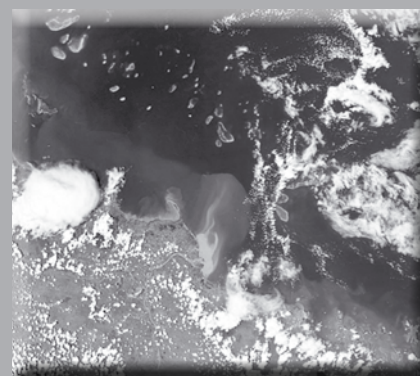


CATCHMENT MANAGEMENT AND CORAL REEF CONSERVATION

CLIVE WILKINSON AND JON BRODIE



**A PRACTICAL GUIDE FOR COASTAL RESOURCE MANAGERS
TO REDUCE DAMAGE FROM CATCHMENT AREAS
BASED ON BEST PRACTICE CASE STUDIES**

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GCRMN Management Group

IOC-UNESCO – Intergovernmental Oceanographic Commission of UNESCO

UNEP – United Nations Environment Programme

IUCN – International Union for Conservation of Nature (Chair)

The World Bank, Environment Department

CBD – Convention on Biological Diversity

GBRMPA – Great Barrier Reef Marine Park Authority

WorldFish Center and ReefBase

ICRI Secretariat – Governments of France, Samoa and Monaco

RRRC – Reef and Rainforest Research Centre, Ltd (Australia) as host

GCRMN Major Supporters and Operational Partners

US Department of State and NOAA – National Oceanic and Atmospheric Administration of USA;

National Fish and Wildlife Foundation of USA

GCRMN SocMon (Socioeconomic Monitoring Initiative for Coastal Management) at NOAA

Reef Check Foundation, Los Angeles;

ReefBase and WorldFish Center, Penang;

CRISP - Coral Reef Initiatives for the Pacific,

World Resources Institute, Washington DC

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Photographs on the Front and Back Cover are explained and credited on Page 108 (inside the back cover).

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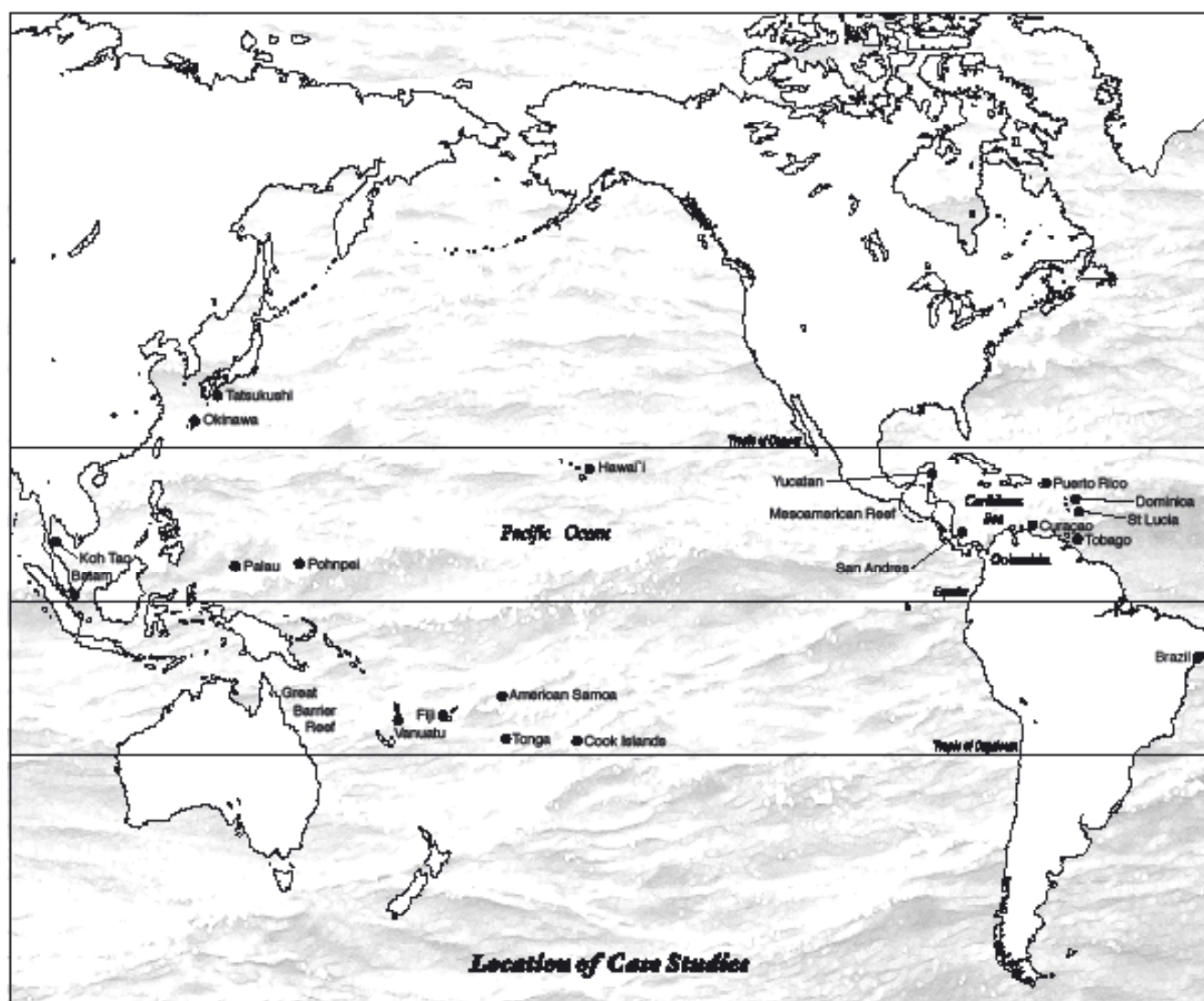
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SUMMARY

This book aims to help people manage coral reefs and other coastal ecosystems; especially to solve problems that flow from nearby catchment (watershed) areas. Such catchment areas may be adjacent to the coral reef, or include areas a long way away and outside the jurisdiction and control of the coastal manager. This book introduces ways to reduce some of that damage through cooperation with people and industries upstream, based on the experiences of many coastal managers around the world.

A **catchment area** is defined as all the land that channels rainwater and groundwater into a river or stream, that then delivers water to coastal areas, in this case areas that contain coral reefs. The term **catchment** is often interchangeable with **watershed**, which is particularly used in the USA and nearby countries. However, watershed is also used to describe the boundary line between two catchment areas i.e. a line drawn across the tops of hills or mountains.

In the distant past, many coral reefs developed downstream of catchment areas and were able to cope with low levels of sediment and nutrient flows, but recent increases in human populations and development near the coast are delivering large increases in sediment and nutrient pollution that is damaging coral reefs, mangrove forests and seagrass beds.

Catchments deliver the following things to the coast:

- **Sediments** from deforestation, farming and development;
- **Nutrients** in sediments from erosion, from farming (fertiliser losses and intensive livestock waste), and industrial and domestic wastewater and sewage;
- **Pesticides** principally from farming;
- **Persistent Organic Pollutants (POPs)** from industries (other than pesticides);
- **Heavy metals** from mining operations and metal processing industries (refineries, smelters) and general urban and industrial wastes;
- **Solid wastes** especially plastics and other litter; and
- Large volumes of **fresh water**

Many people come to the coast from these catchment areas to fish and for recreation. This can result in more damage, but it also presents an opportunity for the coastal manager to involve them in finding solutions to the problems affecting coastal resources. The key message to deliver is to raise awareness of the problems and solutions through effective catchment management.

This book makes many recommendations to reduce, and where possible, remove the damaging impacts that are delivered by rivers and streams to the coast where coral reefs may be damaged. These recommendations have been developed based on the 33 Case Studies from Asia, the Pacific and Australia, and to the wider Caribbean and tropical Atlantic. We have also used the advice of expert reviewers and our own experience in making these recommendations.

These **Recommendations for Action** are generic in nature in that they may apply to virtually all tropical catchment areas, and they are usually not specific for any particular catchment area. That is the task for the natural resource manager; to adapt the ideas in these recommendations to the environment and size of your particular area, and particularly to adapt to sociological circumstances of the population in the catchment and the coast, and economic circumstances of these people, their activities and the various levels of government. Some suggestions for cleaning up pollution are quite cheap and effective, whereas there are some large areas and problems that require very expensive interventions to remedy years of neglect and consequent damage to the downstream coastal areas and coral reefs. Assuming there are problems:

Recommendation 1: The first step to implement catchment management is to determine the extent of the area and activities to be managed. The critical actions are to map the area, determine the responsible agencies and what jurisdiction is applicable. It is particularly important to determine the level of traditional ownership and management.

Recommendation 2: The next step is to identify the problems and issues to manage, and determine the top priority issues that are amenable for management. The primary issue analysis of the problems should include assessment of the economic costs of the damage and the costs involved in potential management solutions, including options for alternative solutions.

Recommendation 3: Management is unlikely to be effective unless the major stakeholders, especially the people living in the catchment areas, are aware of the problems, recognise that solutions are necessary and are part of the team seeking solutions. Open and transparent communication is essential throughout any management activity, especially providing substantial scientific data and advice on the problems and monitoring progress of remedial actions.

Recommendation 4: Probably the most important management action is to control excess sediment inputs into streams that flow out to coastal areas and coral reefs. Recommendation #2 focuses on determining the major issues; the essential specific tasks are to identify the sources of sediments, assess and monitor sediment flows, and implement actions to reduce sediment washing off altered catchments. The largest volumes of sediment flow off hillsides cleared of forests and off agricultural lands, especially land used for cropping and grazing. Hillsides can be reforested and farmers can be assisted to implement sustainable farming.

Recommendation 5: Nutrient pollutants, particularly nitrogen and phosphorus compounds, are often coincident with sediment pollution. The essential tasks are to determine the major sources from the primary issue analysis; where possible measure the major nutrient concentrations; raise awareness about problems and solutions with the catchment community; and implement corrective action to reduce the major sources, especially those that are easier to correct. Large point sources such as sewage treatment plants, intensive animal production and abattoirs are more amenable to solution, although it may be expensive, than widespread diffuse pollution from houses, farms and small factories.

Recommendation 6: Controlling pesticide and other toxic chemical compounds is largely dependent on having good scientific evidence of the compounds involved, the concentrations in the environment, animals and plants, and effective alternatives. These analyses may be expensive, but are essential. Control will also require good scientific advice on types of pesticides to use and their toxicity, timing and level of application for most effect, and alternative compounds of lower toxicity or biological controls to reduce pesticide risk.

Recommendation 7: Solid waste pollution (plastics, metal, glass etc.) is obvious in the environment, but control requires providing suitable waste receiving systems and centres, and altering the behaviour of polluting communities. Recycling some waste materials can provide economic benefits to offset the costs of treatment facilities.

Recommendation 8: Heavy metal pollution is difficult to detect and more difficult to control. Most governments have strong regulations to control the waste material from mining and metal industries, but these are major contributors to the economies of developing countries; thus it may be more difficult to penalise such industries for non-compliance with pollution reduction regulations.

Recommendation 9: Reducing damage caused by flooding from modified catchment areas can be a mix of easy and cheap options, to very expensive engineering solutions. The critical actions are to stop or control removal of vegetation during forestry operations, replant forests and lost ground cover, ensure riparian zones are intact or replaced, reduce the rapid runoff of water from sealed hardened surfaces, and repair or retain wetland areas. Environmental Impact Assessments should be rigorously applied to all large developments in catchment areas to indicate unintended damage to coastal ecosystems and how to reduce damage.

Recommendation 10: Virtually all the problems from catchment areas above will be exacerbated by global climate change. Therefore, Recommendations 4 to 9 above should be reinforced by explaining that climate change will make controlling these impacts more difficult. An emphasis on climate change may provide funding opportunities to control direct damaging impacts, but care is needed that these direct stresses are not ignored in efforts to tackle climate change.

Recommendation 11: Natural resource managers will need financial, logistic and scientific help from their governments, donors and NGOs. Some of this help may come through using the international and regional conventions that apply to coastal and catchment management. The UN agencies and NGOs may also have scientific expertise to assist in determining the nature of the problems and possible solutions.

Above all, natural resource managers will need to gather multi-disciplinary teams to help find solutions, obtain the required logistic and financial resources to tackle the problems, and be prepared for a long slow process. Catchment management is rarely a quick process and many years are often required for success. Good transparent communication is essential, preferably based on sound scientific advice and assessment, to build trusting partnerships with all stakeholders, including those in the catchment areas and downstream at the coast.

This book was suggested by the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA-Marine) of the United Nations Environment Programme. This programme has the specific goal of reducing damage to the oceans from the land. They have helped put these stories together along with National Atmospheric and Oceanographic Administration, and the National Fish and Wildlife Foundation of the USA. Other major topic providers have been the Australian Centre for Tropical Freshwater Research of James Cook University, the International Waters Programme of the Global Environment Facility, CRISP (Coral Reef Initiatives for the Pacific), ICRAN (International Coral Reef Action Network), World Resources Institute, Reef and Rainforest Research Centre, IUCN (International Union for the Conservation of Nature), Great Barrier Reef Marine Park Authority, Caribbean Student Environmental Alliance, Wildlife Conservation Society, WWF (World Wildlife Fund) and the Townsville City Council.

CHAPTER I:

PURPOSE OF THIS BOOK

What is the Connection between Catchments and Coral Reefs?

Many coral reefs around the world have developed along shorelines which are influenced by rivers and streams flowing out of the nearby catchment areas. The reefs may be growing as fringing reefs along the coast and around nearby islands, or as patch or platform reefs within a bay, or sometimes as barrier reefs across the bay or on the edge of the continental shelf. These reef types are shown in the diagram below.

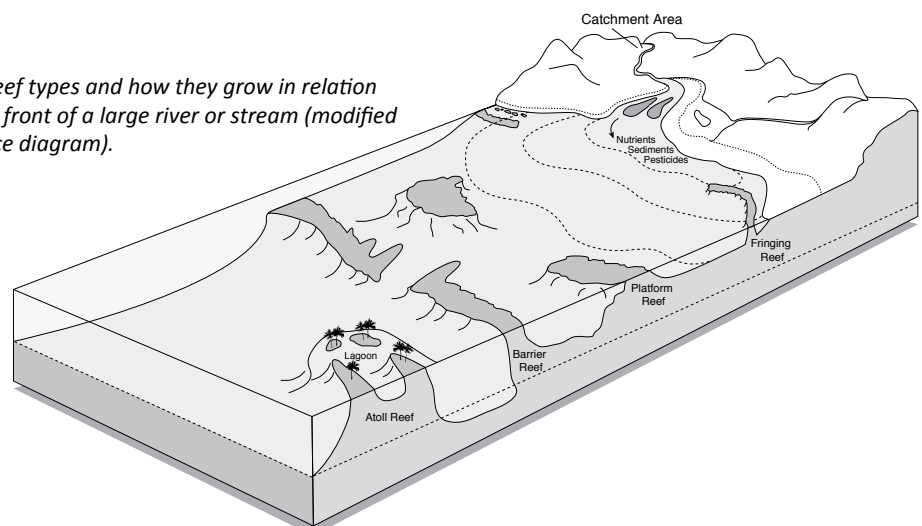
The corals on these reefs have adapted to grow in the presence of some materials coming down the rivers and streams from the catchments. This includes a small to occasional larger flow of sediments; low levels of nutrients; some minerals and heavy metals; organic matter from rotting plants and animal faeces; and occasionally large volumes of fresh water, trees and branches during floods. But they have not grown in the presence of man-made chemicals such as pesticides, pharmaceuticals and detergents. Because these reefs have grown there, they must have some ability or tolerance to withstand damage from these flows or recover afterwards. HOWEVER many reefs are now being damaged by increased flows of these materials from poorly managed and degraded catchment areas. This damage may be from deforestation, mining, poorly managed agriculture, large animal farms such as piggeries, cattle feedlots and chicken farms, development for cities and towns, poorly treated human or industrial wastes and toxic man-made chemicals.

The Global Coral Reef Monitoring Network in 2008 reported that the world has lost 19% of the original coral cover, mainly due to damaging activities from catchment areas, combined with over-fishing and global climate change. The GCRMN also reported that 15% of the world's reefs are under short term threat of major losses in 10 to 20 years; with only 45% of the world's reefs being relatively healthy, except for the imminent threats posed by global climate change.

In 2011, the World Resources Institute and many partners factored in climate change into their predictions to state that more than 60% of the world's reefs are under immediate threat of direct human pressures, many of which come from adjacent catchment areas. This rises to 75% if climate change is factored into the modeled predictions; this rises to 95% by 2050 (just 4 decades from now).

A major problem for a manager in charge of conserving the coral reefs downstream of many catchment areas is that the stresses may come from a long way away and outside the influence or control of the manager. This book aims to provide some advice and examples on how a manager may be able to reduce damage to downstream coral reefs by implementing better management practices in nearby catchment areas. We have collected 33 case studies from around the world to show how other managers have tried to improve land use practices in catchment areas. Some have been very successful in reducing damage from catchment areas, and some case studies have not been so successful. We also provide references and the contacts of those managers who may be able to help you.

This diagram illustrates the major coral reef types and how they grow in relation to a catchment area. Reefs rarely grow in front of a large river or stream (modified from Australian Institute of Marine Science diagram).



What is a Catchment Area?

Definition: The catchment area upstream of a coral reef includes all the land area that drains rainfall into rivers or streams (and some may flow underground) that flow out to the coast and may affect mangrove forests, seagrass beds and coral reefs. Watershed is another term that is used to describe this area, although it is also used to describe the boundary line between two adjacent catchment areas. The diagram in Chapter 2 shows a 'typical' catchment area with a range of activities that may damage ecosystems on the coast. It is often said that management of a coral reef begins at the top of the nearby mountain or hill. The term catchment is also used for the area of land that drains water into dams; or includes sedimentation basins.

Types of catchments

How Large: They can be small, medium, large and very large. The extremes are the enormous Amazon Basin that is 8,235,430 km² in area, to small catchments on steep sided volcanic islands that may be only 1 km².

How Wet: Catchments may drain very wet or very dry areas. The extremes are catchments like those surrounding the Red Sea and Persian Gulf that are deserts most of the time, but occasionally can deliver large volumes of muddy water, to catchments draining tropical rainforests that occur throughout the tropics. Many catchments are very affected by seasons, especially in the tropics where there are often very wet seasons or monsoons, and also dry periods where there is little rainfall. Therefore, the effects on the coral reefs downstream may be highly variable, from very damaging in the wet season to minimal in the dry season.

How Steep: Catchments can range from very steep where the rivers run rapidly to almost flat areas with slow flowing rivers. Steep catchments often deliver large pulses of sediments from eroding hillsides, especially if there is deforestation or hillside agriculture. This is particularly the case with many small, high, volcanic islands that have unstable slopes.

Soil Types: Catchments can also drain from new fertile lands such as on recent volcanic islands where the soils are not yet stabilised, to infertile old lands which usually release lower amounts of sediments and low concentrations of nutrients.

How Developed: They can range from heavily populated and degraded areas where there has been deforestation, poor farming practices, large cities and towns, or major mining or industrial activities. One example is Jakarta Bay in Indonesia which is now virtually lifeless because of massive pollution over many years; reefs in Jakarta Bay have disappeared. Or catchments can be mostly pristine with few people, such as those in remote islands or national parks; these are not the focus of this book because there is no need for intervention to prevent damage downstream.

Activities in Catchment Areas

People, Towns and Cities: By 2015, about 50% of the world's population will live within the coastal catchment areas and the proportion in the tropics will probably be higher. The major activities in catchments are listed below. Activities by people in the catchment areas are critical for their livelihoods and the economy of nations; the role of the manager is to reduce damage from these activities, without significantly reducing livelihoods and the national and local economies. Often the best argument will be showing that coral reefs and other coastal resources have high economic value if retained in a healthy state, and will result in large economic losses if damaged.

Agriculture and Farming: Coastal catchment areas are the major areas for growing crops and raising animals in most countries (except for large continents). These activities will result in increases of polluting sediments, nutrients and organic chemicals that flow into rivers and streams and pollute coral reefs offshore. The use of 'best practice' management of agriculture and farming will reduce the amount of these pollutants that are released. There are a number of Case Studies in this book that list examples of best practice. In addition, many of the wetlands which previously filtered out contaminants from the land have been removed during agricultural development.

Forestry: In many tropical countries, extensive forest industries, including clear felling operations, result in the release of large amounts of sediments and nutrients into rivers and onto coral reefs. Reducing the damage from unsustainable forestry is a major step that a coastal manager can achieve to reduce damage to reefs downstream. If possible, any forestry and land clearing should be limited to the dry season to limit sediment release, and involve selective logging, with smaller trees, shrubs and grasses retained.

Mining: Mining operations will almost always result in some pollution from overburden soil and rock waste discharge (e.g. Ok Tedi and Fly River in PNG; New Caledonia nickel mining; Jamaica and bauxite mining), ore processing waste discharge and chemical wastes from the processing (e.g. cyanide, mercury compounds); the task of the manager is to reduce this to a minimum to assist in coral reef conservation. We have found no Case Study examples of effective management of mining wastes.

Industry: Mineral processing industries such as alumina and nickel refineries have large wastewater/depleted ore streams which may be accidentally released into rivers and the ocean from tailings dams or deliberately released as part of a waste disposal plan (e.g. Lihir in PNG).

Urban development: Urban housing development in tropical regions often involves vegetation removal down to bare soil in an environment of intense rainfall and erosion and often steep slopes. Erosion can be massive and if very close to the coast (as is often the case) the sediment will be exported efficiently to coastal reefs (e.g. Hawai'i, north Queensland, Taiwan, steep Caribbean islands, Fiji). Road construction can be a major source of sediment pollution.

