated tourists perpetuate souvenir and curio demand and pay high prices for freshly caught reef fish in restaurants.

Mining

Elements from mining are leached into waterways. Concentrated toxins are transported downstream, inflicting damage far from their source. Cyanide use poses a serious threat to local water supplies. Often there are instances where it is released into waterways, contaminating downstream water supplies and killing aquatic life. Toxic waste from mines is dumped into local river systems.

Coral Reef Conservation Efforts

Due to increased pressure on coral reef ecosystems, many marine conservation programmes have been developed to study and conserve coral reefs. Many are localised, thus data gathered through them cannot be compared with other regions. To solve this problem, global initiatives have been developed, using common methods and standards. Some of these are:

ICRI (International Coral Reef Initiative)

This partnership between nations and organisations aims to improve management practices, increase capacity and political support, and share information on coral reef health. ICRI identifies four major areas of work: integrated management; capacity building; research and monitoring; and review.

Reef Check

Developed as a volunteer, community-based monitoring protocol measuring the health of coral reefs on a global scale its objectives are: to educate the public about the coral reef crisis; to create a
global network of volunteer teams trained in Reef Check's scientific methods regularly monitoring and reporting on reef health; to facilitate collaboration producing ecologically sound and economically sustainable solutions; and to stimulate local community action to protect remaining pristine reefs and rehabilitate damaged reefs worldwide.

**United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC)**

The UNEP World Conservation Monitoring Centre (UNEP-WCMC) is a collaboration between the United Nations Environment Programme and WCMC, a UK-based charity. UNEP-WCMC is UNEP’s specialist biodiversity assessment arm, and the Centre for UNEP’s collaboration with WCMC. Their goal is to provide information on biodiversity to governments and organisations to enable the development of conservation policies and decisions.

**Convention of Biological Diversity (CBD)**

This aims to maintain the world's biological diversity by conservation and encouraging fair and equitable use of genetic resources. Coral reef degradation contributes to biodiversity loss. Chemical pollution, eutrophication, fisheries operations, global climate change, alterations of physical habitat and invasions of exotic species are targeted.

**Ramsar convention**

This endeavours to conserve and sustainably use wetlands through international cooperation. Many reefs fall within the definition of wetlands, thus are affected by this convention.

**Global Program of Protection of the Marine Environment from Land-based Activities (GPA)**

Some of the largest threats to reef ecosystems are silting and eutrophication as a result of deforestation and sewage or fertiliser runoff. Litter may cause entanglement and ingestion problems in marine animals. The GPA aims to implement Sewage Action Plans (SAP) and reduce the Physical Alteration and Destruction of Habitats (PADH) in coral reef related coastal and marine areas.

**Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)**

This works to ensure international trade in wild animals and plants does not threaten their survival. Many species of coral as well as giant clams, sea horses and the queen conch are listed in Appendix II of CITES as species not necessarily threatened with extinction, but for which trade must be controlled to avoid utilisation incompatible with their survival. International trade in these organisms requires an export permit issued by the country of export, proving the specimen has been legally obtained and the export is not detrimental to species survival.
**United Nations Framework Convention on Climate Change (UNFCCC)**

This aims to stabilise greenhouse gas concentrations at a level preventing dangerous anthropogenic interference with the climate system, in sufficient time to allow ecosystems to adapt naturally to climate change, ensuring that food production is not threatened and allowing sustainable economic development. Scientific information is received from the Intergovernmental Panel on Climate Change (IPCC), an independent body of the World Meteorological Organisation and UNEP, conducting periodic scientific assessments. IPCC research includes assessing the impacts of climate change on coral reefs. Results show that the expected increase in seawater temperature, sea level rise, changes in storm patterns and water currents, as well as changes in rainfall patterns and increased sedimentation will all affect coral reef ecosystems.

**Coral Cay Conservation's Contribution**

**Community Conservation**

Over the last 22 year CCC has contributed to conservation projects around the world. CCC’s work involves building local people’s capacity to manage their own natural resource. By working with local, national and international NGO’s and governments using the 'bottom-up' approach we can provide ecological data and designate marine protected areas to help preserve these fragile ecosystems, while aiding and empowering local communities in the surrounding areas.

Coral Cay Conservation’s marine conservation projects consider each of these factors:

**Local:** engaging stakeholders through alternative livelihood provision and capacity building e.g. skills training, environmental awareness schemes, award and scholarship scheme and much more.

**National:** collaborating with NGOs and government departments to ensure more effective conservation outputs.

**International:** promoting the project work and outputs at international forums and through relevant media to encourage greater support for work 'on the ground'.
Survey Methodologies

CCC volunteers conduct a variety of quantitative and semi-quantitative surveys which typically involve undertaking ‘transects’ at various depths across the reef in order to gather detailed ecological information. This information includes data on fish, coral and invertebrate abundances and diversity, as well as general reef health. This information can be seen as a ‘stock-take’ of that particular habitat. Survey teams consist of either two or four divers and a boat marshal who gathers data on abiotic factors such as temperature, in addition to ‘marking’ the survey location on a GPS.

Some surveys are repeated bi-annually in order to gather data over time. These surveys are used to study the recovery of reef systems. A good example of monitoring would be to assess the effectiveness of marine parks at preserving reef health and increasing fish stocks for local communities. Other surveys focus on the prevalence of coral diseases or coral bleaching using a series of 1m² ‘quadrats’ laid along a transect line. This provides vital information on the health of coral reef systems and how they are being impacted by coastal development, providing a strong case for the implementation of mitigation measures.

We often utilise Reef Check surveys to collect quantitative data on species that are good indicators of reef health and overharvesting such as sea urchins, giant clams, groupers and parrotfish, thereby contributing to this important global database which assesses the current status of reefs around the world.

When necessary, other, specific surveys are carried out including rapid reef assessments, sedimentation assays, mangrove surveys and the impacts of severe weather events such as hurricanes or tsunami’s on coral reefs. These are often undertaken at the request of national governments or project partners. An example of this was in 2005 in Tobago when the Tobago House of Assembly and the Buccoo Reef Trust asked Coral Cay to conduct an extensive assessment of the mass-bleaching event that took place in the Caribbean. In this case, a small team of scientists conducted comprehensive surveys around the island to assess the impact of this event on the island’s reef systems.

Scientific Results & Outputs

Results

CCC assists coral reef conservation by conducting surveys of these natural resources in countries with limited financial and technical resources to do the job themselves. This information can then be compiled and analysed in order to formulate recommendations for sustainable management and conservation.
Sustainable management plans can only be developed by local stakeholders through well-informed decisions requiring a basic knowledge of the existing resources within the area.

**Outputs**

Collected information is compiled into user-friendly reports that allow resource users and managers, such as fisherfolk and local government officers, to make decisions regarding resource use. Reports are made available to institutions wishing to incorporate the information in their own research.

Every volunteer contributes valuable data to a wider conservation effort. Your surveys contribute to the development of environmental databases, resource maps and other outputs. Unfortunately it is not possible to compile reports regarding the data collected by individuals but all data is summarised in regular reports.

All of CCC’s reports are currently available for download can be found at:
http://www.coralcay.org/science-research/scientific-reports/

The website is regularly updated and changed. As such it may not feature all outputs produced at a particular expedition location. However, CCC’s head office holds an extensive library of past reports, outputs, and other literature relating to the work of CCC, that we welcome you to consult.

For further information, please contact CCC’s science department: science@coralcay.org.