Damming rivers: This may cause a reduction in nutrient flow to the coast and inhibit productivity of coastal ecosystems (e.g. damming of the Nile River has caused major decreases in nearby Mediterranean fisheries) including coral reefs. One solution is to ensure environmental flows for the downstream environment in water planning schemes.

What Catchments Deliver to the Coast

Catchments deliver the following things to the coast:

- Sediments from deforestation, farming, mining and development (in this book, this refers to extra sediments over the normal level);
- Nutrients in sediments, from farming (fertiliser losses) and industrial and domestic wastes;
- Pesticides principally from farming and Persistent Organic Pollutants;
- Heavy metals from mining operations and industrial wastes;
- Solid wastes especially plastics and other litter; and
- Large volumes of fresh water.

Global climate change must be factored in as many of the above threats will be exacerbated in coming decades. These are all discussed in more detail in the following chapters on the stresses.

Integrated River Basin Management defined

Integrated river basin management (IRBM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximize the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems.

(Adapted from Integrated Water Resources Management, Global Water Partnership Technical Advisory Committee Background Papers, No. 4, 2000)

IRBM rests on the principle that naturally functioning river basin ecosystems, including the accompanying wetland and groundwater systems, are the source of freshwater. Therefore, management of river basins must include maintaining ecosystem functioning as a paramount goal. This 'ecosystem approach' or 'ecosystem based management' are central tenets of the Convention on Biological Diversity. River basins are dynamic over space and time, and any single management intervention has implications for the system as a whole.

The seven key elements to a successful IRBM initiative are:

- A long-term **vision** for the river basin, agreed to by all the major stakeholders;
- **Integration** of policies, decisions and costs across sectoral interests such as industry, agriculture, urban development, navigation, fisheries management and conservation, including through poverty reduction strategies;
- Strategic **decision-making at the river basin scale**, which guides actions at sub-basin or local levels;
- Effective **timing**, taking advantage of opportunities as they arise while working within a strategic framework;
- Active **participation** by all relevant stakeholders in well-informed and transparent planning and decision-making;
- Adequate investment by governments, the private sector, and civil society organizations in **capacity** for river basin planning and participation processes; and
- A solid foundation of **knowledge** of the river basin and the natural and socio-economic forces **that influence** it.

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CHAPTER 2:

STRESS TO REEFS FROM CATCHMENTS: WHAT CATCHMENTS DELIVER TO COASTAL AREAS AND IMPACTS

Catchments channel much of the water that falls over the drainage area (or watershed) and delivers the water through streams and rivers into the ocean. An undisturbed catchment will deliver water that carries:

- sediments as mud, sand and rocks;
- nutrients like nitrogen and phosphorus compounds;
- minerals and metal compounds;
- organic compounds from degrading plants and animals; and
- large volumes of fresh water and trees and branches during floods.

Coastal systems have evolved with these natural flows such that there are often mangrove forests adjacent to estuaries, large sand and mud flats with seagrass beds, shallow lagoons and fringing and barrier coral reefs. Coral reefs rarely grow immediately adjacent to a river mouth, but can be found close to smaller streams.

Over-developed or modified catchments, however will deliver more of these natural elements as well as other pollution:

- Increased sediments from logging, deforestation, cropping, grazing and urban development via enhanced erosion on less vegetated landscapes;
- Heavy loads of nutrients:
 - o in sediments from increased erosion in agricultural and urban landscapes;
 - o dissolved nutrients from fertiliser loss in cropping areas; and
 - o from industrial, domestic and intensive livestock wastes;
- Heavy metals from mining operations and industrial wastes;
- Pesticides principally from farming;
- Solid wastes especially plastics (litter); and
- Large volumes of fresh water increased above natural volumes due to increased runoff from catchment 'hardening'. This occurs particularly when large surfaces are covered with roads, car parks and buildings in urban areas. In agricultural areas in catchments 'hardening' is a function of lack of vegetation cover, soil compaction due to grazing animals and improved drainage.

In other cases, damming of river systems reduces freshwater flows and nutrient delivery to coastal waters, thereby reducing essential marine productivity.

Heavily modified catchments will often deliver far greater volumes of fresh, muddy waters as floods into the ocean in short bursts often through stormwater drains. This is particularly the case of rivers flowing through towns where the rain water runs off hardened surfaces such as roads, roofing and concrete surfaces in urban areas and vegetation cleared areas in agricultural lands, rather than soak into the soil. Much of this will change with increasing global climate change. Some areas will receive more rainfall and hence deliver more of these damaging materials. One of the clear predictions of climate change is that there will be wider fluctuations in weather with a likely consequence that more rain will arrive as storms causing flash flooding.

Sediments: Deforested catchments, catchments under intensive logging, those with poorly planned cropping and those with low pasture cover due to overgrazing can deliver 5 to 50 times more sediment than natural forested catchments. For example, the Burdekin catchment in North Queensland, Australia which has been developed almost completely (80% of area) for beef grazing over the last 150 years delivers on average 8 times as much suspended sediment load than it did in 1850 before development began. Similarly the catchments discharging to the Mesoamerican Barrier Reef system in eastern Central America now deliver 20 times the sediment load as previously due to human modification of the catchment landscape while sediment discharge from rivers in Taiwan in many cases have risen by 10 times just in the last 40 years. In Coral Bay, Virgin Islands sediment delivery from rivers to the Bay has increased by 10 to 20 times in the last 60 years due to development on steep slopes in a very high rainfall situation.

Sediments cause major problems for coral reefs because sediment in the water reduces the light energy available for corals and other photosynthetic organisms, and also when small amounts of sediment settle on corals they are required to spend considerable energy clearing off the sediment with either specialized ciliary (hair like) cells or via the production of mucus. Large amounts of sediment will smother corals or build up around the base of corals which will favour the growth of competing organisms and those that can burrow into the skeletons, like worms. Fine sediments do eventually settle out to the bottom, but they are readily disturbed by even the smallest waves to be re-suspended in the water column, recreating the turbid water problem all over again. It may take many years for fine sediments to be moved, consolidated and/or trapped in deep water or in mangrove forests so as to minimise resuspension and subsequent increased turbidity.

Management of erosion to reduce sediment delivery to reefs can occur through many mechanisms including reafforestation of denuded steep slopes, as shown in Case Study 21 from Vanuatu. Similarly in Thailand (Case Study 25) a mixture of grass and tree revegetation plus sediment control structures were used to reduce sediment delivery. Alternatively existing forested areas can be protected from clearing as shown in Palau (Case Study 21) where mangrove clearing has been controlled.

Nutrients: the major nutrients of concern are compounds of nitrogen and phosphorus e.g. nitrates, ammonia, phosphates, which are present in normal soils but particularly concentrated in human sewage and animal farming wastes as well as from fertiliser used in agriculture. These compounds are either free in solution in freshwater or attached to soil particles or combined with organic compounds that are washed out with freshwater. Microbes can rapidly attack these organic compounds and thereby release the nitrogen and phosphorus compounds. In addition, there are many other compounds and elements that come under the general heading of nutrients such as low concentrations of iron, manganese, magnesium, sulphur etc. all of which may stimulate the growth of undesirable algae.

These nutrients favour the growth of planktonic algae (phytoplankton) that block out sunlight (Case Study 23 from Hawai'i) and some may be toxic (possibly causing toxic algal blooms or paralytic shellfish poisoning), as well as supporting the growth of macro-algae that can out compete corals and overgrow them. Phytoplankton from excess nutrients also support many of the organisms (often filter feeders) that either compete for space with corals such as sponges, tunicates or burrow into their skeletons such as burrowing clionid sponges, mollusks and worms. Also excess nutrients can stimulate the growth of coral disease organisms and increase the frequency of crown-of-thorns starfish (a coral predator) population outbreaks.

There are examples of nutrient pollution in the Case Studies from, American Samoa (Case Study 9, specifically phosphorus), Case Study 23 on Kaneohe Bay; Case Study 12 on runoff from Belize and Honduras, and Case Studies 29 to 32 on the Great Barrier Reef (GBR). In addition there are Case Studies specifically focussed on human sewage effluent management from Dominica (Case Study 3) and from Mexico (Case Study 2) and piggy waste from St Lucia (Case Study 4).

Heavy metals: these are released from mining operations or industries in the catchment area and carried out to the coral reefs in streams. The pollutants include mercury, cadmium, lead which enter the food chain. Probably the best example of mercury pollution was in Minimata in Japan, where large quantities of mercury were released into the bay from industries and entered the food chain to be taken up by fish, which in turn were eaten by the local population causing serious disease, including paralysis.

Pesticides and POPs: the use of pesticides has increased rapidly in the past 30 years in tropical areas and these are now being washed into coral reef waters. Pesticides, that include insecticides, fungicides and herbicides are known as Persistent Organic Pollutants (POPs) and often take many years to breakdown; therefore they either remain in the sediments or accumulate in animals and plants and may increase in concentration as they pass up the food chain. We know that these compounds cause major damage to ecosystems on the land, but we have limited information on what they do on coral reefs. But the evidence is coming in and the damage will become worse in the future as these complex organic compounds accumulate in the food chain, and take many years to degrade.

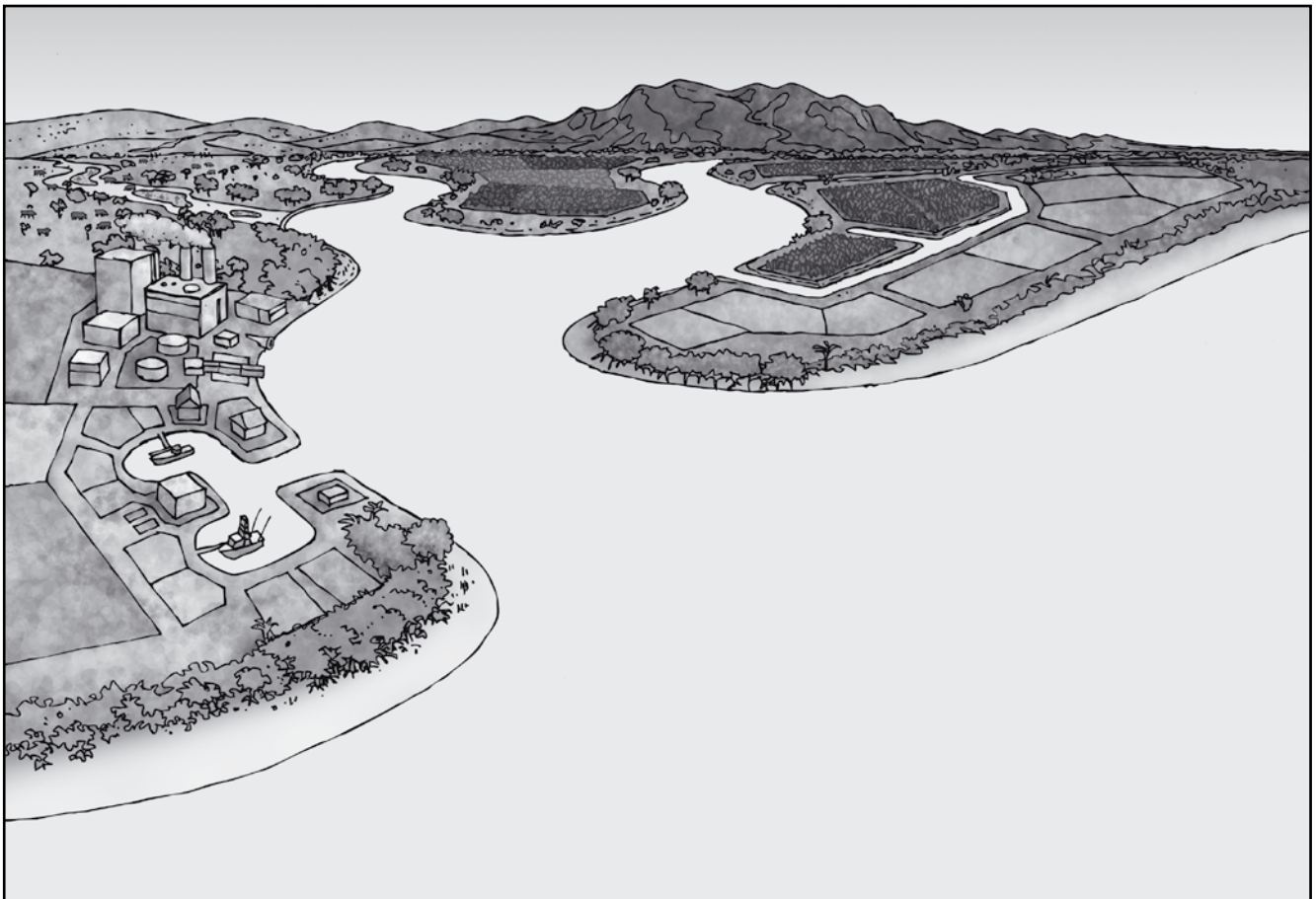
An example of pesticides potentially damaging coral reef systems comes from the Great Barrier Reef where herbicide residues (particularly atrazine and diuron) have been found in nearby coastal waters (and in rivers draining into the GBR) at concentrations known to reduce photosynthesis in marine plants (seagrass, coral zooxanthellae, macroalgae, microphytobenthos, phytoplankton). Reduced photosynthesis for a prolonged period has long-term effects on plant and coral health and through repeated exposure, herbicides may alter the species composition of marine ecosystems such as coral reefs and seagrass meadows.

Other organic pollutants include compounds present in antifouling paint, industrial chemicals such as benzene, detergents and hormones contained in birth control pills that are contained in human sewage. There are examples of pesticide pollution in the Case Studies 29 and 32 on the GBR and on the Mesoamerican Barrier Reef (Case Study 13).

Solid or particulate wastes: these are the obvious materials that catchments deliver to coasts and reefs. Much of this material does not degrade and will remain in the ecosystem for years, especially plastic bags and bottles. As well, there are metal cans and glass bottles, discarded cloth, paper and cardboard. The major problem with these wastes is that they can cause major damage on coral reefs by smothering corals and other organisms because plastic bags and waste cloth can take many years to degrade. Plastic is also one of the major causes of death of marine turtles when they swallow large quantities of plastic material mistaken as their jellyfish food. Also seabirds, fish and dolphins can swallow plastic and thus can become unhealthy or die. These solid wastes are particularly seen on coral reefs near cities and towns in developing countries where these wastes can seriously damage the reefs and make them particularly unattractive for tourists, especially when they wash up on the beaches.

Fresh water: the amount of water delivered by well managed and damaged catchments may be similar, however the big difference is the rate of delivery. Cleared and over-developed, hardened catchments have lost their capacity to soak up heavy rainfall and slow the delivery of the water into streams, such that flooding of freshwater has increased in front of damaged catchments. Large inputs of fresh water will kill corals and seagrasses, and also these large volumes of water carry high concentrations of nutrients in the first hours after heavy rains.

Recommendations for Action to reduce, and where possible eliminate, these problems are presented in Chapter 5. These are a series of management initiatives to reverse damage from unsustainable activities in the catchment area, based on the advice of natural resource managers who provided the 33 Case Studies in Chapter 6.



This diagram illustrates a typical catchment area with many of the activities that contribute pollution through the river to offshore ecosystems. Effective catchment management can reduce the pollution of sediments, nutrients, pesticides and heavy metals coming from inland grazing, sugarcane and other agriculture on the flat lands, urban areas, and industries and ports near the coast.

Potentially useful graphic examples of catchment management are in Kelley R, Barnett B, Bainbridge Z, Brodie J, Pearson R (2006). *Nutrients, catchments and reefs - a guide to nutrients in the tropical landscape*. A publication from the Catchment to Reef Program, a joint initiative of Rainforest CRC and CRC Reef Research Centre. ISBN 0 86443784 6. www.rrrc.org.au/catchment-to-reef/index.html (developed by R. Kelley, Communication design, modified illustration of Gavin Ryan).

CHAPTER 3:

CLIMATE CHANGE AND CATCHMENT MANAGEMENT

In addition to the stress problems listed in Chapter 2, another particularly serious problem faces coral reef and coastal resource managers. Global climate change is dominating the news in many developing countries and the local managers will be asked to manage these additional stresses. For example, it is clear that the effects of water quality degradation will interact strongly with the effects of climate change; so both issues must be considered when examining how to manage marine ecosystems.

There is now wide agreement by most scientists and managers that climate change is already occurring and having serious consequences for some tropical countries. The predictions from the experts on climate change are that the problems will increase and make management of coral reefs even more difficult. The threats include the following which are predicted to cause major problems for coastal resources in the next few decades:

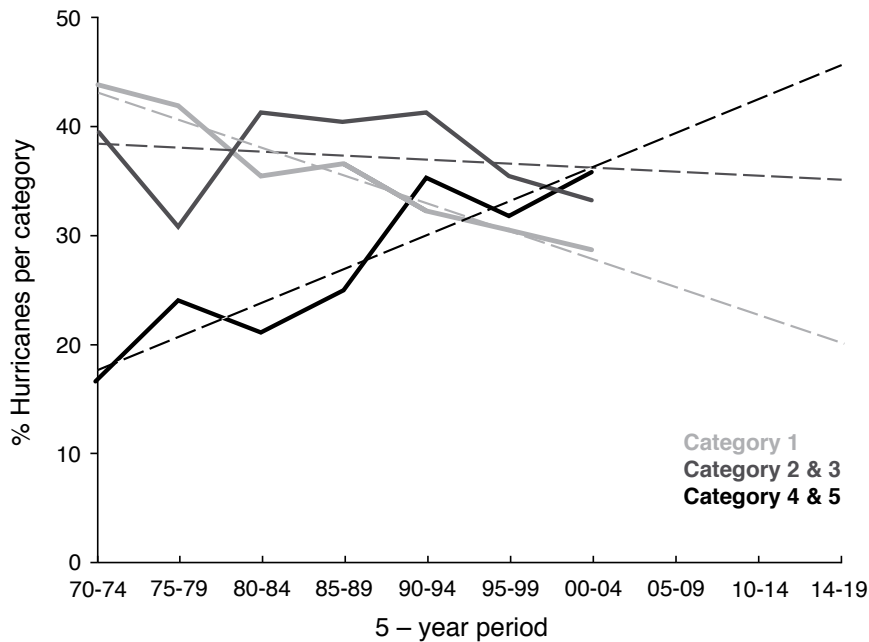
1. more unpredictable weather in catchment areas;
2. there will be increases in strong storms;
3. sea levels will continue to rise;
4. temperatures will rise on land and in the waters; and
5. ocean acidification is occurring .

These problems are in addition to the existing local stresses, but resolving climate threats are largely outside the direct management activities of coastal managers. The best current advice is that healthy coral reefs and coastal ecosystems will be more resistant to the effects of climate change and then bounce back more rapidly after climate stress events. That is show more resistance and resilience.

The predicted changes that will affect catchment areas and coral reefs are listed with our estimate of the [*certainty*] of the effects on coral reefs occurring:

1. more unpredictable weather. Increasing global temperatures will increase the energy in the atmosphere, which will result in larger daily and seasonal fluctuations in weather. This will increase as the climate gradually warms. These changes in weather may result in damage to coral reefs, especially through variations in rainfall. The experts predict that there will be more local, severe weather events; rainfall will come as more frequent bursts of heavy rain, possibly followed by longer periods of little or no rain. Sediment flows will increase as soil erosion rates are linked to rainfall intensity and when heavier rains fall on lands made very dusty after longer dry periods. This will increase sediment damage to coral reefs and reduce coral growth [**low certainty**] (Case Study 32).

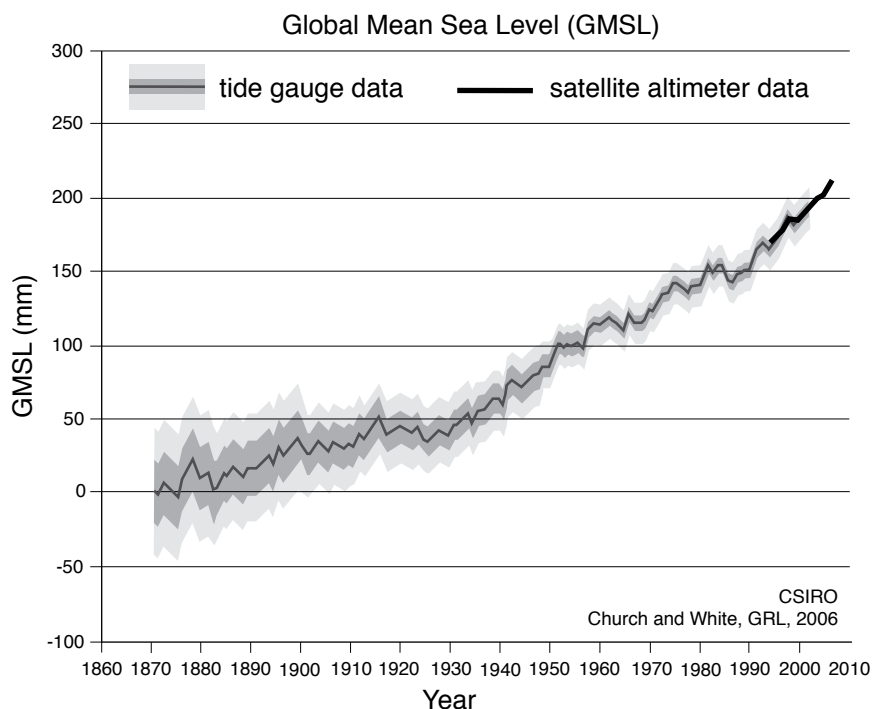
2. increases in strong storms. There is now increasing evidence that tropical storms are becoming stronger and causing much more damage. Rises in global temperatures increase the energy in the oceans and atmosphere that generate tropical storms. The total number of tropical storms does not appear to be changing; but there are more and more category 4 and 5 severe tropical cyclones (i.e. typhoons and hurricanes). These will damage coastal areas and directly damage coral reefs. A good example was the damage done by Hurricane Mitch in Central America (Case Study 12) [**moderate certainty**].



This graph shows an increase in strong hurricanes since 1970 in the Atlantic Ocean; however the number of hurricanes has not changed significantly. The graph also predicts stronger hurricanes to the year 2019 (Adapted from Webster, 2005; dashed lines show significant linear trends).

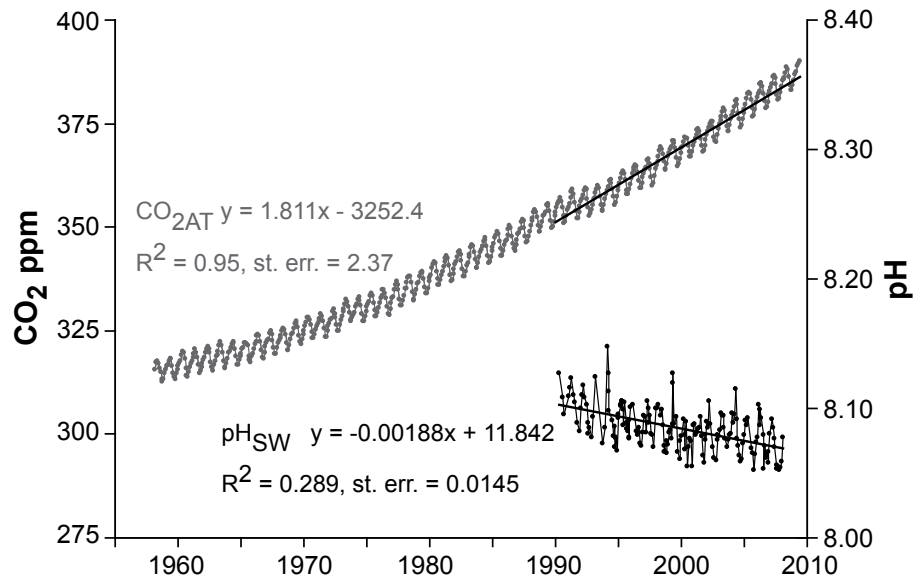
3. sea level rise. This will particularly affect coastal lands, estuaries and low lying islands. Salt water will penetrate further into estuaries and also enter coastal water tables thereby damaging coastal agriculture. Large volumes of salty seawater will wash over coral reef islands during storm surges, which will be exacerbated by rising sea levels. In addition, sea level rise will result in more coastal erosion, particularly as storms become more intense. The effects will be particularly devastating for the many tropical coral islands that are only 1 to 3 metres above sea level or flat lands beside the sea. These low lying countries must either build up the land by dredging sand, often from nearby reefs (causing much local damage) or abandon these lands. While recent research suggests coral islands may not lose **area** due to sea level rise they may still end up under water at high tides and during storms; thus become uninhabitable [**high certainty**].

Loss of coral growth due to water quality issues (and ocean acidification) may exacerbate this problem by reducing the quantity of coral available to produce rubble and sand to sustain coral islands.

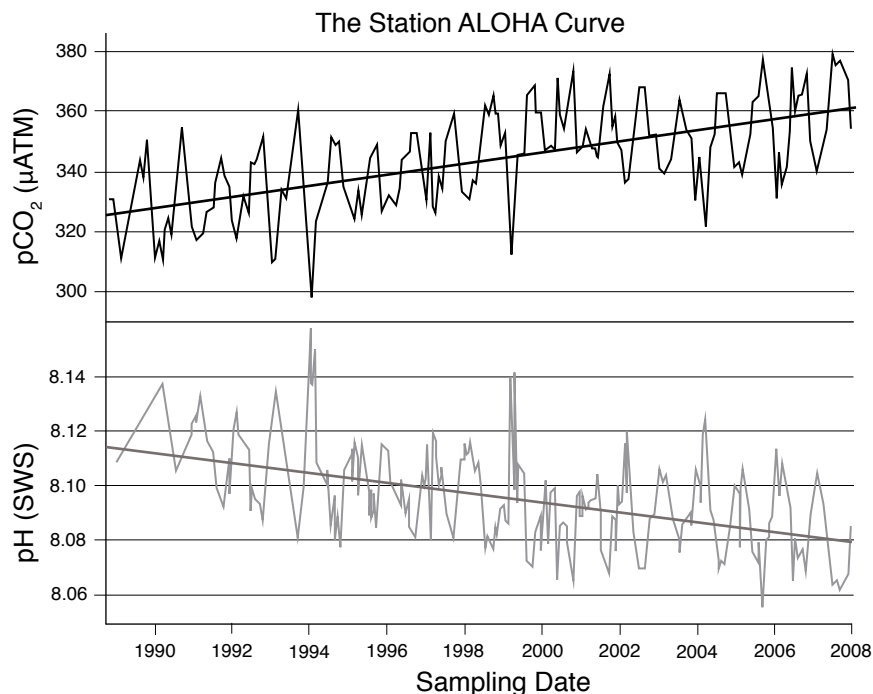


Sea level has risen by 20 cm during the last 140 years and is set to increase more rapidly in the future (Church and White 2006).

4. temperature rise in air and in water. This will mean that evaporation will increase and some streams and ponds may dry out. This means that soils will be more susceptible to heavy rain. The most dramatic changes will be bleaching damage to coral reefs. The first major global bleaching event occurred in 1998 when coral reefs around the world were devastated. In 2005, there was unprecedented bleaching mortality in much of the Caribbean. Bleaching is likely to occur when sea surface temperatures rise to just 1–2°C above the normal summer maximum for a few weeks under clear tropical skies. If these stresses continue or get worse, many corals will die. During the 1998 and 2005 events, there was 80% to 90% coral death on many reefs. The reefs that recovered best after this damage were those that were well managed or not stressed by human pressures of sediment and nutrient pollution, over-fishing, mining of sand and rock and coastal development [high certainty].



This graph and the one below show the relation between increases in carbon dioxide and decreases in pH (lower numbers are more acidic). The top graph shows the relation between CO_2 in the atmosphere (as parts per million) and pH in the world ocean; whereas the bottom graph shows one site in Hawai'i where the amount of dissolved CO_2 in seawater is directly related to a drop in pH.



5. increasing ocean acidification. This is unlikely to affect catchment areas but will result in corals becoming more sensitive to damage from other stresses like pollution and bleaching. As more CO_2 dissolves in seawater it makes the water more acidic. This will reduce the corals ability to make limestone skeletons and therefore become more fragile. This acidification also affects other organisms with limestone skeletons such as gastropods (snails), bivalves (clams and the like) and coralline algae [medium certainty].

Cacification has already declined in corals on the Great Barrier Reef due to ocean acidification therefore the task of the manager is to ensure that the corals are as healthy as possible to resist ocean acidification.

Conclusions

With all these climate change threats, the major tasks for a coral reef manager are to ensure that other stresses on coral reefs are reduced as far as possible and that the public are well informed about climate change. Climate change is a global stress and largely outside the immediate control of the manager; specifically the public should be given predictions on what may occur on local coral reefs in the near future and advice on what can be done. This can be achieved by regularly educating people about the threats posed by climate change and the need to act on the global 'stage' to seek a reduction in greenhouse gases as well as addressing other issues such as effects of land-based pollutant runoff and destructive fishing which act, with climate change effects, to degrade the reef and for which local mitigating action is possible

CHAPTER 4:

WHAT IS CATCHMENT MANAGEMENT AND WHAT CAN IT ACHIEVE?

A catchment can be described as an area of land surrounded by higher ground like hills and mountains, where water drains to the lowest point (e.g. creek, river, lake or ocean). A large catchment area is often made up of a number of smaller catchments called sub-catchments. A catchment can be as small as one or two houses or a small village or it could cover an area greater than 250,000 km² like the Amazon basin. Because water flows down-hill, any activities involving the use of, or management of natural resources in the upper catchment can affect the lower part of the catchment and the marine environment. Consequently, there is a need to adopt a whole catchment approach to ensure that damaging activities such as pollution do not impact on others within the catchment or in coastal waters.

In this book the term 'catchment' is used in the same sense as the North American term 'watershed'. Catchment is more commonly used in most of the world. 'Watershed' can be ambiguous because it can mean either a water basin draining to a hydrologically defined area, or as the dividing line between two basins.

Recently land and water management has been increasingly based on catchments and the 'catchment or watershed approach', and particularly the interaction of the two. This approach has received wide acceptance to implement actions to reduce water degradation, and improve or restore the land. This approach has also been used to bring about environmental improvements, particularly at the broad scales where changes are required in areas involving many landholders, multiple land and water uses, and often, multiple government authorities. Research can be organised and integrated to support implementation of watershed based projects aimed at environmental improvement. The catchment represents a logical natural unit for the management or study of water resources and the land, because water is intricately linked to land use and management. The river which the drains the catchment (watershed) is a natural integrator that responds to activities within the catchment and the receiving waters where the river discharges (ocean, lake, wetland). This approach explicitly requires the development of partnerships between people affected by land and water management decisions; therefore the aim of integrating the decisions is to ensure that the economic, social and cultural goals of those affected are met as much as possible. The partnerships also bring together those who cause problems with those who are damaged by them. It is expected that joint problem identification and decision making will bring about long-term improvements to land and water management.

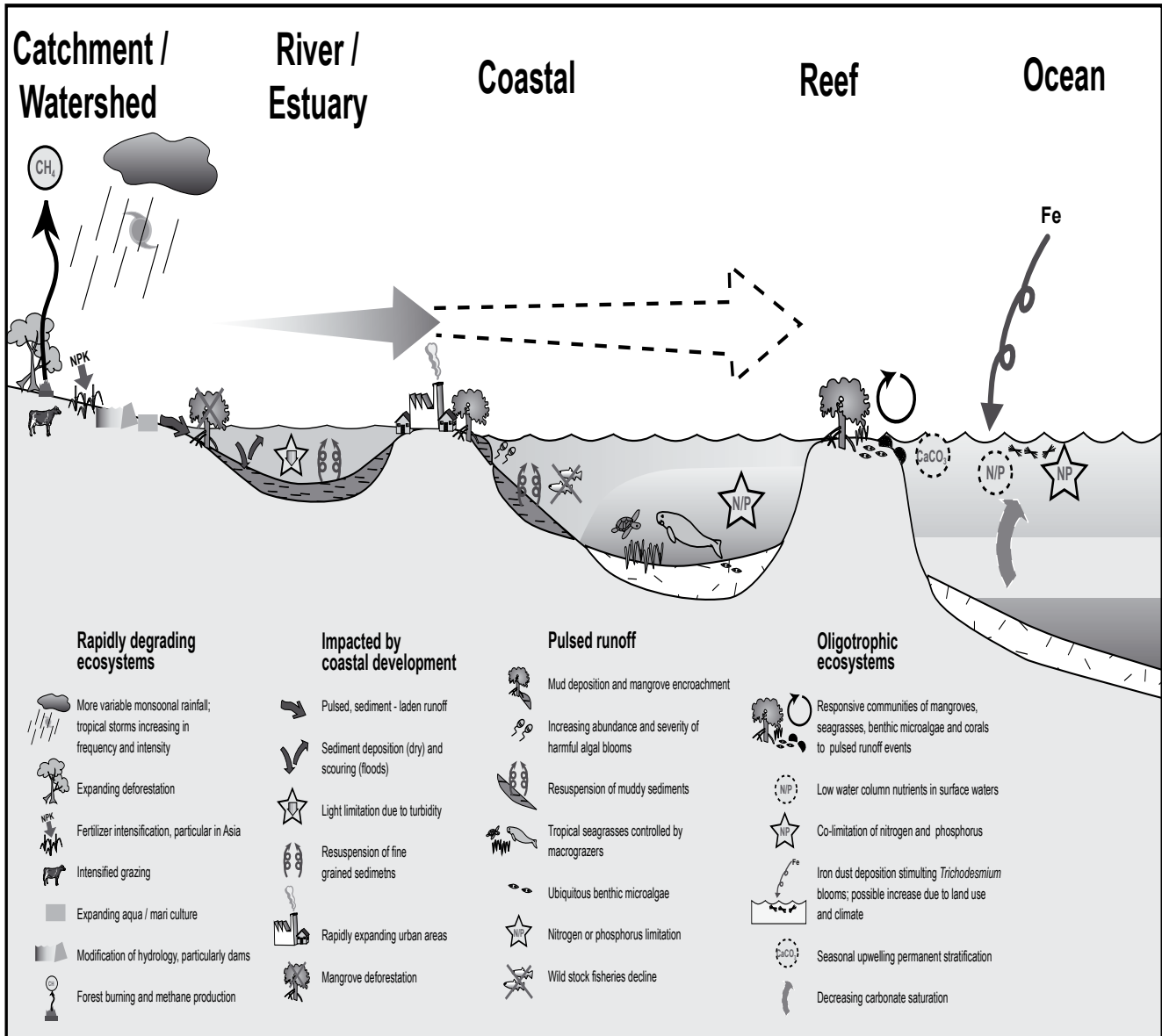
Rivers have a dominant influence on their estuaries and surrounding coastal areas. During the last 10 years, it became increasingly more obvious that coastal zones near rivers cannot be managed independently from the rivers and their catchments. Since the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, the Integrated Coastal Zone Management (ICZM; also called Integrated Coastal Management ICM) concept has been used by many nations and states as the basis for effectively and sustainably managing coastal areas. Most environmental management concentrates on improving integration in catchments (through Integrated Catchment Management, another ICM) and in coastal areas (through ICZM) but there is often little coordination between these two programs. Integration of catchment and coastal management is necessary to avoid duplication between management objectives, and to set out clear responsibilities for the authorities involved. Integrated catchment and coastal management can avoid duplication between management objectives and ensure the most appropriate planning tool is adopted to achieve better environmental outcomes and more effective management of natural resources. ICZM is a management process that acknowledges interrelationships between catchment, coastal, and marine environments, therefore the area extent of ICZM programs typically include the upland catchments, as well as estuarine and coastal waters and as far as the ocean that is affected by the coastal area. The process is designed to overcome the fragmentation that occurs with single-sector management approaches, and where splits occur in jurisdiction among different levels of government that manage land and water resources.

The United Nations Environment Programme (UNEP) integrated coastal area and river basin management (ICARM) approach also incorporates the idea of combining catchment and coastal management. The objectives are to raise awareness, and to promote and ensure sustainable integrated coastal water and river management. ICARM regions are based on catchments rather than on local government boundaries. This is because catchments form natural boundaries and are a logical management unit for ICARM activities.

Better catchment management under formal catchment management planning (both voluntary or regulatory), improved regulations and community action can lead to major reductions in the delivery of pollutants to coastal waters. Some of most important management priorities can be addressed through an integrated ICZM process so that pollutant discharge to coastal waters is minimised, for example:

- Identifying the priority pollutants in the catchment, particularly those that pollute coastal ecosystems and coral reefs;
- Identifying effective land management practices which will work to reduce pollution;
- Managing forests, farms and urban development for sediment, nutrient and pesticide reduction. Erosion controls, fertiliser management, animal waste management and pesticide use management will be important parts;
- Developing codes of practice for logging may reduce erosion through controls over clear felling and logging on steep areas, minimizing access road development for log haulage tracks, and minimising erosion from log storage and handling areas. However the codes of practice must be enforced;
- Retaining crop residues to protect the soil, such as sugarcane (the leaves of the sugarcane known as trash), oil palms (empty bunches and dead fronds) and bananas (fronds, trunks). Retaining these residues can reduce erosion markedly, especially at the planting stage after tillage. Minimum or reduced tillage in cropping systems also reduces erosion significantly. Prevention of clearing land and cropping on extremely steep slopes is particularly important in erosion control, although often difficult to implement due to land ownership arrangements;
- Managing fertiliser use is an important issue. Most cropping systems use fertiliser 'in excess' of plant requirements as nutrient uptake is an inefficient process (often only 40% of applied fertiliser nitrogen or phosphorus ends up in the plant). Some farmers believe that if some fertiliser is good, then more will be better. The excess application of fertiliser leads to large losses of N and P into waterways. Improved management through providing advice to farmers and tight controls on 'excess' fertiliser use can lead to dramatic reductions in nutrients in waterways;
- Trapping sediments and nutrients from the farm in riparian areas, vegetated drains and wetlands (natural and constructed) will reduce sediment and nutrient discharge to coastal waters. One cautionary comment; these trapping systems are less effective in high rainfall runoff regions where water volumes are large and residence times of water in the vegetated 'buffers' is short. Usually too short to effectively allow denitrification, N and P uptake by plants, sedimentation, herbicide breakdown or long-term adsorption into soils/sediments;
- Maintaining pasture cover on grazing lands, especially in 'dry tropic' environments, is critically important in preventing erosion. Removal of the plant cover by tree clearing and overgrazing of grass leads to massive increases in erosion on hill slopes, formation of gullies and stream bank erosion. Managing grazing induced erosion by retaining pasture cover is possible, but complicated by the irregular rainfall often experienced in the dry tropics where droughts can be followed by massive rainfall during cyclones (hurricanes) and monsoons;
- Controlling residential and tourism development is essential. However these are normally carried out under very poor land management principals. Usually the land is completely cleared of all vegetation (whether grass, trees or even weeds), often clearing occurs in the wet season on steep to very steep hill slopes that are 'cut and filled' for house and hotel sites and roads. Often only minimal efforts are made to trap sediments before they reach streams (a few hay bales are placed around the sites or small detention ponds are dug). Efforts to manage such developments are surprisingly difficult to implement due the power of 'developers' especially near attractive coastal areas. Strong guidelines often exist for 'minimal soil disturbance' urban development, but there are few cases where these have been successfully implemented. Fortunately the potential for erosion declines after urban developments become established and vegetation is re-established or hard surfaces are introduced;
- Treating mining and industrial wastes;
- Managing domestic and industrial water effluents. Urban sewage management will be a priority in many places;
- Controlling the release of fresh water into the rivers and to the coasts. Operational rules for dams and irrigation schemes will be an important component;

- Setting targets for pollutant discharge reductions into coastal waters. In all pollution mitigation projects some idea of a target is important e.g. what level of reduction is necessary and in what timeframe to protect the ecosystem (e.g. coral reef) you are interested in. Targets are best considered in the context of SMART (Specific, Measurable, Achievable, Relevant, Timed) targets;
- Monitoring and assessment at the scale of 'catchment to reef'. Assessing the effectiveness of management on the land by monitoring in the marine environment (i.e. at the reef) is complex, expensive and there are long time lags. It is better to monitor at the scale of the management intervention i.e. at the end of the paddock, at the end of the sewer pipe, in a small stream or at the end of the river where it discharges into the sea;



This diagram shows an example of a tropical catchment-estuarine-coastal-reef-ocean system (Source: Bill Dennison, University of Maryland; Dennison WC (2008). *Environmental problem solving in coastal ecosystems: A paradigm shift to sustainability. Estuarine, coastal and shelf science* 77, 185 - 196)

CHAPTER 5:

RECOMMENDATIONS FOR ACTION

This chapter outlines possible management initiatives to arrest damage to coral reefs and other coastal resources from poor catchment management, with special reference to the Case Studies.

These recommendations are based on the Case Studies, plus suggestions from expert reviewers and our experience on what effective actions you may be able to take to reverse or at least reduce the damage coming from catchment areas to coral reefs and other coastal ecosystems.

The Case Studies cover a wide range of problems and scales of operation. Some are short-term and use basic technology, whereas others have been ongoing for many years and have attempted to manage many problems occurring in catchment areas. We draw your attention to some Case Studies that cover many aspects of catchment management and could be cited for most of the Recommendations below. Please look at these for many recommended actions:

- **Case Study 7** *Guanica Bay Puerto Rico*, p. 52.
- **Case Study 11** *San Andres, Colombia*, p. 60.
- **Case Studies 5, 12 & 13** *from Central America*, p. 44, 62 & 64
- **Case Study 14** *Tamandaré Brazil*, p. 66.
- **Case Studies 17 & 18** *from Gau Island and Vanua Levu, Fiji*, p. 72 & 74
- **Case Studies 29 & 32** *from the Great Barrier Reef Australia*, p. 96 & 102

Recommendation 1: Mapping and jurisdiction

Before any management of upstream catchment areas can start, it is essential to determine:

- the size of, and what is in, the catchment area;
- which are the responsible agencies, existing regulations and ongoing management programs;
- who are the people and communities involved in managing the catchment, especially those who are responsible for controlling damaging activities; and
- whether traditional ownership rights are in existence.

1. (a) Collect good quality maps and aerial photographs. If possible, gather digital images of the catchment area, including the coasts and marine resources. Low altitude aerial photographs and maps that can be digitised are best. The next best are digitised satellite images compatible with GIS (Geographical Information Systems) technology; these are often held by national and state governments. Google Earth is also a good source of satellite images and maps when others are not available. If possible, start the project using GIS technology and add the information obtained in 1.b to 1.e below to these 'maps'. Most governments and larger NGOs have planning departments that use GIS technology; try to work with them as partners.

***Case Study 5 Central America GIS**, p. 44. The World Resources Institute used GIS computer technology and satellite images in Central America to map a large area and determine the major sources of sediment and pesticide pollution draining into the rivers and flowing out to the reefs. That allowed the management focus to be put on the major polluting streams, especially the main point sources and diffuse sources of sediment.*

***Case Study 7 Guanica Bay Puerto Rico**, p. 52. Management of the coral reefs in Puerto Rico was particularly complicated as there had been massive engineering modifications of the catchment area by bringing in water from other catchments and draining wetlands. The project started with thorough mapping of the catchment and a comparison with aerial photos of what wetlands and lagoons were originally in the area.*

***Case Study 14 Tamandaré Brazil**, p. 66. The first coral reef protected area on the coast of Brazil was opposite large farming areas. They initiated a GIS analysis to follow activities and especially to map sediment flows out to nearshore coral reefs; ground truth measures of sediment loads were also collected weekly.*

***Case Study 20 Takuvaine Cook Islands**, p. 78. Government staff in the Cook Islands used Google Earth images to determine the boundaries of the catchment area that was delivering sediment and other pollution downstream and out to the coral reef lagoon.*

Case Study 8 Sakau Pohnpei, p. 54. GIS mapping of the extent of forests on the Micronesian island of Pohnpei showed that there had been a decrease of about 70% of the island forest cover over 35 years. This clearly illustrated the massive extent of the problem.

1. (b) Determine the legal administrative boundaries for the catchment area and review what legal arrangements exist. These boundaries will determine who is responsible for activities in the catchment areas; the boundaries will include state and local government boundaries, military areas, industrial and farming areas, national and other conservation sites, including forestry reserves, and traditional ownership rights. Also, obtain the names and contact details for the people responsible for managing the areas. This will include government departments and ministries, state and local government equivalents, military, local ownership including customary tenure, international agreement arrangements (e.g. Ramsar), protected area boundaries. Mark these out on the GIS or paper maps. Assess whether laws exist, whether they are being enforced and are effective. There are often overlapping responsibilities and laws; it may be very complex!

Case Study 27 Okinawa Japan, p. 92. They found that erosion and soil runoff from agriculture, industrial and urban development were not regulated by existing laws. Therefore new laws were drafted to start activities to reduce sediment loss.

Case Study 28 Shikoku Japan, p. 94. Similarly on Shikoku island, there was no clear line of authority when major landslides damaged the coral reefs. New laws developed soon after clarified the situation and the environment agency was able to start cleaning up the reefs and control activities in the catchment, in partnership with other stakeholders.

Case Study 21 Babeldaob Palau, p. 80. Project success was due to an in-depth understanding of traditional decision making systems and boundaries in Palau, both those of the community and the ecosystem. They asked the traditional leaders to facilitate behaviour changes in local communities.

Case Study 30 Townsville 1 Australia, p. 98. The major task of the Creek to Coral project was to ensure that activities in the catchment area were not damaging the Great Barrier Reef which was stipulated by government legislation and requested by the community. The first step of management was to determine the catchment size and nature, and who was responsible for managing all 'water' aspects.

1. (c) Determine the demographics. These data include the population size and distribution in the area, and also the location of major activities undertaken e.g. farming, forestry, mining, national park activities etc. This will provide essential data to determine what are the likely major sources of pollution and where they come from. If possible, gather data on increases and movements of population, and major projects being planned; this is essential to anticipate future pressures in the catchment. Mark these data on the maps being produced above.

Case Study 11 San Andres, Colombia, p. 60. Before any management could start on this archipelago in the Caribbean, the government and NGO partners gathered massive amounts of data on all activities and populations on the islands. That was the basis for a large-scale, comprehensive management program.

Case Study 26 Batam Indonesia, p. 90. The population in Batam Indonesia was increasing rapidly because the proximity to Singapore was attracting many people seeking better economic opportunities. This alerted the local and national governments that pollution control had to start immediately before the problem got out of hand.

Case Study 14 Tamandaré Brazil, p. 66. A large MPA in Brazil was near large populations and extensive agriculture. They started with an assessment of populations and activities in the catchment using a GIS approach.

1. (d) Identify the major stakeholders. It is essential to know who owns the land (and the sea), who uses land and sea resources, and who has responsibility for resource and environmental management of the land and sea. This should include those who have legal title to the land, and especially those who claim traditional ownership or rights to use the land. There also may be other national and international 'stakeholders' because of the iconic nature of the marine system e.g. World Heritage status, Ramsar sites, national or local marine parks, national and international tourism use.

Case Study 9 traditional law Pohnpei, p. 56. This example from the Pacific clearly illustrates the importance of traditional laws, even though they may be unwritten. Involving the traditional leaders was the most effective way to control forest clearing that was resulting in major sediment flows onto the coral reefs. It also illustrated that by not directly involving the leaders, the community did not trust the elected and bureaucratic government, which had 'strong' written laws.

Case Study 21 Babeldaob Palau, p. 80. A similar situation to Pohnpei exists on Palau with the traditional land owners and chiefs being at the core of decision making.

Case Study 17 Gau Island Fiji, p. 72. There was a strong focus on clear and open communication with all people and communities on the island. While the traditional chiefs were the key to success, special attention was paid to involve women and youth.

Case Study 27 & 28 Japan p. 92 & 94. In Japan, erosion and soil runoff from multiple activities was damaging the coral reefs. Therefore it was essential to identify the activities and major stakeholders, before any catchment management could commence.

Case Study 26 Batam Indonesia, p. 90. The spreading sewage and heavy metal pollution coming from the island could only be solved by determining the major sources and contacting the community leaders and the industry directors.

1. (e) Make contact with the key people. Making personal contact with the key stakeholders and decision makers upstream in the catchment area is a very effective way to start the process. A key lesson from many of the Case Studies is that the contacts should be about working together to solve the problems downstream without blaming the people upstream. Contact with people who claim traditional ownership of the lands and use of those lands is absolutely essential. If you can get traditional leaders and decision makers on board (e.g. the chiefs) you will have 'Champions' for your management projects. Ensure that these people are on the 'team' and possibly leading the team.

Case Study 13 Central America pesticides, p. 64. A long process was needed to reduce the use of damaging pesticides; but the key was forming collaborative partnerships with farmers and big agricultural and agrochemical companies to reduce damage to the Mesoamerican coral reefs.

Case Study 15 American Samoa detergents, p. 68. They targeted community chiefs at the start of the project and this made it easier to work in the communities to find solutions. Having a 'champion' is great, but can be a problem if the chief dies.

Case Studies 8, 9 & 21 from Micronesia, p. 54, 56 & 80. These projects all depended for success on the influence and involvement of the traditional leaders in the communities.

Case Study 22 Houma Tonga, p. 82. Action to resolve a problem of forest degradation was only resolved when a chief from Houma raised the problem and requested assistance to replant the coastal forests; he was also the Prime Minister of Tonga at the time.

1. (f) Request an Environmental Impact Statement (or Assessment) before any big development projects start. Almost all governments insist on the EIS process before projects are approved; unfortunately many EISs are ignored and much more costly repair work is necessary to repair damage and return some of the environment to its former state (or nearly so). The Case Studies 11 San Andres, Colombia p. 60; 7 Guanica Bay Puerto Rico p. 52; 21 Babeldaob Palau, p. 80; 27 Okinawa Japan p. 92; & 28 Shikoku Japan, p. 94 all were established to repair damage from previous government and development activities.

Recommendation 2: Identify and prioritise the issues to select the management response.

You must know what are the major problems from the catchment that damage downstream coral reefs before starting any action; this is a **primary issue analysis**. Therefore, it is essential to determine what the problems are, assess the costs due to the damage and also the costs involved in finding solutions, and determine a range of solutions. It is especially important to be able to put what you are trying to achieve in a few sentences i.e. the 'vision' statement. For example, there is a need to analyse water quality issues in catchment areas which effect downstream marine ecosystems. This will help prioritise the issues to tackle first, analyse possible management responses, prioritise management and regulatory responses, and determine costs involved. This analysis should also include determining possible sources of funding and expertise, such as from national, regional and local governments, UN Agencies and donor governments, local and international NGOs, local resource people (see also Recommendation #11). The output will inform a catchment management program based on these analyses and which must be locally 'owned' and driven.

The Case Studies below undertook a careful issues analysis before commencing action. At the start they had a vision of what they were trying to achieve or repair in an ecosystem.

Case Study 11 San Andres, Colombia, p. 60. The islands had undergone rapid and unsustainable development following declaration as a 'free port'. The islands went into a downward spiral of poverty and environmental damage that had to be rectified. That drove the issues analysis and planning process.

Case Study 32 Science & GBR, p. 102. An extensive research program looking at the effects of different pollutants on GBR ecosystems (e.g. coral reefs, seagrass beds) and organisms (e.g. corals, algae, seagrass, fish, crown-of-thorns starfish) and the sources of these pollutants in nearby catchments indicated that the priority pollutants were suspended sediments, nitrogen and phosphorus compounds, and a few pesticides.

Case Study 33 Townsville #2 Australia, p. 106. The local council formulated their vision for a clean catchment that was not damaging the GBR to get the community to sign on to many changes in behaviour and modifications of how water was treated throughout the whole catchment area.

2. (a) Determine what is being delivered by the catchment area. Catchments can deliver many potential pollutants to coastal areas and especially coral reefs. These are outlined in Chapter 2 on page 7 & 8 and include sediments, nutrients, toxic compounds and large volumes of water. To implement effective management, first determine what are the major causes of problems and the main sources. For pollution, these are termed the major point sources (examples include mines, factories, sewage treatment plants); or alternatively there may be many diffuse sources of pollution (stormwater runoff from farms and towns, septic tank outflows from villages). For example, sewage may contaminate rivers from many houses without any sewage treatment or poorly performing septic systems. Likewise, sediment pollution may be coming from many small farms or land areas cleared for development. Most Case Studies started with these assessments; here are some examples:

Case Study 5 Central America GIS, p. 44. GIS computer technology was used to assess satellite images to locate the major sources of sediment and pesticide pollution flowing into the Caribbean from Central America. This analysis indicated where to focus first for management attention.

Case Study 23 Kaneohe Bay Hawai'i, p. 84. The assessment of the pollution sources that were destroying the reefs in Kaneohe Bay was helped by having a University of Hawai'i research station there. The sewage outfall was top priority for action before the many diffuse sources of pollution could be tackled.

Case Study 29 GBR Burdekin, p. 96. A 20 year monitoring program linked to a catchment modelling program allowed estimates of the total pollutant loads from the Burdekin River to the Great Barrier Reef. In addition the sources and concentrations of the different pollutants (sediment, nitrate, the herbicide diuron) were determined.

Case Study 6 Buccoo Reef Tobago, p. 48. The damage from sediment and nutrients to the reefs was obvious in Tobago, Caribbean, but there were no data on pollutant levels or their sources. They measured levels of nutrients and sediments as the basis for a project to reduce pollution damage to the reefs.

Case Study 21 Babeldaob Palau, p. 80. It was very useful that the project was conducted by the Palau International Coral Reef Center which had good scientific data on sediment concentrations and the effects on the coral reefs downstream. These data were conveyed carefully during many community meetings.

Case Study 26 Batam Indonesia, p. 90. Identification of the sources of sewage and heavy metal pollution coming from the island indicated where the national and local government should start corrective action.

2. (b) Determine the damage to coastal areas and community costs arising from the damage. Decision makers are often influenced by economic arguments and consequences. Thus you need to understand which particular stressors are causing the damage to coastal ecosystems and resources and assess the costs to communities and governments of this damage. You need to understand which problems start in the catchment and can be managed through actions in the catchment area (this excludes problems like over-fishing). Estimates of the costs of lost resources are very important e.g. fisheries loss, tourism loss, soil productivity losses, health losses, iconic status loss, ecosystem services loss. These estimates should be matched by estimates of the costs of solving the problems, and likely timeframes.

Case Studies 27 & 28 from Japan, p. 92 & 94. Excessive sediment flows were damaging coral reefs which were major tourist attractants and sources of fishes in Japan. These economic consequences were a major catalyst for corrective action.

Case Study 16 Pigs in American Samoa, p. 70. The critical problem of pollution from pig farms was a health one with many people infected with Leptospirosis disease. This caused major concern and economic losses in the affected communities.

Case Study 24 Sediments in Hawai'i, p. 86. This case study illustrates that developers often do not consider the costs to the environment and local community of land clearing. Thus the role of government was able to negotiate with developers, backed by having a 'big stick' of large money penalties for breaches of pollution control laws.

Case Study 31 GBR Economics, p. 100. A large-scale economic assessment and modelling study was performed of farming in 'dry' and 'wet' catchments of the GBR. These helped develop programs for farmers to reduce sediment loss and fertiliser use with minimal disruption to the financial running of the farms.

Case Study 32 Science & GBR, p. 102. Comments as above

2. (c) Develop an action plan and build capacity. It is essential to have a plan (a catchment management plan) that stakeholders, managers and scientists agree with so that: management actions can be prioritised (you can't do everything at once); everybody knows their role; everybody understands the management options; and how they are going to be implemented. It is also important to determine carefully whether voluntary or regulatory mechanisms (if they are available) are more appropriate. It is also important to realise that management may be restricted by available human, financial and logistical capacity and whether training programs are available to improve human capacity.

***Case Study 11 San Andres, Colombia.** p. 60. After identifying that there were a wide range of damaging issues, the project team established a large program to combat the problems and build capacity in the communities.*

***Case Study 17 Gau Island Fiji,** p. 72 Many development problems were destroying customary life and the environment on this island. The whole community was involved in planning repair actions, based largely on their assessment of the problems and suggested solutions.*

***Case Study 19 Takitumu Cook Islands,** p. 76. There was a distinct capacity building advantage in training young government workers from the Cook Islands, especially by taking them to see management in action in other countries.*

***Case Study 18 Vanua Levu, Fiji,** p. 74. They used holistic, ecosystem-based management to address problems on the land and over-fishing in the coral reef lagoons. The problem of poor water quality in streams and over the coral reefs was a major threat.*

***Case Study 25 Koh Tao Thailand,** p. 88. An integrated plan was developed with the cooperation of most stakeholders, including the national government, to reverse considerable damage from a poorly constructed and placed dam on a major tourist island in Thailand.*

***Case Study 29 GBR Burdekin,** p. 96. As a result of socio-economic and biophysical research and monitoring programs, a Water Quality Improvement Plan was developed and agreed to by the major stakeholders.*

2. (d) Show success by developing demonstration sites. Talking about success is not as effective as actually seeing success in action. Therefore, it is recommended to develop working demonstration sites that solve problems, and invite people to see them and meet the people who make them work. Such demonstration sites can be at large scale of a whole catchment or island, but more frequently at the scale of a domestic sewage treatment system.

***Case Study 2 Yucatan, Mexico,** p. 38. They had trouble convincing small tourism operators of the need to treat sewage and other liquid wastes, until they showed the operators, architects and government staff a low-cost and effective septic tank system.*

***Case Studies 1, 3, 4, 11, 16 & 26,** p; 36, 40, 42, 60, 70 & 90. These similar case studies from Curaçao, Dominica, St Lucia, Colombia, American Samoa and Indonesia all were successful by building low cost demonstration sites for domestic and pig wastes. These septic systems were all built by the communities using readily available materials.*

Recommendation 3. Raise awareness of the problems and solutions.

Often people are unaware that their actions are causing damage to downstream areas. Many of the Case Studies in this book were successful because there was an active and effective awareness campaign. With good information and explanatory materials, it is possible to form partnerships with people living and working upstream in the catchment area to solve problems that happen downstream.

3. (a) Develop an awareness raising campaign: The important feature of an awareness campaign is presenting clear examples of damage from upstream areas showing the probable causes and suggested solutions. Theoretical discussions are not nearly as effective as being able to show people damage that is coming from their actions. Developing a cooperative partnership with people upstream should be the focus of the campaign; it is best not to start with blame or criticism. It is often more effective to raise awareness quietly and if necessary confidentially by contacting people directly and not through the media. The material for the campaign should be targeted at the major stakeholders using the languages and methods they use and where possible have people from the community or industry deliver the message. Good quality aerial photographs, maps and basic scientific information, accompanied by photographs of the damage are useful starting points.

***Case Study 16 Pigs in American Samoa,** p. 70. The importance of an effective awareness campaign was seen in American Samoa, where one case a disease coming from pigs provided the impetus to change behaviour (and incidentally conserve the coral reefs).*

***Case Study 24 sediments in Hawai'i,** p. 84. It is incorrect to assume that wealthy, well-developed countries have all the answers. Three case studies from Hawai'i show that different branches of government often do not communicate with each other. They relied on an informed public to report pollution.*

Case Study 33 Townsville #2 Australia, p. 106. The first action was to allow people to meet and start with small, simple actions, while having a clear but larger vision: a healthy environment (catchment area) that was not polluting the GBR. They used a 'systems approach' to get the community fully involved.

3. (b) Inform people in catchment areas of problems and solutions. Person to person contacts are usually the most effective. This will involve people from the coastal areas and the coastal managers visiting communities upstream to inform them of problems and solutions in a non-confrontational manner. If the distances are not large, people from the catchment area upstream could be invited to visit the coral reefs and other coastal resources to see first hand the damage and that the livelihood of coastal people is being affected.

Case Study 12 Best Practice Central America, p. 62. A major success factor in Central America was because the NGO employed a local who had long experience in the banana farming industry and able to talk to the farmers about the problems and solutions.

Case Study 8 Sakau Pohnpei, p. 54. They developed awareness campaigns using English and local languages and distributed colourful posters and brochures. These were handed out at community meetings explaining the problems.

Case Study 17 Gau Island Fiji, p. 72. Many meetings were held with local communities to communicate problems and permit them to suggest culturally appropriate solutions. The end result was that there were different initiatives in adjacent villages seeking solutions to common problems; but the communities 'owned' these initiatives.

Case Study 15 American Samoa Detergents, p. 68. The focus was on finding the problems in American Samoa and asking the community to suggest solutions; rather than blaming some people or communities for the problems. When they organised 'Clean up' days they handed participants T-shirts carrying conservation messages.

3. (c) Determine what issues are important for user communities. Do not assume that user communities will have the same concerns as people developing the projects, or the scientists, or government people responsible for conserving the environment. Spend time talking to community leaders to find out what are their concerns, before trying to convince them to change behaviour about something that is of little concern to them e.g. marine biodiversity, distant coral reefs. However, many people upstream in the catchment area may go to the coast to fish on weekends or regularly eat fish from the coral reefs.

Case Study 16 Pigs in American Samoa, p. 70. The project managers found that preventing disease from polluting piggeries was more important than the more distant problem of pollution damage to coral reefs, even though these reefs are a source of valuable food.

Case Study 21 Babeldaob Palau, p. 80. Clean water for washing and cooking was more important for the community in Palau than conserving biodiversity on coral reefs, which had virtually no cultural meaning.

Case Study 17 Gau Island Fiji, p. 72. The people on Gau Island were particularly concerned about erosion of the coastline due to climate change. The project developed around this concern mostly involved improving catchment management.

Case Study 30 Townsville #1 Australia, p. 98. This case study describes a process to get people involved and to change behaviour by first asking about their concerns and suggestions to solve problems.

3. (d) Recognise the economic costs of changing behaviour. Wherever possible, provide financial assistance or alternative livelihoods when asking farmers and other stakeholders to change behaviour or systems to conserve the environment, especially if that environment is a long way away. Stakeholders may want to use less damaging practices, but often cannot afford to change. Therefore try to include extra money in projects to assist in making changes.

Case Study 16 Pigs in American Samoa, p. 70. After demonstrating that extensive pig raising was causing disease and also damaging the environment, farmers in American Samoa were given financial assistance to build new, less polluting, pig farms. They also gained extra income from compost.

Case Studies 4 & 26, p. 42 & 90. These report similar situations where the projects installed waste digesters that generated methane cooking gas in St Lucia, and compost in Indonesia.

Case Study 24 Sediments in Hawai'i, p. 86. The Hawaiian government agencies had the capacity to fine developers and also force them to contribute to cleaning up sedimentation problems that they had created. These were large fines that demonstrated to other developers that best environmental practice is also good business practice.

Case Studies 29 & 31 GBR Burdekin & GBR Economics, p. 96 & 100. Managers recognised that to recommend changes to farmers, they first had to understand the industry and the balance between costs and income; then the Government provided 1 to1 incentive funding to change to less polluting, best practice farming.

3. (e) Promote positive incentives to change behaviour. Find ways to reward people and organisations who change their activities to improve catchment management and protect the environment. Many schemes have been developed that reward best practice farming with increased financial rewards for labelled products. These include 'green ticks', prizes, public endorsement and particularly best practice certificates. A theoretical example could be 'biodiversity friendly rice' certified by Ramsar and targeted at international markets at a premium price.

Case Study 12 Best Practice Central America, p. 62. *The Sustainable Agriculture Network developed a certification scheme for bananas and other agricultural products grown under their best practice guidelines. This provided extra income for farmers from the public who wanted a healthy product and also to protect the environment.*

Case Study 15 American Samoa Detergents, p. 68. *The NGO put on barbeques and handed out free T-shirts to people who participated in clean up the environment campaigns.*

Case Study 17 Gau Island Fiji, p. 72. *It was clearly recognised that to change behaviour on the island, there was a need to provide positive economic incentives and not penalise people. They developed several alternative livelihood options for different villages.*

Case Study 13 Central America Pesticides, p. 64. *The problem was that pesticides were damaging downstream coral reefs; the solution was to work with farmers to reduce pesticide use and switch to cheaper, less toxic pesticides by applying good science on when and how to apply pesticides. This also saved the farmers money.*

3. (f) Recognise the value of involving the women, youth and schools. Work with existing community groups and local schools in awareness campaigns. These can include women's and youth community groups, as well as local NGOs. These are very effective ways to get the conservation message out into the wider community.

Case Study 1 Schools in Curaçao, p. 36. *They involved local schools in Curaçao to manage an above ground septic system at a small tourist resort; the school organised events for parents to observe the system, and regular monitoring and maintenance of the system was included in school classes; some of which were held at the tourist site.*

Case Study 17 Gau Island Fiji, p. 72. *The project people in Fiji made special efforts to involve women and youth in managing the land and also in developing and managing small scale economic projects such as raising cattle or planting Pandanus for mat making.*

Recommendation 4: Control sediment inputs

To control and prevent excess flow of sediments into your coastal area, the essential tasks are to identify the sources, assess and monitor sediment flows, and implement actions to reduce sediment washing off altered catchments. The specific steps are outlined below:

4. (a) Identify major sources of sediment. For the **primary issue analysis**, a two scale approach can be employed with a combination of satellite or aerial imaging combined with ground-truth visits to as much of the catchment area as possible (Recommendation #1). The likely sources of sediment will be from:

- i) deforestation and forestry;
- ii) cropping, especially on steep erodible slopes for coffee, bananas, pineapples, sugarcane, oil palm and subsistence gardening;
- iii) urban and industrial development;
- iv) animal grazing; and
- v) dredging and coastal modification such as building seawalls, ports, marinas.

Case Study 5 Central America GIS, p. 44. *Comprehensive analysis of watershed-based threats from agriculture to the Mesoamerican reef area was carried out, focused on the loads of sediment, nitrogen and phosphorus compounds. The discharge of these into the major rivers was determined using a GIS and modelling approach. These results were used to make recommendations for better management of agricultural industries.*

Case Study 29 GBR Burdekin, p. 96. *Long-term catchment monitoring and modelling showed the sources of sediment in the Burdekin River catchment to be rangeland beef grazing areas, particularly those on steeper slopes with erodible soils and many gullies, and where pasture cover was consistently low.*

Case Study 14 Tamandaré Brazil, p. 66. *GIS technology and satellite images were used to track sediments from farmlands flowing out to the coral reefs. This was combined with direct collection and analysis of sediments in reef waters.*

Case Study 23 Kaneohe Bay Hawai'i, p. 84. *The first stage of this story involved removing sewage pollution; the second phase was to identify the diffuse sources of sediments and nutrients.*

4. (b) Measure the amount of sediment entering the ecosystem, including during wet and dry seasons. Monitoring of sediment loads in waterways with basic sediment traps is relatively simple and low cost, and also very reliable. Monitoring is essential to raise awareness among the upstream people releasing the sediments and to illustrate soil loss from agricultural lands. A regular sediment monitoring system is essential for management to determine whether corrective actions are successful and to identify new sources of sediment. This monitoring should be conducted throughout the year, but particularly in times of high rainfall and runoff when most erosion occurs.

***Case Study 6 Buccoo Reef Tobago**, p. 48. The damage from sediments and nutrients to their reefs was obvious, but there were no data on how much or the sources. They measured levels of nutrients and sediments as the basis for a project to reduce pollution damage to the reefs.*

***Case Study 20 Takuvaie Cook Islands**, p. 78. Gathering good data on water quality in the streams was essential to identify the problem and demonstrate this to communities before seeking to change their behaviour.*

***Case Studies 14, 21 & 29** p. 66, 80 & 96. See Tamandaré Brazil, Babeldaob Palau, and GBR Burdekin above, and in 2. a.*

4. (c) Promote sustainable forestry to reduce sediment flows and stabilise hill slopes. Logging or clear felling increases river sediment loads by at least 2 times and up to 50 times, compared to natural forests. Increases due to selective logging are lower (2 – 5 times) while sediments from clear felled forests are higher (5 – 50 times). Ideally, clearing of natural forests should be replaced with timber plantations. If this is not possible, selective logging should be encouraged rather than clear felling that removes all ground cover. Forestry operations should be restricted to the dry season; if possible prevent all operations during wet seasons. Prevent forestry operations on steep slopes. Adopt codes of sustainable forestry; there are examples of codes available from the Forest Stewardship Council (at www.fsc.org).

***Case Study 10 Aneityum Vanuatu**, p. 58. The hill slopes were so badly damaged by deforestation and wild fires on an island in Vanuatu that drastic action was necessary. They used Vetiver grass to first stabilise the soils, then planted a native Acacia, and finally planted other commercially valuable trees to fully stabilise the soils.*

***Case Study 25 Koh Tao Thailand** p. 88. This is another example of using the non invasive Vetiver grass to stabilise steep slopes to prevent sediment pollution in Thailand.*

4. (d) Replant degraded forest areas. Forest areas which have been lost to logging or converted to cropping and then abandoned may be restored. A major issue to resolve for revegetation are degraded, unfertile soils, continued disturbance from domestic and feral animals, the presence of weed species, and finally the cost. Selection of locally suitable plant species is important (whether native or introduced) which will not become weeds, but still grow rapidly. A successional scheme (e.g. grass, then quick growing shrubs, and trees, then 'climax' trees) is needed as the reforested areas change through time. This reforested area may have economic returns if the new trees can be harvested sustainably in the future. It is essential to plant vegetation and block erosion gullies on cleared slopes to prevent sediments flowing into streams.

***Case Study 22 Houma, Tonga**, p. 82. The coastal forests had been lost and degraded through clearance for timber, use for cropping and introduction of domestic animals (pigs, cattle, horses) and their function as a buffer from the sea was lost. Revegetation in a planned scheme of weed removal, planting pioneer species (e.g. Casuarina), preferred coastal species and then species to increase diversity was successful.*

***Case Study 8 Sakau Pohnpei**, p. 54. After identifying loss of native forest as the cause of heavy sedimentation on these coastal coral reefs of Micronesia, they trained forest rangers to enforce controls over illegal clearing. This was only partially successful and subsequently an education, awareness, extension and outreach program to protect watersheds and support forest and coral reef conservation was undertaken. This shows that legal solutions do not always work and voluntary cooperative initiatives may be a better solution (see Case Study 20 Traditional Law Pohnpei, p. ##).*

***Case Study 10 Aneityum Vanuatu**, p. 58. Chemical analysis of soils was needed to select the best plants to restore damaged hill slopes on Vanuatu. These soils were acidic, with toxic levels of aluminium and manganese and devoid of plant nutrients; this guided the selection of the replacement plants. Initial revegetation with grass (Vetiver) followed by trees (Acacia) has stabilised the steep slopes and reduced erosion.*

***Case Study 11 San Andres, Columbia** p. 60. The large-scale management plan also highlighted revegetation, reforestation and forest management as key management initiatives.*

4. (e) Improve agriculture to reduce sediment loss. There are many ways to reduce sediment runoff from agricultural lands. Explain to farmers that loss of sediment reduces farm fertility and productivity, damages water supplies, and will reduce fish catches and income from tourism in downstream coastal areas. Following are some basic sediment control measures:

- i) Establish riparian zones around creeks and streams. Plant trees, shrubs and grasses on stream banks in a strip between 2 and 25 m wide, depending on stream size (wider strips on larger streams) to reduce stream bank erosion and also trap sediments before they enter the streams.

Case Study 25 Koh Tao Thailand p. 88. A succession of plants from initially Vetiver grass, to local tree species were planted around an eroding reservoir and along streams and erosion gullies.

Many other case studies focus on riparian zones including Case Studies: **7 Guanica Bay Puerto Rico, p. 52; 11 San Andres, Columbia p. 60; 12 Best Practice Central America, p. 64; 14 Tamandaré Brazil, p. 66; 18 Vanua Levu, Fiji, p. 74; 29 GBR Burdekin, p. 96. 30 Townsville #1 Australia, p. 98; 32 Science & GBR, p. 102.**

- ii) Promote green agriculture, do not burn cane fields, trap sediments in grass strips around fields or in shallow ditches. If crop residues are retained on fields e.g. sugarcane trash left on the soil, and return nutrients for the next crop.

Case Study 32 Science & GBR, p. 100. In sugarcane cultivation near the Great Barrier Reef, the recommended 'Green Cane Trash Blanketing' practice is to harvest the cane 'green' i.e. without burning and leave the leaves, which are stripped off by the harvester, on the ground as a 'trash blanket' to prevent soil erosion.

- iii) Implement contour ploughing, that is ploughing around and across the hill slopes and not in the direction of water flows. This will retain soil, fertiliser and moisture in the fields.

Case Study 12 Best Practice Central America, p. 62. Among many practices in Central America, one recommended was changes in ploughing to reduce sediment loss.

- iv) Do not clear creek beds, but allow natural ponding to slow water flows and allow sediments to settle in these ponds. (see Recommendation # 9 below);

Case Study 27 & 28 Japan p. 92 & 94. Major concreting and straightening of streams in Japan has resulted in rapid flows of water that send large volumes of water rapidly out onto nearby coral reefs.

- v) Avoid cropping on steep slopes. If flatter lands are unavailable (e.g. this is the only cropping land available to you) use terracing and other water drainage controls to minimise erosion.

Case Study 7 Guanica Bay Puerto Rico, p. 52. A government incentive convinced coffee growers in Puerto Rico to change from shade grown coffee to higher producing sun grown coffee, but this resulted in major sediment erosion off slopes. The process was reversed to change back to shade grown coffee which protects the soils better and sells for more money.

Case Study 12 Best Practice Central America, p. 62. Advice to farmers in Central America allowed them to change to shade grown coffee, and gain a 'Green-Seal of Approval' certificate allowing them to sell their coffee at top prices.

- vi) Build sediment control structures e.g. constructed wetlands downstream of eroding areas. A series of many small dams and barriers will slow water flow and allow sediments to settle, before flowing into streams

Case Study 25 Koh Tao Thailand p. 88. A series of sediment control structures including small dams on streams (to form sediment traps), rock baskets (Gabion), erosion control blankets and erosion control logs were installed to trap sediment from eroding upland sites. This was in addition to revegetation of upland slopes (see 4. e. i above).

Case Study 10 Aneityum Vanuatu, p. 58. The revegetation in Vanuatu was successful because they were able to build barriers across eroding gullies to stop sediment flows.

Case Study 7 Guanica Bay Puerto Rico, p. 52. They set out to stabilise stream banks in the whole catchment and also prevent the erosion of other flood plain sediments that had built up since the engineering modifications of this, and the adjacent catchment area.

Case Study 20 Takuvaine Cook Islands, p. 78. They showed that by gathering good data on water quality, they were able to identify the problems and demonstrate solutions to communities about keeping steep catchments clean to ensure drinking water quality in the Cook Islands.

4. (f) Work with local government and communities to reduce sediment flows during the construction phases of urban, industrial and resort development. Many developers are unaware that the sediment released from clearing land causes major damage downstream, or they are too busy, or don't want to spend more money to prevent sediment flows. Most national and local governments have regulations to restrict sediment loss from land clearing; examine your laws and seek to apply them rigorously and ensure that developers and inspectors are adequately trained. These are a few steps:

- i) Permit land clearing for urban development only during the dry season; if possible prevent clearing in the wet season;
- ii) Ensure that developments are set back from the rivers, streams and the shore. Leave a buffer strip of 10 to 50 m wide which also allows the public to walk along the rivers;
- iii) Leave existing riparian zone vegetation, or thin it just enough for people to be able to enjoy river views through the trees, but still stabilising the stream banks;
- iv) Establish sediment traps; gross pollutants traps (grills, pits, sumps), grass swales and constructed wetlands in drainage areas. Unpaved roads are a particular problem to focus for management action.

Case Study 24 Sediments in Hawai'i, p. 86. *All the involved arms of government (National, State and Local) met together to develop better communication between them and more efficient lines of decision making and reporting. They also involved the community, who assisted by reporting examples of sediment pollution throughout Hawai'i. Success was assisted by the government having regulations and financial penalties for breaches of the law.*

Case Study 25 Koh Tao Thailand, p. 88. *The project team generated considerable community support amongst all stakeholders on this small tourist island to lobby the government and also use volunteers to stabilise hillsides to prevent sediments flowing out to the coral reefs.*

Case Study 30 Townsville #1 Australia, p. 98. *The Townsville Council developed many mechanisms to trap sediments and pollutants. They actively involved the local community in learning from these developments and assisting in cleaning them of solid wastes.*

4. (g) Promote sustainable grazing by working with farmers to reduce erosion. Land that is over-grazed exposes the soil to heavy rain, especially during storms. This removes valuable topsoil, fertilisers and grass seeds; and fills streams with sediments which flow out to sea. Work with farmers to maintain good vegetation cover in grazing lands with both trees to stabilise soil and provide shade for animals, and grass cover. Especially stabilise riparian areas and river frontage country.

Case studies 29 GBR Burdekin, p. 96. & **32 Science & GBR**, p. 102. *Beef grazing on arid rangelands was the major source of suspended sediment flows to the Great Barrier Reef because poor grass cover did not control erosion. Funding incentives from the Australian Government to maintain higher pasture cover was supported by Queensland Government regulations to enforce these practices. For example, complex fencing arrangements reduced grazing pressures on pastures by permitting rotation of stock between paddocks.*

Case studies 17 Gau Island Fiji, p. 72. & **22 Houma Tonga**, p. 82. *Controlling the grazing of cattle, pigs and other animals was part of reforestation and land repair projects in Fiji and Tonga.*

Recommendation 5: Control nutrient (Nitrogen and Phosphorus) inputs

If increased nutrient loads are causing problems (similar to **Recommendation #4** above), the essential tasks are to: determine the major sources from the primary issue analysis; where possible measure the concentrations of the major nutrients (nitrogen and phosphorus); raise awareness in the catchment community of the problems and possible solutions; and implement corrective action to reduce the major sources and/or the ones easier to correct. The major sources are likely due to increases in:

- i) Sewage effluent from inadequate sewage treatment plants, ineffective or poorly maintained septic systems, or unsewered towns and houses;
- ii) Fertiliser losses from intensive agriculture, especially from sugarcane, oil palm, horticulture (fruit and vegetables), root crops, grain crops and fertilised pastures (dairy, beef, sheep);
- iii) Intensive animal production systems, such as piggeries, cattle feed lots, chicken production, aquaculture (prawns/shrimps, fish);
- iv) Urban stormwater washing out fertilisers, detergents and other wastes such as animal faeces; and
- v) Secondary industry, such as food processing plants and canneries, abattoirs, sugar mills, palm oil mills, fish processing factories.

5. (a) Identify the sources and measure concentrations. These chemical analyses for nutrients are more complex and expensive than measuring sediments, but they are essential management tools. In many cases, most nutrients are discharged from diffuse sources in high rainfall/runoff events. Monitoring should focus on these periods to get a good estimate of the loads. In contrast, point source discharges (e.g. sewage treatment plants) are relatively constant and a regular (e.g. monthly) monitoring regime is satisfactory.

Case study 32 Science & GBR, p. 102. *Extensive long-term monitoring identified land use and the agricultural industry as the major sources of nutrients from catchments along the Great Barrier Reef. Erosion in beef*

grazing lands was shown to be the largest source of particulate nutrients (both N and P), while fertiliser use in sugar cane, horticulture and grain crops was the largest source of nitrate.

Case Study 6 Buccoo Reef Tobago, p. 48. The project team aiming to protect the coral reefs in Tobago realised that there were no data on nutrient concentrations, as well as data on sediments (above). This was the first task to measure levels of nutrients with the technology they had, and also collected some samples for long term storage to be measured when more accurate methods become available.

Case Study 5 Central America GIS, p. 44. A comprehensive analysis of watershed threats from agriculture to the Mesoamerican Reef showed that sediments and nitrogen and phosphorus compounds were the major problems flowing from the larger rivers. These data were used to recommend solutions at the scale of complete catchment areas.

Case Study 15 American Samoa Detergents, p. 68. Imported high phosphate containing detergents were polluting the streams and reefs. They convinced the government to ban importation and stores to stop buying these detergents.

5. (b) Raise awareness within source communities. The Recommendations for nutrients are similar to the examples in 4. f above. Increases in sediment are usually obvious, whereas data are required for increased nutrients as these are often not easily seen. Also the concentrations of nutrients in waters and marine sediments can vary considerably between seasons. A particular problem is historical concentrations of nutrients buried in sediments. These can be slowly released with time, or rapidly during rough weather in the ocean; therefore higher concentrations and effects on the coral reefs will occur even after pollution from the catchment is markedly reduced.

The Case Studies in 5. a above focused on collecting data on nutrient pollution; these data should be used to raise awareness. The Case Studies in 5. c below developed demonstration sites to show communities that sewage treatment does not need to be complicated or expensive.

Case Study 2 Yucatan Mexico, p. 38. Initial reaction to an artificial wetland was negative but they used it as a successful demonstration site for other tourist operators, communities and the engineers in the region as a simple mechanism to remove nutrients from waste water.

Case Study 1 Schools in Curaçao, p. 36. The involvement of local school children and their parents enabled them to spread the word throughout Curaçao on how to manage sewage wastes to protect coral reefs which are major tourist attractants.

Case Study 23 Kaneohe Bay Hawai'i, p. 84. After the point source of sewage effluents was removed, reef recovery was delayed because stored nutrients in sediments were slowly released for years into the water. This shows the need to manage community and government expectations of a 'quick fix' to problems when long time lags may occur between management action and eventual recovery of the ecosystem.

5. (c) Treat sewage and other agricultural wastes. Wherever possible, treat high concentration nutrient waste water in sewage treatment systems; preferably to tertiary level. Basic treatment is called 'primary' which settles out particulate matter; secondary treatment reduces the organic and much of the nutrient concentration in the remaining waste water; and tertiary treatment is the final step to reduce the concentrations of nutrients, especially nitrogen and phosphorus. There are several case studies that demonstrate low cost methods of treating sewage and other wastes in septic tanks, with the waste water draining out into soils, ponds or wetlands. For larger towns and industries, a secondary plus tertiary sewage treatment system is required to reduce pollution into streams and the ocean. Treated effluent waters are valuable as these can be used to water crops, grasslands and gardens; or reused in tourist areas to flush toilets, thereby saving valuable drinking water.

Case Study 23 Kaneohe Bay Hawai'i, p. 84. When the major point source sewage outfall was diverted, the coral reefs in Kaneohe Bay Hawai'i showed relatively rapid recovery; but this was only part of the story (see 5. b above).

Case Study 2 Yucatan, Mexico, p. 38. Because of the porous nature of the limestone soils in the Yucatan region of Mexico, the only option to treat sewage and other liquid wastes was to build a sealed artificial wetland to protect the coral reefs that the tourist trade depended on.

Case Study 3 Mero Village, Dominica, p. 40. This is an example of low tech, low cost methods to control pollution that was damaging an important beach and offshore coral reefs in Dominica. With a good information base and help from the local Rotary Club, the community built and managed a septic system on the beach. The study also highlights the use of a 'demonstration plant' to convince local communities that such systems do work.

Case Studies 11 San Andres, Colombia, p. 60. & **26 Batam Indonesia**, p. 90. These case studies also feature small scale low cost constructed wetlands for domestic sewage treatment.

5. (d) Reduce fertiliser use on crops by using scientific assessments to determine the best application methods and rates for fertiliser use that will best promote plant growth. The best process is to analyse nitrogen and phosphorus concentrations in the soil using basic soil testing kits. Many farmers think that by adding more fertiliser, they will get greater productivity; frequently much of the additional nutrients (and 'money') are washed out of the soils before plants can take them up. There are best practice guidelines available that describe how much fertiliser to use and when to apply it to fields for maximal production.

***Case Study 12 Best Practice Central America**, p. 62. The Sustainable Agriculture Network developed 'Best Management Guidelines' for coffee, banana, citrus and pineapple farming with extensive advice provided on reducing fertiliser use.*

***Case study 32 Science & GBR**, p. 102. Fertiliser use, especially on sugarcane crops, was the major source of nitrate pollution on the Great Barrier Reef causing nutrient enrichment problems on the reefs (excessive algal growth and promoting crown-of-thorns starfish outbreaks). The Australian Government Reef Rescue program provided sugarcane farmers with funds on 50:50 matching basis to promote more precise fertiliser management matched to crop needs, based on extensive soil testing for nitrogen and phosphorus.*

5. (e) Control waste from intensive animal production. It is essential to treat waste water from large scale farming of animals. These can be massive point sources of pollution if not treated effectively, causing human health problems and environmental damage. All intensive animal farms produce large volumes of high concentration organic waste. These include cattle feed lots and intensive farming of pigs, chickens, and more recently freshwater and marine aquaculture. A condition of government permission to establish such production facilities should be tertiary treatment of all liquid wastes and no releases of solid wastes

***Case studies 4, 11, 16 and 17** focused on pig farming wastes and effective and low cost ways of treating the wastes in **St Lucia** (p; 42), **San Andres, Colombia** (p; 60), **American Samoa** (p; 70), and **Fiji** (p. 72). Relatively simple low cost treatment systems are described with some deriving financial benefit from methane generation or compost fertiliser for sale.*

5. (f) Control and reduce urban storm water runoff. Natural storm water systems and flood plains trap nutrients and sediments, whereas concrete drains speed up the release of these to streams and the ocean. Establish vegetated buffer (riparian) zones to trap nutrients around creeks and streams (4. e above), and construct artificial wetlands and rehabilitate natural wetlands. Local government staff will need training and guidance to handle storm water issues.

***Case Study 30 Townsville #1 Australia**, p. 98. The major task to prevent pollution flowing out to the World Heritage listed Great Barrier Reef was to make major modifications to storm water systems in Townsville. The Council developed many mechanisms to trap sediments and pollutants and reduce as much as possible storm water running out untreated through the streams.*

5. (g) Work with industry to reduce pollution. Food processing factories are a special case of large point sources of pollution. Contact these industries and seek a collaborative approach to reduce pollution and treat all wastes to tertiary level. Seek the best and most effective mechanisms and advise industries on how to reduce wastes and where possible turn some of these wastes into valuable by-products, such as animal and fish foods and fertiliser. This cooperative approach should also be supported by national and local government legislation and regulations on permissible levels of pollution, as well as odours and noises. Special cases of food processing are abattoirs, chicken factories and fish processing plants which are very polluting with high concentrations of animal, bacterial and faecal wastes. Similarly fruit and vegetable factories produce wastes with high concentrations of sugars that can deplete oxygen levels in streams.

***Case Study 26 Batam Indonesia**, p. 90. The government and local management group worked with industry to reduce pollution by providing advice on programs developed by the national government. While the activities were mostly about reducing heavy metal pollution, it illustrates the cooperative approach supported by government regulations and regular monitoring.*

Recommendation 6: Control pesticide and other toxic chemical inputs

The most difficult pollutants to detect and measure are pesticides and other persistent organic pollutants (POPs); but these can, and do, cause major damage to animals and plants in coastal ecosystems. If you suspect that increased pesticide loads are a problem for your area, it is essential to identify the compounds and measure their concentrations with detailed and often expensive scientific analysis. With sound scientific data and the general issue analysis, the essential tasks are to: determine what are the major sources and compounds; raise awareness in the source areas without blaming the suspected polluters; and develop programs to reduce the amount used and shift to less toxic compounds. Increases may be due to:

- i) Agriculture, particularly cropping of sugarcane, oil palm, vegetables, fruit, and grain crops including rice and corn;
- ii) Urban uses including malarial control, weed control;
- iii) Synthetic chemicals e.g. wood preservatives, pharmaceuticals from sewage effluent discharges, including synthetic hormones;
- iv) Accidental or illegal discharges from industry

6. (a) Measure the amount of pesticide and other POPs entering the ecosystem, and determine when most are being delivered throughout the year (e.g. include wet and dry seasons). This will require careful collection of samples from animals and plants in the coastal ecosystems, and measurement of pesticide concentrations in waterways and sometimes in the soil. Pesticide analysis will require access to reliable scientific laboratories that may only occur in another country; analyses may be expensive, therefore it is essential to carefully design collection protocols to reduce the number of samples to be tested.

***Case Study 13 Central America Pesticides**, p. 64. This long-term project involved detailed scientific detection of pesticides in animals and plants from the Mesoamerican Barrier Reef. The first analyses were useful to determine there was a problem; it required analysis in expert laboratories, with the cooperation of major pesticide and farming companies to obtain convincing evidence of pesticide pollution and the sources of that pollution.*

6. (b) Develop strategies to reduce pesticide use with the people upstream using good scientific information and advice to reduce or change use of the most toxic compounds. Pesticides include herbicides such as diuron, glyphosate, 2,4-D and paraquat, insecticides such as chlorpyrifos, malathion, imidacloprid, DDT, and compounds used in animal husbandry. Awareness campaigns are best done without attributing blame to farmers or agricultural companies, and by involving facilitators that are trusted by all involved. These campaigns require very good science on measuring and using pesticides most effectively; with this advice the best approach is to develop cooperative partnerships with all major stakeholders.

***Case Studies 12 Best Practice Central America**, p. 62, & **13 Central America Pesticides**, p. 64. They were successful in Central America because no blame was suggested for the pollution, and either the scientific data were kept confidential among the critical stakeholders, or they employed a local person trusted by the farmers. The NGOs signed confidentiality agreements with major pesticide and farming companies and/or agreed to work cooperatively to reduce pesticide use.*

***Case study 32 Science & GBR**, p. 102. Pesticide use is being improved in the catchments near the Great Barrier Reef because of effective data gathering and management responses. Farmers have reduced the use of herbicides in sugarcane cultivation through better targeting of sprayed areas i.e. spray the weeds not the whole paddock; and changed to newer more environmentally friendly herbicides.*

6. (c) Manage pesticide use by assisting farmers and industry to adopt best practice in pesticide use, especially by explaining the economic benefits of using less compound. Provide advice on correct concentrations to use, the best timing of application to control pests, selecting pesticides with lower toxicity, and better application technology to minimise use. Use of pesticides can be reduced using crop rotation and multi-cropping. **Apply integrated pest management techniques.** Seek advice from agricultural experts on what crops to plant adjacent to the commercial crop or the best rotations of different crops to reduce pest build up. An example was placing owl breeding boxes near canefields in Australia to reduce cane rat populations instead of continued use of the pesticide (a rodenticide called klerat, which is a highly toxic compound containing selenium).

***Case Studies 12 Best Practice Central America**, p. 62, & **13 Central America Pesticides**, p. 64. The project leaders provided good scientific advice on how best to use pesticides and convinced farmers that using more pesticide than is recommended will not be more effective. They worked with farmers, major agricultural producers and chemical companies to develop best management practices, including crop selection, to reduce pesticide pollution downstream. See examples above.*

Recommendation 7: Solid wastes and plastics

Solid waste and litter are easy to see and recognise as a problem for your coastal area, the essential tasks are to determine the major sources e.g. increases may be due to poorly managed tips, lack of solid waste collection facilities, lack of awareness in communities, or poor government supervision of industry. The major pollutants are plastics and glass (especially floating bottles), metals, cloth, paper and cardboard.

7. (a) Measure or estimate the amount of solid waste and litter entering the ecosystem. Also determine where the solid wastes are coming from. Taking photographs of large masses of wastes will be useful for raising awareness. Also showing damage to animals and plants in the coastal areas e.g. the gut contents of birds washed up on beaches. Document when most waste is delivered and continue to monitor this throughout the year (e.g. include wet and dry seasons);

7. (b) Raise awareness in communities and local governments. Raising awareness of litter and the responsibilities and control that communities have over the problem is the major task for resource managers. There are many techniques that can be used to raise awareness e.g. 'clean up days' to remove wastes that will end up in the streams; provision of accessible waste bins and dumps; and television, radio, newspaper and poster campaigns. Often religious leaders and village chiefs can be the leaders in controlling solid wastes. Solid wastes and litter are virtually unknown in many small traditional villages; however when these villagers come to larger towns, litter becomes a major problem. Therefore a valuable task is to remind communities of their traditional practices.

Case Study 15 American Samoa Detergents, p. 68. Awareness was raised by holding clean-up days with a free T-shirt, followed by a barbeque. This was associated with another problem of phosphate pollution from detergents, but the litter control was effective in raising community understanding and awareness.

Case Study 26 Batam Indonesia, p. 90. There was no domestic solid waste management systems, therefore they provided free bins for waste that can be composted, and other bins for other wastes that were sent to new waste dumps.

7. (c) Introduce better waste management systems. Many communities do not have places to dispose of waste. Local government should be encouraged to establish waste collection systems and tips, ensure good tip management including controlling liquid runoff by surrounding the tips with drains and ponds, and especially implement more recycling. The best methods to reduce waste volume is to sort waste into compostable organic material which can be sold as fertiliser (food scraps, garden waste, non-recyclable paper) and other non-digestible materials (plastics, rubber, metals), with some of this being recycled. Volume can be reduced by compacting waste. Another effective method is to value solid wastes by including a money deposit on bottles, cans, and metals. Change plastic bags to ones that break down to a powder after a few months. Litter controls should focus on a series of measures including:

- i. Public education and awareness;
- ii. Legal remedies e.g. fines for excess littering;
- iii. Deposits on drink containers and redemption systems;
- iv. Introduction of degradable types of plastics;
- v. Collection at source, with efficient garbage collection system from homes and public areas (larger bins etc.);
- vi. Trapping in waterways by installing Gross Pollutant Traps, or constructing wetlands; and
- vii. Directly clean up the waterways and marine environment, by involving the community in litter clean up days

Case Study 26 Batam Indonesia, p. 90. An investigation into domestic waste management in revealed lack of compliance by industries and poor awareness in coastal villages of proper waste disposal techniques. A multi-sectoral board was established to guide projects in waste management. Industries are now developing compliance schemes with the Board while a demonstration village communal septic system is being trialled.

Recommendation 8: Heavy metals and other mining and industrial wastes

The major problem with heavy metals is that they remain in ecosystems for a very long time and will often accumulate in animals and plants. Thus, some heavy metals can enter the human food chain, such as mercury, cadmium and lead in seafoods. If there is evidence of toxic metals in streams and the ocean in your area, the major sources of toxic metals, with the emphasis on large point sources, are likely to be:

- i. mining and mineral processing;
- ii. manufacturing industry (especially battery production and electro-plating);
- iii. port operations with the use of antifouling paint, spills from ore shipments and metal-rich port stormwater runoff; and
- iv. agriculture which will be diffuse sources of pollution (cadmium residues in fertilisers, mercury in fungicides, copper compounds as fungicides, selenium compounds in rat poisons).

8. (a) Measure the amount of toxic metals entering the ecosystem and determine when most of it is being delivered and monitor it throughout the year (e.g. include wet and dry seasons). With this information it is possible to develop strategies with the people upstream to reduce the pollution or in some cases eliminate it altogether. However, obtaining accurate measures of heavy metal concentration will require specialised and expensive chemical analyses. Sometimes it may be necessary to send samples to overseas laboratories.

8. (b) Improve mining and mineral processing waste treatment and disposal. Governments usually have strong general legislation and specific rules for mining operations, but surveillance is often poor and many accidental or deliberate releases of heavy metal wastes occur during the wet season. The mining industry is usually required to install effective tailings dams to hold mining wastes and allow the heavy metals to settle out; some also have wastewater treatment facilities to chemically lock up toxic metals and keep them for long-term stable storage. However many of these facilities are built on streams in high rainfall areas and leakage or collapse of dams does occur. Some mining operations on tropical islands rely on dumping mine tailings into rivers or sometimes directly into the ocean. Mining in many countries is a major economic industry and can seek to avoid stringent control. Some international NGOs may be able to assist by contacting the mining company headquarters in distant cities. Applying pressure to your government may be effective.

There are no Case Studies in this book on this problem. We could not find any that were successful in controlling mining waste damage to coastal ecosystems. There are, however, many examples around the world where mining wastes have resulted in damage to coral reefs and other coastal ecosystems.

8. (c) Establish port environmental operation plans. There are effective guidelines available through the International Maritime Organisation and also through some UN conventions such as the London Dumping Convention that regulates, for example, the pollutant content of dredge spoils which is allowed to be dumped at sea; www.londonprotocol.imo.org.

8. (d) Apply trade waste policies for sewage treatment plants. These will involve prohibiting discharging noxious wastes from industry into the urban sewage system; that is having a separate collection, treatment and disposal system for this waste.

Recommendation 9: Reduce damage from flooding off modified catchment areas.

Avoid modifying catchment areas to reduce the rapid delivery of large volumes of water carrying sediments, nutrients and solid material after heavy rain. Healthy and near natural catchment areas act like a sponge by slowing the release of fresh water and allowing much of it to soak into the soil. Healthy catchment areas reduce erosion and downstream flooding and pollution because the delivery of water from heavy rain has been slowed. If possible: reduce and repair damaged catchments by preventing forest clearing, poor forestry practices and replanting depleted areas; retain and repair riparian zones beside streams; reduce the area of hardened surface by including intermittent strips of vegetation, grass, sand or gravel; retain natural ponds and wetlands in drainage areas; and remove litter and other solid material that can be carried away with flood water.

9. (a) Avoid unnecessary clearing of vegetation and modification of streams and wetlands. Many case studies above cover actions to repair damage to forests and catchment areas. Any significant modification of land areas and streams should be accompanied by careful hydrological studies show that this will not result in severe damage to ecosystems downstream.

Case Studies 27 Okinawa Japan, p.92 & 28 Shikoku Japan, p. 94. There was considerable modification of two catchment areas in Japan that have resulted in the rapid delivery of water and sediments out to the sea to damage nearby coral reefs from even minor rainfall events. This happened in Okinawa and in the catchment of Tatsukushi Bay and caused massive damage to coral reefs that were valuable for tourist industries.

9. (b) Avoid complete sealing of car parks and public areas by leaving strips of grass, sand and gravel, and by planting shade trees. These strips will absorb water to recharge ground water and reduce runoff. Where possible, channel stormwater into ponds before release into streams. These ponds will filter out sediments and pollution, and will often support more bird life.

Case Study 23 Kaneohe Bay Hawai'i, p. 84. After the sewage point source was diverted, the extent of diffuse sources of sediment and nutrient pollution became more evident. Large areas of the catchment area had been covered by concrete with the storm water rushing into the Bay and resulting in extensive coral death. This is now recognised as a management task to rectify the hardening of the area.

Case Study 24 Sediments in Hawai'i, p. 86. Poor developments in many steep catchment areas have resulted in massive amounts of sediment clogging up rivers and running out over fringing reefs. While they had many laws and regulations, there was no clear chain of management responsibility. This is now their major task; to improve enforcement of existing laws to prevent damaging catchment modification.

Case Study 30 Townsville #1 Australia, p. 98. The City Council is redesigning all developments to include more areas to soak up rainwater, rather than forcing it out through storm water drains. However a balance is necessary to prevent localised flooding, therefore a substantial stormwater drainage system is necessary to prevent localised flooding.

9. (c) Protect riparian areas (strips of land bordering rivers and streams) by leaving trees, shrubs and grasses; or replant these riparian zones to reduce erosion of stream banks. A special case is revegetating the immediate coastal areas and sand dunes to prevent erosion from the sea, especially in the face of rising sea levels. Repairing riparian zones is covered in many Case Studies reported above in Recommendations #4 and #5.

Case Study 22 Houma Tonga. p. 82. The revegetation in Tonga has reduced coastal erosion from the sea by replacing lost trees and shrubs as a measure to reduce climate change erosion and salt spray over the farms and villages

9. (d) Revegetate stripped hillsides and abandoned farm lands. This is also covered in Recommendations #4 and 5 above. Case Studies 11, 21, 8, 10 & 25 p. 60, 80, 54, 58, & 88. Case studies from San Andres, Palau, Pohnpei, Vanuatu, and Koh Tao have all focused on techniques to revegetate deforested areas. In the case of Koh Tao, Pohnpei and Vanuatu the hill slopes were very steep and often a multi-stage process was required to first stabilise the soils and prevent further erosion in gullies, then successive stages followed with the planting of rapidly growing grasses such as Vetiver, followed by shrubs and then trees. The last stage has potential economic benefits in that some of these trees can be harvested.

9. (e) Promote the use of rainwater tanks attached to houses and other buildings. This will reduce runoff, but more importantly reduce problems in drought periods and lower the costs involved in providing freshwater. Current climate change predictions are that there will be wider fluctuations in weather with the probability of longer dry periods followed by more intense rainfall. Be careful to prevent these tanks becoming breeding sites for mosquitoes and other animals.

Case Study 20 Takuvaine Cook Islands, p. 78. The government of the Cook Islands is promoting domestic rain water tanks for drinking water and growing taro, to reduce the pressure on the piped water system and the need to build more dams. Many Small Island States are encouraging domestic self sufficiency in water

collection and use, with the benefits of raising awareness of the costs of treating water and protecting valuable groundwater supplies.

Recommendation 10: Adapt catchment and coastal areas against climate change.

Most of the damaging effects of catchments to coral reefs listed in this book will be increased as the global climate continues to change. Therefore, the Recommendations 1 to 9 above should also be emphasised as climate change adaptation measures. You should find cost effective ways for this climate change adaptation and reinforce all the other measures to prevent damage from the catchment by emphasising that climate change will make things worse. However, care should not be taken to focus on future climate change effects at the expense of measures to improve catchment management now; however managing catchments for climate change may open funding opportunities.

Recommendations #1 to #9 will assist in adapting the catchment and coastal areas to the effects of climate change. Good management of catchment areas will reduce the damage in the future from climate change, especially from more unpredictable weather, increases in major storms, rises in sea levels and increasing temperatures in the atmosphere and sea.

Case study 32 Science & GBR, p. 102. *Management of water quality issues in the GBR (see also Case Studies # 29 & 31) is seen as an achievable (that is direct management we can actually do with available capacity and resources) way to increase the resilience of the GBR to ocean acidification and coral bleaching effects resulting from global climate change i.e. implementing many of the recommendations in 1 to 9 above.*

The major potential problems to catchment areas from climate change are:

- 10. (a)** more unpredictable weather in catchment areas;
- 10. (b)** increases in strong storms and severe weather events; see Recommendation (9. c) and *The Case Studies 17 in Fiji and 22 in Tonga specifically attempted to address accelerating climate change damage to coastal areas, by implementing sound catchment management.*
- 10. (c)** sea levels will continue to rise. See Recommendation (9. e) above about the installation of rainwater tanks. Sea level rise has the real risk of contaminating ground water with salty water; domestic tanks will provide a limited amount of water security.
- 10. (d)** temperatures will rise on land and in the waters; see all Recommendations about water runoff; and
- 10. (e)** ocean acidification will continue to increase; no specific Recommendations here.

Recommendation 11: Seek help from donors and the conventions.

As a manager of a coastal area, you should look for projects in your country that deal with catchment development and determine lessons from those and how these were organised and funded. There are a number of donor agencies and governments that have programs of catchment management; these may be able to assist, however the major international and UN agencies require that the requests come from national governments. The major ones are listed below.

Examine regional and international conventions that apply to coastal and catchment management to determine whether these can be applied to the problems arising from the catchment area and also whether they may provide advice on funding for remediation. The pertinent ones are also listed below.

There are also many international and regional NGOs that can assist with projects aimed at reducing damage to coastal areas from the catchment areas. These are also listed below:

Case study 11 San Andres Colombia. p. 60. *The archipelago had previously been declared as the Seaflower Biosphere Reserve by UNESCO; this provided some impetus for Colombia and many partners to reverse many years of damage to the islands and coral reefs.*

Case Study 32 Science & GBR, p. 102. *The power of the World Heritage Convention and the Australian Government's strong support for this convention and its implementation in Australia allowed a strong management response to pollution of the GBR. This may not have been the case without designation as a World Heritage Site.*

Case Studies: *almost all case studies in this book have received help from donors. In many cases the funding was relatively small, but specifically targeted at a problem that was clearly defined with a cost effective solution.*

There are many agencies and NGOs that focus on assisting developing countries implement effective catchment management, with one of the objectives preventing damage to coastal areas. The summaries below focus on those that have assisted in implementing the Case Studies in this book.

Major Funding Agencies and Networks

National and regional aid agencies often support projects in developing countries to enhance food security and alternative livelihoods, build capacity, and ensure sustainable environmental development of agriculture and fisheries. Check with your national contact points for the most appropriate agency.

These are some of the major national donors from the Case Studies:

- Australia (Australian Agency for International Development, AusAID, www.ausaid.gov.au);
- Europe (EuropeAid Development and Cooperation, <http://ec.europa.eu/europeaid>; and other European countries);
- Japan, (Japan International Cooperation Agency, JICA, www.jica.go.jp);
- New Zealand (New Zealand Aid Programme, NZAID, www.aid.govt.nz);
- USA (US Agency for International Development, USAID; www.usaid.gov).

The following agencies associated with the United Nations assist in catchment management. Following are some that have assisted in the Case Studies:

- World Bank, specifically the Environment Department (www.worldbank.org);
- Global Environment Facility, especially the Integrating Watershed and Coastal Areas Management Programme (www.thegef.org);
- UNEP, United Nations Environment Programme (www.unep.org) and UNEP GPA-Marine, Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (www.gpa.unep.org);
- UNDP United Nations Development Programme (www.undp.org);
- SPC Secretariat of the Pacific Community (www.spc.int).

In addition there are agencies associated with the Regional Seas Programme of UNEP, specifically:

- Secretariat of the Pacific Regional Environment Programme (SPREP, www.sprep.org);
- The Caribbean Environment Programme (www.cep.unep.org);
- Regional Coordinating Unit for East Asian Seas (EAS/RCU, www.unep.ch/regionalseas/regions/eas);
- South Asia Co-operative Environment Programme (SACEP, www.sacep.org);
- The Nairobi Convention for East Africa and nearby islands in the Indian Ocean (www.unep.org/nairobiconvention)

International Conventions for Catchment Management

Some of these international conventions below may be applicable in your area as justification for catchment management and also for the provision of technical and policy support. Each country has designated contact points within national government departments:

Ramsar – International Convention on Wetlands. This has special arrangements for tropical wetlands such as catchment areas, lagoon systems, estuaries, mangroves and coral reefs. Ramsar is particularly important for migratory species, especially birds, which use catchment area wetlands for feeding during migrations: www.ramsar.org.

CBD – Convention on Biological Diversity (and Jakarta Mandate). This is the major convention that can be applied for resource conservation and management. The focus is on reducing loss of species and by extension the maintenance of habitats. There are special working groups dealing with wetlands: www.cbd.int.

CITES – Convention on the International Trade in Endangered Species of Wild Fauna and Flora. This focuses on reducing the trade in endangered species including those that occur in catchment areas and wetlands. The convention can be used to assist tropical ecosystem management: www.cites.org.

World Heritage Convention – Convention for the Protection of the World Cultural and Natural Heritage. This is particularly important if there are areas in the catchment that have exceptional value for the world such as valuable ecosystems, or cultural sites etc.: <http://whc.unesco.org/>

CCC – Framework Convention on Climate Change. The implications of Global Climate Change on environments including catchments, wetlands and coasts with a special emphasis on island states is covered under the convention, with suggestions for remedial actions and political approaches to slow climate change threats: www.unfccc.int

Prominent NGOs involved in Catchment Management

Below are some of the international NGOs that have assisted in catchment management pertinent to this book:

- CI - Conservation International with head office in Washington DC, www.conservation.org;
- Caribbean SEA (Student Environmental Alliance) a Caribbean agency; www.caribbean-sea.org;
- ICRAN – International Coral Reef Action Network, based in Cambridge UK www.icran.org;
- IUCN – International Union for the Conservation of Nature with head office in Gland Switzerland and regional offices around the world, www.iucn.org;
- TNC – The Nature Conservancy with head office in Washington DC, and other offices elsewhere in the world, www.nature.org;
- Sustainable Agriculture Network (SAN) in Central America, www.rainforest-alliance.org/agriculture;
- WCS – Wildlife Conservation Society based in New York with scientists based throughout the world, www.wcs.org;
- NFWF – National Fish and Wildlife Foundation based in Washington DC, www.nfwf.org;
- WRI – World Resources Institute with head office in Washington DC, www.wri.org;
- WWF – World Wildlife Fund with head office in Gland Switzerland www.wwf.org, and regional offices around the world, especially in Washington DC, www.worldwildlife.org.

Case Study 1

COMBINING SCHOOL EDUCATION, ARTIFICIAL WETLANDS AND ECOTOURISM ON CURAÇAO, A SMALL CORAL ISLAND

MARY BETH SUTTON, PAUL HOETJES, RICKI HARRIS

The challenge

The task was to treat wastewater effectively in a small tourism resort built in 1958 where there is no available land for a standard treatment plant. The new owners of the Sunset Waters Beach Resort and the communities on the west coast of Curaçao, Netherlands Antilles, wanted to develop a 'green resort' and reverse the damage that poorly treated wastewater was causing on the coral reefs that were the main tourist attraction. Not only was there no spare land on this small island, there was also little available fresh water and the base was solid coral rock; so an underground sewage treatment system was not possible. These islands rely on tourism for about 85% of their gross domestic product, therefore any system had to be effective, inexpensive and not smelly, otherwise tourists would not come.

What was done?

The owners decided to build an above ground treatment 'wetland' instead of a pond, and put it in full view of the tourists to demonstrate environmentally friendly treatment. They wanted to replace the old method of piping the effluent directly out over the coral reefs. The bigger goal was to build a demonstration system for the island to show how easy it is to have an environmentally friendly treatment system. The side benefit was that they could use the recycled water to grow trees and flowers.

The wetland treatment plant was built of concrete blocks cemented onto the bedrock. The basin was 15 by 60 feet (5 m x 18 m) and divided into 4 compartments, two larger ones for the initial treatment and then two smaller for final purification. It was lined with an impermeable liner, and filled with coral rock (but not from the reef) to provide spaces for the water to flow through and surfaces where the microbes could grow. Some of the rock came from around the tourist resort, however more had to be trucked in from across the island. After testing with freshwater, resort sewage was pumped into the septic tank and a range of suitable plants were planted.

The other strategy was to involve local school children in the project as a lesson in conservation, hospitality management and also to spread the word around Curaçao. The resort assisted the government to conduct the first systematic study of the reefs to identify major breeding sites and sensitive zones. The Lee's Reef Project started with the installation of permanent moorings to prevent anchor damage to the corals. Teachers from the 5 district schools were hosted by the resort and trained in coral reef conservation and environmental education methods by Lee's Reef Project and Caribbean SEA (Student Environmental Alliance) teams. The goals were to: educate the younger children about coral reefs and the need for conservation; engage the secondary students in a sustainable development project to solve problems and monitor the process; reduce wastewater pollution on coral reefs; and raise teacher and community awareness about protecting their precious coral reef resources, so that native Curaçaoans would become the strongest advocates for reef protection.

How successful has it been?

The wastewater wetland has reduced water use and improved sewage treatment, which all helped protect the coral reef. The education program on the wetland for older students was particularly valuable because it included hands-on testing of the treatment efficiency and evaluation and testing of the best plants to grow in the wetland.

A key activity was to bring in an expert who had already designed and patented wastewater wetlands for towns and farms. Proof of success came when the resort manager, who was convinced it would fail, reported that the water coming out of the wetland was crystal clear and had no smell. This water is now used in landscaping and growing fruits and vegetables.

The other big success was with the children and the development of new teaching tools. These kids have become the best ambassadors for the technology and the need to conserve their coral reefs. The student classes asked: "How effective is the treatment? What plants grow best in the wetland and the gardens? Can vegetables be grown in the garden or should they be in irrigated land outside the wetland?" The students visited twice a month to check water quality and either put plants in the wetland or evaluated growth and health of existing plants. This included a banana tree that has produced fruit. The students effectively 'own' the wastewater garden. In addition, the intern coordinators of the project report that staghorn coral (*Acropora cervicornis*) is sprouting new growth in the formerly dead coral area where the sewage had been discharged.

The education project was expanded to include all of the schools in the district, and thanks to the Lee's Reef Project, the Sunset Waters Beach Resort became an outdoor classroom next to the beach and coral reef where they could go snorkeling. Teachers from across the island learnt how to teach using a variety of innovative methods. At the end of the school year, the teachers invited the families to the wetland project for a celebration of what they have accomplished.

The Senior Policy Advisor for the Netherlands Antilles Ministry of Environment and Health has visited the artificial wetland to assess progress and determine whether this technology can be used to increase the sustainability of tourism around the Netherlands Antilles. A conference for policy people from across the Netherlands Antilles is planned to demonstrate the environmental and economic benefits of wastewater cleaning and reuse.

Lessons learned and recommendations

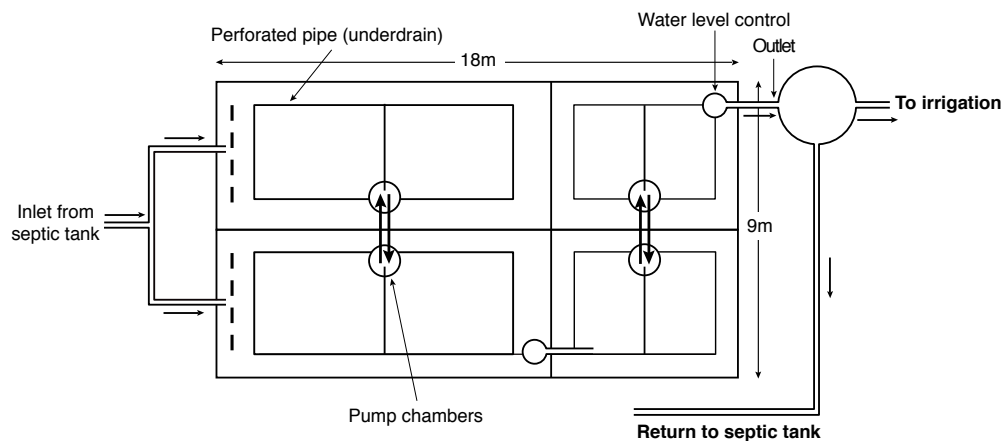
- Any household or business can install a suitable sized wetland to protect their coral reefs from nutrient and bacterial pollution;
- Decentralized sewage treatment is more cost effective and therefore more likely to be installed. It is also easier to operate and maintain;
- There is no fixed design for an artificial wetland. To be truly effective it should cost less than either piping sewage to a distant treatment system or pumping waste out into deep water; the staff and management readily recognize direct economic benefits, but this needs to be explained carefully;
- Continual evaluation and monitoring are important to assess progress on reducing nutrient and bacterial content, and determine whether changes to the design are needed;
- Another useful 'monitoring' method is provided by the tourists who walk past the wastewater wetland in front of the resort; if there are no complaints, then it is working well, and in fact, most comments were incredibly positive with the visitors donating funds to keep the project going;
- The education and training part was also assessed through feedback from the teachers and students, and modified to make it more efficient and also entertaining;
- This project succeeded because all stakeholders were involved either in developing the wetland or assessing the effectiveness. The stakeholders included teachers, school children and their parents, staff from other resorts, and policy people from the Ministry of Environment;
- Transparency and sharing of information throughout all the activities were important and the project received wide newspaper, radio and television coverage, and was reported in scuba diving magazines;
- But patience is necessary as it required 2 years of training and working with the teachers to get them comfortable with teaching the lessons of the project.

Contacts

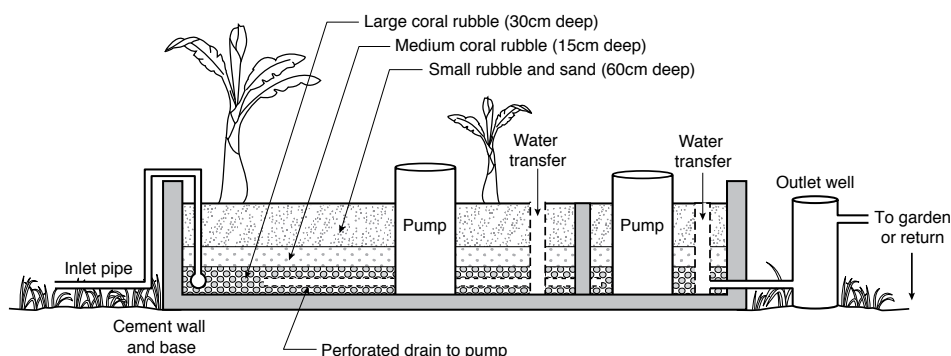
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A stylised plan view of the above-ground sewage treatment system showing the 2 sets of double chambers filled with coral rubble and sand, with the output water being used for watering lawns and gardens.



The cross section view illustrates a simple but effective system for treating sewage wastes while also growing a garden to remove some of the nutrients, improve appearance and also provide some bananas and flowers.

Case study 1

Case Study 2

SEWAGE TREATMENT USING ARTIFICIAL WETLANDS IN YUCATAN MÉXICO

PAUL SÁNCHEZ-NAVARRO, KATE RILEY AND EDITH SOSA

The challenge

Sewage was passing rapidly through the porous limestone and entering the ocean in Akumal, Mexico where it was damaging the coral reefs and seagrass beds. Because the Yucatan peninsula consists entirely of limestone, there are no surface rivers and all water and pollution passes through the limestone into underground rivers that drain rapidly and directly into the ocean. The overall objective of the project was to reduce the amount of untreated sewage and other domestic waste water that was flowing out to the coral reefs and seagrass beds. This area is also a major tourist area largely because of the easy access to coral reefs that grow just off the beaches. Thus the immediate task was to construct artificial 'wetlands' as cheap and efficient treatment systems for toilet and shower waste water. But first they needed to make the local people aware of the problem and get them to seek possible solutions. They needed a demonstration site of how an effective toilet and shower system can function. They achieved this by cleaning up an existing 'wetland' and showing that the polluted water was not passing through the limestone out to the nearby coral reefs.

What was done?

The Yucatan Environmental Foundation for Centro Ecológico Akumal built demonstration composting toilets and constructed and maintained artificial wetlands. They used a property owned by Centro Ukana I Akumal (CUIA), known as Centro Ecológico Akumal (CEA), where there were staff employed who could guarantee proper maintenance of the facilities over the long-term. The work started with remodeling an existing toilet into a composting toilet for women, and building a toilet for men. These served as effective demonstration sites, but only provided that there was proper maintenance.

They then cleaned up an artificial wetland that had been built to treat wastewater from the showers at a local dive shop. Originally the wetland was not functioning efficiently, so the first step was an extensive clean up and maintenance in this artificial wetland. Construction was begun of another wetland that will be connected to the septic tank that serves the rooms that house program volunteers, researchers and staff working at CEA; this was fully operational in July 2009, after help from a local foundation.

How successful has it been?

Within 36 months, the new facilities were effective in treating 100% of the wastewater from toilets and showers, thereby protecting the health of people who use the beach and preventing contamination of the coast and offshore coral reefs. The biggest value was in being able to promote the system to property owners, property managers, real estate agents, architects and local authorities illustrating that simple and effective alternative technologies can be used to treat wastewater at relatively low cost of construction and maintenance (see Case Studies 1,3 & 26 for examples).

At first, there was direct involvement of 5% of targeted participants in a workshop at the start of the project. These included the construction team, local authorities and the president of the Construction Infrastructure Architects Academy, who was able to inform and influence many other architects in the region. CEA now actively promotes this technology because they are gaining direct benefits from the wastewater treatment installations which are on private property, but used by the public, including local residents, as well as Mexican and foreign tourists.

It was difficult to find a demonstration site because many potential locations, such as kindergartens and schools, were not willing to maintain the facilities after construction. Therefore, the CEA property was selected because they could guarantee ongoing maintenance. Now owners of local businesses are reporting widespread acceptance of these with public bathrooms even though they have open pits. A major advantage is that there are no unpleasant smells when these facilities are well-managed.

Yucatan Environmental Foundation monitored the water quality from the artificial wetland each month to demonstrate that it is effective. These data were shared with all stakeholders. Now dormitories are being built by CEA with all the wastewater being treated in artificial wetlands. The monitoring also includes measuring the quantity and nature of the wastewater to demonstrate that these technologies can serve communities that do not have wastewater treatment plants. They plan to determine how many other institutions and communities would be able use these technologies on their properties.

The construction of these installations has been incorporated into the local Akumal sewage treatment system, directly complementing the water quality program of Centro Ecológico Akumal. This is especially important as there are no Municipal sewage treatment systems in Akumal. The success of this project is by promoting better management of wastewater in small communities, such as Akumal, that lack municipal services or have inefficient systems for wastewater

treatment. Moreover, the effective handling of wastewater and organic wastes that occurs with these alternative technologies is benefiting the environment now and in the long-term by protecting the underground aquifers and reducing contamination downstream.

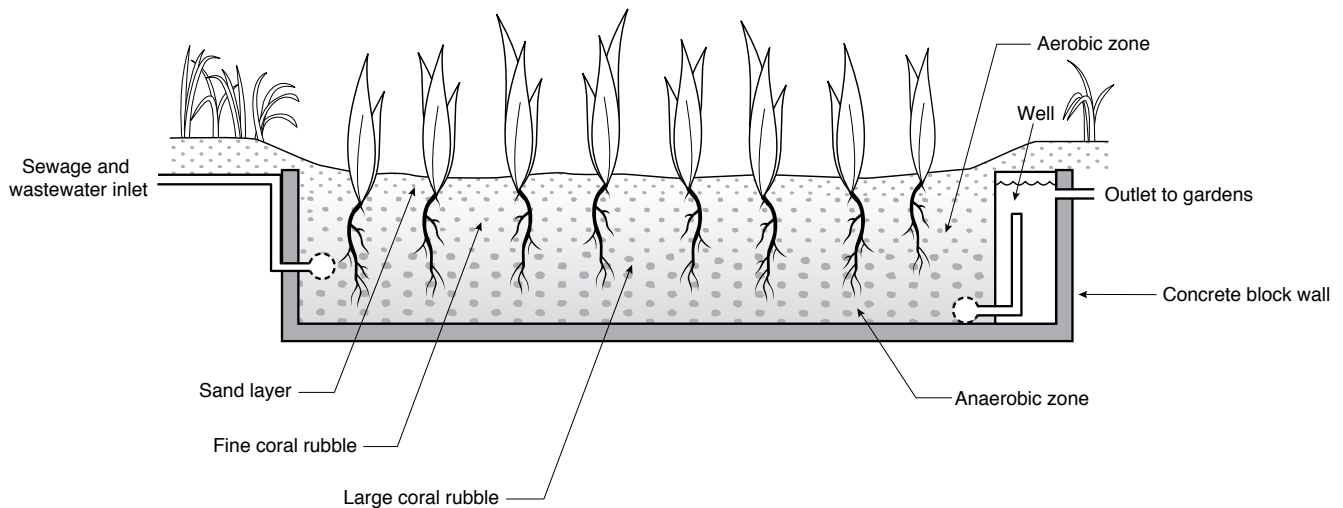
These facilities, however, have limited treatment capacity, and will need to be expanded to cater for more people. Eventually when these areas are served by municipal sewage treatment systems, these alternative technologies will be retained as demonstration facilities for other areas without wastewater treatment.

Lessons learned and recommendations

- It is far more effective to demonstrate wastewater treatment using demonstration sites, even small ones, rather than talking or providing literature. Now state government and local communities want to use composting toilets connected to artificial wetlands;
- The artificial wetlands are cheap to build and do not require extensive maintenance (see photographs on www.ceakumal.org);
- This wetland technology has been promoted to state government committees for watershed protection through presentations, brochures and formal and informal personal communication;
- The Potable Water and Sewer Commission is now interested in using artificial wetlands for wastewater treatment in small and remote towns that lack sewage treatment services;
- Moreover, homeowners in new developments, small hotels and people from other Mexican states are requesting help to construct wetlands on their properties;
- The demonstrations have directly influenced state government policies for wastewater treatment in communities with no treatment facilities;
- Monitoring is important to show that the wetlands do clean up the water. It is essential that the monitoring data are shared with the communities, especially those who directly maintain the systems;
- Community members see the benefits because they draw water for laundry, cooking and drinking directly from the underground aquifers. The improved treatment will potentially reduce disease transmission from contaminated water; and
- There are benefits for the tourism industry because the water is cleaner around the beaches and on the coral reefs. This will have economic benefits in the future for little direct cost.

Contacts

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This is a simple water treatment wetland that can be built to any size depending on the volume of wastewater entering from toilets and showers. The tank is first filled with coarse coral rock and rubble and then progressive layers of finer rubble are added until the top layer is predominantly sand. The system breaks down organic wastes aerobically and anaerobically in the sand and rubble and the plants take up nitrogen and phosphorous wastes. Cleaner water coming out the other end can be used to water gardens or flush toilets.

Case Study 3

PUBLIC TOILET AND WASTEWATER TREATMENT ON THE BEACH IN MERO VILLAGE, DOMINICA

MARY BETH SUTTON, LES BEHREND, ADLER HAMLET

The challenge

The coral reefs off Mero Village on the West side of the island of Dominica were being damaged by sewage wastes from a small village which now has a large population of Haitian immigrants. The main beach of Mero is used for celebrations, and on weekends several thousand people might come to swim in these waters. The reefs are also important for fishermen, nature based tourism, and coastline protection. However, most houses in the village do not have indoor plumbing and therefore the public toilet and showers next to the beach are very important to the village. However, these facilities were built more than 50 years ago and the toilets did not function properly, so most people would not use them. Instead, these folks chose to defecate directly in the bush, on the beach, in the river, or into plastic bags which they threw into the sea, or into night toilet bowls which were emptied just off the beach. Even the underground soakaways from septic tanks were at beach level and drained directly into the sea.

The other big problem was that the only real sewerage system on the island simply collected the wastewater and piped it directly out to the coral reefs. The fishermen could see that the sewage was killing the reefs, so they believed that sewage treatment is a bad thing since the collection system was termed 'sewage treatment'. Previously, the local population was small, such there was not much damage to the reefs from the small amount of pollution coming from the open street drains that channelled the sewage out to sea. But now, one of the most popular reefs, 'Champagne', is becoming damaged because it is popular with tourists and fishers, and also because of the drainage from the bathrooms which have been constructed for the surge in visitation. Changes in perception and practice were needed.

What was done?

The Rotary Club of Dominica and the Rotary Club of Conyers, Georgia, USA collaborated with Caribbean SEA (Student Environmental Alliance) and gained funding from the Rotary Foundation to rebuild the public toilet and construct an artificial wetland for wastewater treatment since the soakaway systems on the beach were not working properly. When the Mero Enhancement Committee was asked whether they would accept being a demonstration site for a constructed wetland technology for Dominica, they immediately became enthusiastic partners. Villagers were employed throughout construction under the guidance of the lead Rotarians and Dr. Les Behrends, a wetland designer. Caribbean SEA also engaged the children while the wetland was being built to emphasize the need for sewage treatment and to raise awareness about protection of the reefs via treatment of the sewage. The local students were also taken on field trips and given lessons about protecting the water from 'Ridge to Reef', especially on working with environmental health officers to monitor the effectiveness of the wetland.

The wetland is a simple 3 compartment system with dimensions of approximately 10 by 24 feet total (3m x 7m). Each cell has an impermeable rubber liner and is infilled with layers of rock. The young people of the village are planting the wetland, but since it is next to the sea, they are trying to find the best and most beautiful plants that can also withstand salt spray. Within 2 months, the students found a 98% reduction in *E coli* in water flowing out of the septic system.

How successful has it been?

The Mero Enhancement Committee contracted with a local radio personality to advertise the new cleanliness of the water around Mero. Part of the catchy tune included the phrase "no more faeces for our fishes"! The awareness building has already become quite successful.

The collaboration between the Rotary clubs, the villagers and Les Behrends has added to the awareness by ensuring that the facility is now 'owned' by the village. The villagers themselves raised enough money to pay for one toilet in the new facility. They were full participants! One man who sells tourist souvenirs and snacks from a hut on the beach next to the wetland has been involved in every step of the process and is very determined to make sure the wetland is taken care of by the locals. Ownership was officially passed to the villagers in July 2010 at a formal Rotary ceremony and their involvement has been overwhelmingly positive.

The community is now being encouraged to empty their night toilet bowls into the public toilet, and not into the sea. Similarly it is hoped that the use of plastic bags will stop with no more of these floating 'jellyfish' just off the swimming beach.

Lessons learned and recommendations

- Constructed wetlands can even function at sea level. Small decentralized sewage treatment systems can be very effective at improving water quality;
- Partnership with and engagement of village leaders and the community is essential;
- Involving the children makes the community even more receptive and involved. The community must own the project or it will fall into disrepair;
- Patience is especially important in a collaborative project. Building a public toilet may seem to be a simple project, engaging all stakeholders to get it started sometimes takes longer than planned. But in the end, the sum is greater than the parts since everyone has played a role in making it happen, from the kids to the international experts!
- Awareness raising is essential. Everyone, local business leaders to the youth, needs to understand the connection between what happens on land to the health of the reefs. You must be willing to talk about 'poo';
- Awareness raising among the fishers was important to reverse their previous impression that the sewerage system was the cause of the problem;
- Toilets and wetlands on the beach must be able to withstand an occasional inundation with sea water. Therefore it is essential to select the systems carefully and monitor the wetland after storm events to determine whether it is still working;
- The leaders were proud that Mero village was chosen as a demonstration site. They know this will also attract more people to their village and help their economy. They also know that cleaning up the water will bring more tourists; and
- Pollution from the land is controllable and the benefits are cleaner reefs for the community, fishers and tourists; and a better economy and health for all.

Contacts

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The community proudly accepted responsibility for the wetland after a handover from the Rotary clubs and Caribbean SEA.



Local school children have selected salt tolerant plants and planted them into the beach level wetland that is now treating sewage and wastewater from communal showers.

Case Study 4

INCENTIVES FOR KEEPING PIG WASTE OUT OF THE RIVER IN ST LUCIA, LESSER ANTILLES

MARY BETH SUTTON, CORNELIUS ISAAC, SONIA CAZAUBON

The challenge

When the banana market in St. Lucia collapsed because of the loss of favoured nation trading status with Europe, the farmers in the primary agricultural watershed, the Mabouya Valley began to raise pigs to supplement their income. During the last 5 years, there has been an exponential increase in pig production in the Mabouya Valley and growth shows no sign of slowing. Most piggeries have been located on the banks of rivers and streams with all the waste being washed directly into the waterways. In addition to the pig waste, the septic systems in many households do not function properly due to the lack of soil depth, so that wastewater flows over the rocks into the rivers and streams. Also there is considerable erosion from the banana fields. Therefore the large amounts of sediment, pig wastes and sewage were all flowing out to the sea over the coral reefs which were a critical resource for the tourist economy and the local food supply. Something had to be done to clean up the ecosystem.

Concentrations of the faecal indicator bacterium, *E. coli* (*Escherichia coli*), increased considerably in the rivers and have been measured at over 200,000 colony forming units per 100 ml in some places. During the drought in the winter of 2010, the lack of piped water meant that people were forced to use the rivers for their drinking water, bathing, and washing. There was an immediate major outbreak of intestinal illnesses. Therefore, the problem expanded to one of human health as well as a coral reef health. Much of the St Lucian economy depends on healthy coral reefs and coastal waters to attract tourists; therefore it was essential to find ways of reducing pollution from pig wastes that were damaging the coral. The reefs also provide subsistence living for many families in poor villages on the coast. The nutrient laden water has also caused algal cover to increase to the extent that the Soufriere Marine Management Agency officials are studying control of algae and assessing the species covering the reefs using Reef Check surveys.

What was done?

The UN sponsored program, Integrating Watersheds and Coastal Areas Management (IWCAM), funded a demonstration project in the Mabouya Valley targeted at the high rate of gastric illness as well as the pollution of the water. The goal was to involve the people of these communities to be a part of the solution, with the long term goal of creating a community based NGO to oversee the environmental monitoring and improvements. Many different ideas were offered during meetings with the community and pig farmers; many more ideas evolved through further conversation. IWCAM first built a model artificial wetland to demonstrate an easy method to treat household wastes. We saw the need to provide the pig farmers with an economic return for investing in pig waste management in addition to the incentive of keeping the water clean. Pig waste collection systems and biogas digesters were constructed for one farmer in Mabouya Valley and another in Fond St Jacques (directly upstream of the Soufriere Marine Management Area). These digesters are simple models using materials procured on island and give the farmers methane gas for cooking and lighting. In addition, the digested waste solids are excellent fertiliser for their crops. For another farmer in Mabouya Valley, a collection system and composter was constructed with the additional incentive of a maintenance contract with vegetable farmers downstream to help maintain his waste system in return for having cleaner water for their vegetables. Since economic incentives motivate most people, it is anticipated that these installations will be maintained over the long term. After the projects began in 2009, the Ministry of Agriculture became very interested and has now sponsored three additional biogas digesters on the island. We have used the models designed by the Santa Fe Women's Group in Rural Costa Rica, www.ruralcostarica.com/biodigester.html. In St. Lucia, we have used both the concrete holding tank with plastic cover and the Ministry of Agriculture has used tubular structures. While the first was more complicated to build, it has a longer life span.

Students from the community have been monitoring the water quality to check the effectiveness of the installations. When the guys at the local bar see young people acting as the stewards and monitors, they take note. Their own kids are telling them that they don't want to swim in or drink 'pig poo' and are proving these installations are effective.

How successful has it been?

While these systems are relatively new, there has already been a reduction in *E. coli* in the rivers. Long term success will mean less bacteria and nutrients flowing out to the sea to grow algae on the reefs, a big issue on the nearshore reefs of St Lucia. While these digesters were only constructed in 2009-2010, we are already seeing a reduction in nutrient loading in the river, so we expect to see the nutrient and bacterial loading on the reefs also declining.

More farmers are interested in the installations and have requested assistance. If we can continue to provide incentives for pig waste management, the farmers will not pour it into the river. The digesters were funded through the National Fish and Wildlife Foundation in the USA, the UN GEF Small Grants program, and the Food and Agriculture Organization of the UN in cooperation with the St. Lucia Ministry of Forestry, Fisheries, and Agriculture.

The farmers are discovering pig waste is a product they can use or sell after it is composted. Using this compost allows the banana farmers to use fewer inorganic fertilisers and therefore gets them a higher price for bananas through the Fair Trade market system. Having the community kids monitor the water improves effectiveness since their kids are the ones making sure things are working effectively. They don't want to have their own kids report back that the *E. coli* concentrations suddenly went up!

Lessons learned and recommendations

- Incentives, particularly economic ones, can encourage farmers to manage their pig wastes better and not pour it in the river;
- Communication and demonstrations of best practice encourage other farmers to get involved;
- Monitoring the effectiveness of the installations by the kids gives even more incentives to the farmers to do it right;
- Contracts between pig farmers and vegetable farmers not only gets them communicating with each other better, it also makes them help each other.
- Awareness building is essential. From the local business leaders to the young people, everyone needs to understand the connection between what happens on land and the health of the reefs. You must be willing to talk about 'poo'.
- Small decentralized sewage treatment systems can be very effective at improving water quality.
- Land based sources of pollution are controllable and if we control them, the impact of climate change on our reefs may not be as severe.

Contacts

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The Soufriere Marine Management Agency and Caribbean Student Environment Alliance worked with pig farmers to reduce pollution of the Soufriere coral reefs in St. Lucia. They assisted them to build these pig waste digesting systems which also produce excellent compost fertiliser for sale. The wastes flow first into a small mixing chamber at the far end, and then into the concrete block or plastic tube digester. The slurry is mixed inside the digester by a simple plastic jug on a rope which was set in the construction phase. The mixing ensures the methane can escape into the plastic cover and through the PVC piping at the top; this is piped into the farmer's kitchen. They do not need to purchase cooking fuel and use gas lights to reduce electricity charges. The next goal is to provide small methane powered electricity generators as an additional incentive.

Case Study 5

WATERSHED-BASED THREAT ANALYSIS FOR THE MESOAMERICAN REEF: USING THE POWER OF SATELLITES AND GIS TECHNOLOGY TO TRACK PROBLEMS

LAURETTA BURKE AND ZACHARY SUGG

The challenge

Road construction and agriculture in Mexico, Belize, Guatemala, and Honduras have increased flows of sediments, nutrients, and other pollutants into the 1,000 km Mesoamerican Reef (MAR). These have damaged the coral reefs and more threats are pending as land clearing moves higher up the steep slopes into more easily eroding soils. There are more than 300,000 hectares of banana, oil palm, sugar cane, citrus, and pineapple farms from which sediments, fertilisers and pesticide residues drain through rivers and streams into the Caribbean. The release of sediments has been exacerbated by heavy rainfall during particularly strong and recent hurricanes, especially Mitch in 1998. The sediments reduce light for photosynthesis and cover the bottom, preventing new coral settlement; the increased nutrients stimulate the growth of macroalgae.

The problem with attempting to reduce sediment flows in such a large area was to determine where to focus efforts on cleaning up the largest sources of sediment pollution with the limited capacity in these countries. A well designed and geographically targeted assessment of the problem was needed before any attempts at improving land-use practices. Therefore it was decided to use the latest satellite images and computer analysis technology to pinpoint the sources of the sediments and where they were flowing to.

What was done?

A comprehensive analysis of watershed-based threats from agriculture along the MAR was led by the World Resources Institute (WRI) within the International Coral Reef Action Network (ICRAN) Mesoamerican Reef (MAR) partnership. They estimated impacts of human changes to the landscape to assist in land-use planning, agricultural policy and practice, conservation priority setting, and coastal threat mitigation efforts. The analysis includes evaluation of future threats using scenarios of future land use in watersheds across the region developed by the UNEP World Conservation Monitoring Centre. The World Wildlife Fund (WWF) worked with agricultural businesses in the region to implement better management practices to reduce sediment, nutrient, and toxic pollutant delivery to coastal waters (Case Studies 12 & 13; p. 62 & 64).

WRI and partners modeled erosion and pollution coming from more than 400 watersheds (catchments) across the region. They estimated: sediment and nutrient (nitrogen and phosphorous) concentrations coming from each plot of land; eroded sediments and nutrients reaching the river mouth (coastal discharge point); and sediments reaching the reef. They also estimated the increase in sediment and nutrient delivery from human activities now, and predictions for 2025 under varying land-use scenarios. This watershed analysis provided information and tools to examine the potential impact of different land uses and development options, and the downstream impacts on water quality. The project objectives were to:

- Link patterns of land use within watersheds to the impacts on coral reefs, and identify reefs at greatest risk of degradation;
- Identify watersheds most vulnerable to erosion which contribute the most sediment and pollution to coastal waters;
- Adapt tools to forecast potential trends, evaluate different policy or development options, and facilitate improved land management within the region;
- Evaluate sediment transport to the reef using an ocean circulation model for the MAR; and
- Use the results of the models and diagnostic tools to help educate and encourage key stakeholders to adopt 'better management practices' to reduce impacts on the coastal and marine resources.

The analysis showed that the Ulua watershed in Honduras was the largest source of sediment, nitrogen and phosphorous of 400 watersheds across the MAR region. Other rivers contributing significant sediment and nutrients loads were the Patuca (Honduras), Motagua (Guatemala and Honduras), Aguan (Honduras), Dulce (Guatemala), Belize River (Belize), and Tinto o Negro (Honduras). The models show that more than 80% of sediment and 50% of all nutrients come from Honduras; Guatemala catchments contribute about 17% of sediments and 25% of the nutrients flow into the Caribbean. River flows from Belize and Mexico were substantially less, but still threatened the reefs.

How successful has it been?

This information was used to recommend best management practices to reduce erosion and pollution. The analysis identified the vulnerable areas where poor land use has been contributing large amounts of sediments. It also identified those areas where future land use will increase erosion and should be avoided, or where better agricultural and conservation practices should be implemented, especially in high erosion and nutrient runoff areas. Early results show that pollution in the region is being reduced: with sustainable forestry management and integrated watershed management in Guatemala; improved land use planning, reforestation and soil conservation programs in Honduras; and similar initiatives in Belize and Mexico. The results are being widely disseminated via CDs and over the Internet to guide policy interventions, including the implementation of improved agriculture management practices for banana, citrus, pineapple and sugar cane farms recommended by WWF and partners (Case Studies 12 & 13; p. 62 & 64). More than 20 people from 4 MAR countries have been trained in watershed analysis, specifically the NOAA Nonpoint-Source Pollution and Erosion Comparison Tool (N-SPECT) model and the WRI Relative Erosion Potential (REP) method. The goals are to implement a consistent region-wide analysis and train local people to apply them at higher resolution in smaller areas by including local measures. The projects also assessed water circulation to model and predict the transport of sediment in coastal waters.

Lessons learned and recommendations

- The big picture is valuable for priority setting. This watershed analysis was particularly valuable because it integrated a wide range of data, and adapted the models for an innovative and region-wide analysis;
- Broad-scale analysis offers less detail. A limitation was the lack of detail on crop type and agricultural management practices, which are often available for local areas. Therefore, the model can be expanded to refine local estimates by including higher resolution data for smaller areas, such as single watersheds. Similarly the model can use higher resolution data on slopes and land cover, including local soils and rainfall patterns;
- Reality is more complex than the model reflects. The N-SPECT model considers agriculture as a single category of land use and does not differentiate different crops or different land management practices e.g. the influence of different tillage practices or nutrient application regimes is not captured. This is an important limitation of N-SPECT, which will be improved in the future. This improvement would require detailed information on how each practice influences erosion rates and pollutant runoff and then evaluate reductions by treating each management intervention on each land cover type separately. For example, citrus trees with cover crops planted to reduce erosion could be a separate category.
- N-SPECT is free, but not perfect. It is recommended as a tool to analyse erosion, nutrient runoff, sediment and nutrient delivery because: it is user-friendly; free in the public domain; and works with available GIS software. However, N-SPECT does not account for sediment and pollutant loss in the rivers, and overestimates sediment and nutrient delivery at the coast. N-SPECT outputs can be improved by calibrating the results with field measurements of river discharge, sediment and pollutant delivery taken near the river mouth; and
- Broad scale modeling of erosion and sediment and nutrient delivery to coastal waters was valuable to set priorities in this region. The information base can be improved by adding agricultural land use data and direct field measurements of erosion and nutrient runoff. This would help farmers improve soil management, and save money on fertilisers. It is now possible to view the models directly on Google Earth.

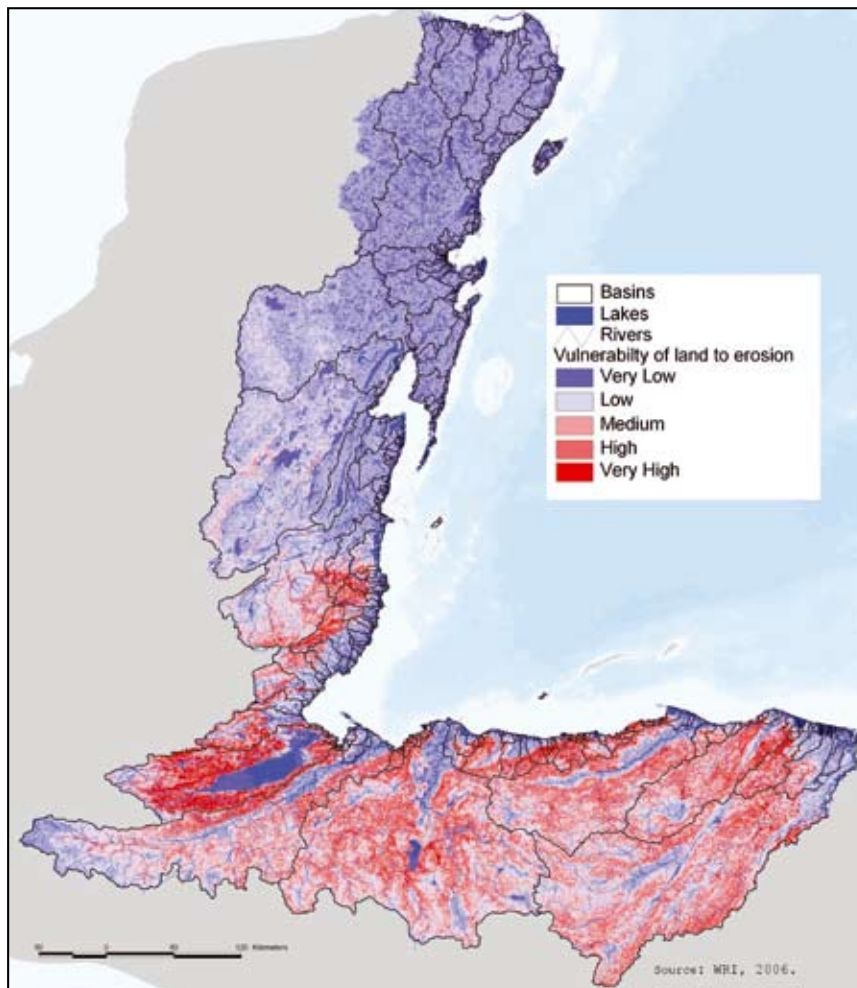
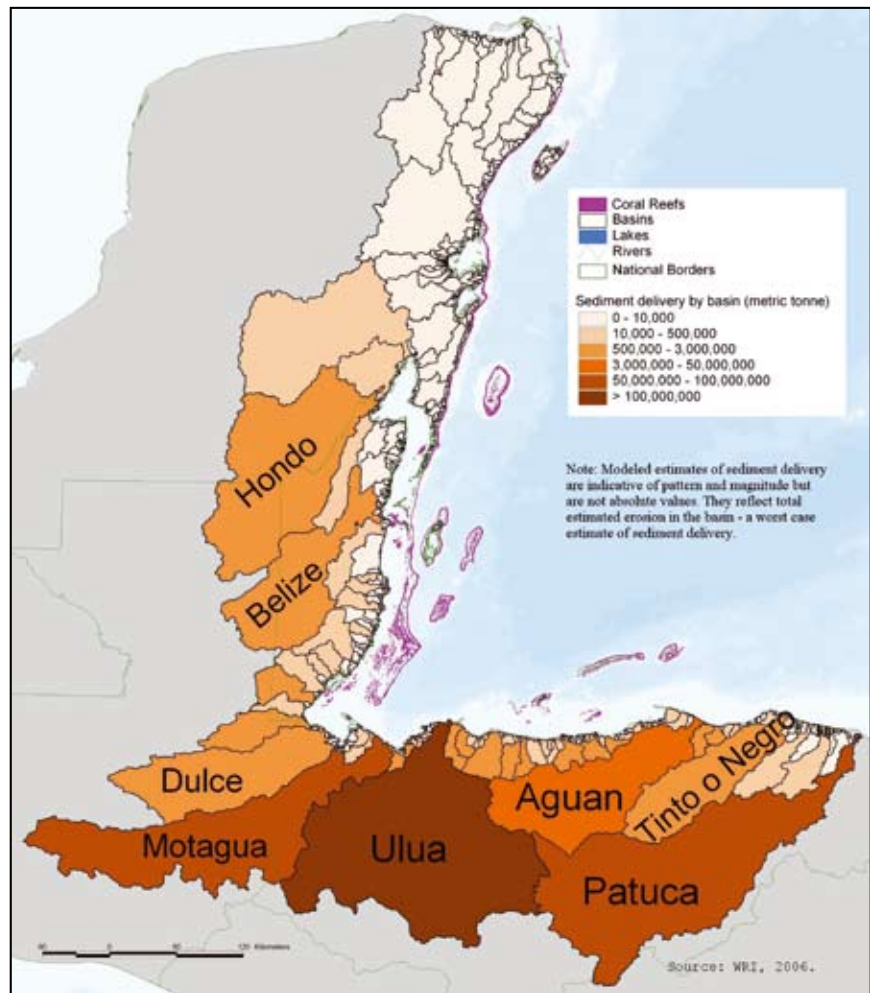
References

All spatial data, model results, maps and summary papers are available on the data CD, *Watershed Analysis for the Mesoamerican Reef* (WRI/ICRAN MAR project, 2006) available from the authors. All material can be downloaded from <http://www.wri.org/publication/watershed-analysis-mesoamerican-reef>

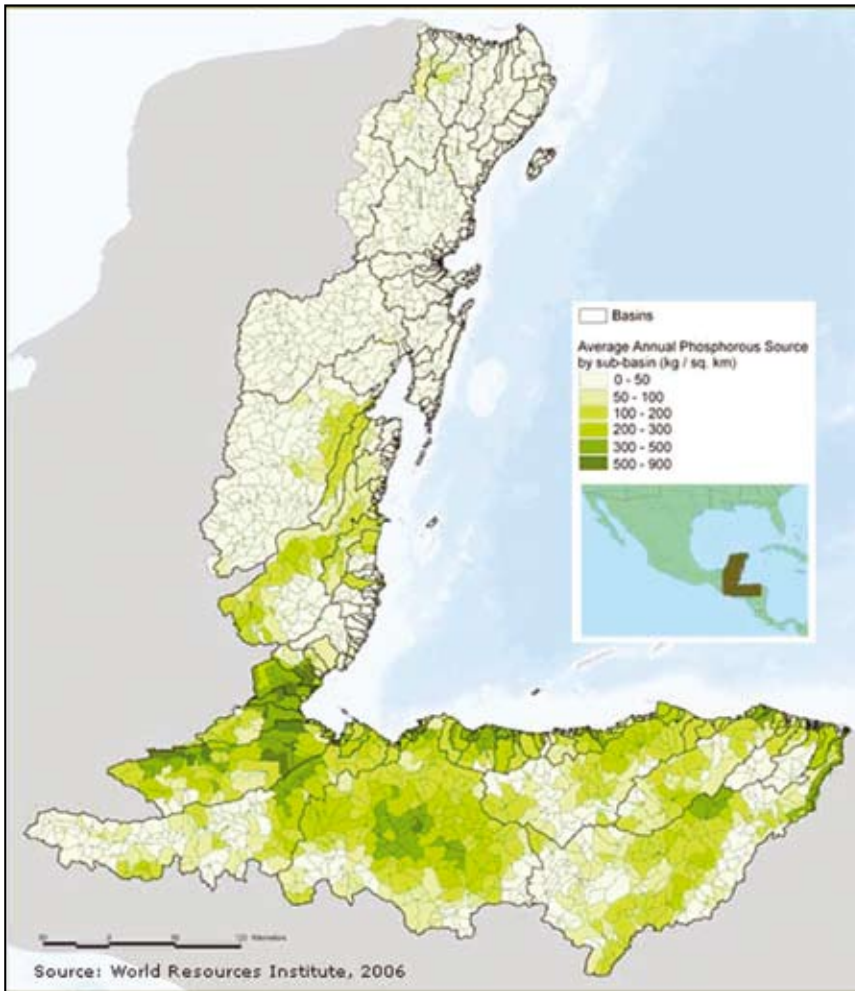
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Lauretta Burke, World Resources Institute, Washington, DC, Lauretta@wri.org; and Zachary Sugg, University of Arizona School of Geography and Development, Tucson, Arizona, zsugg@email.arizona.edu. Details: www.reefsatrisk.wri.org

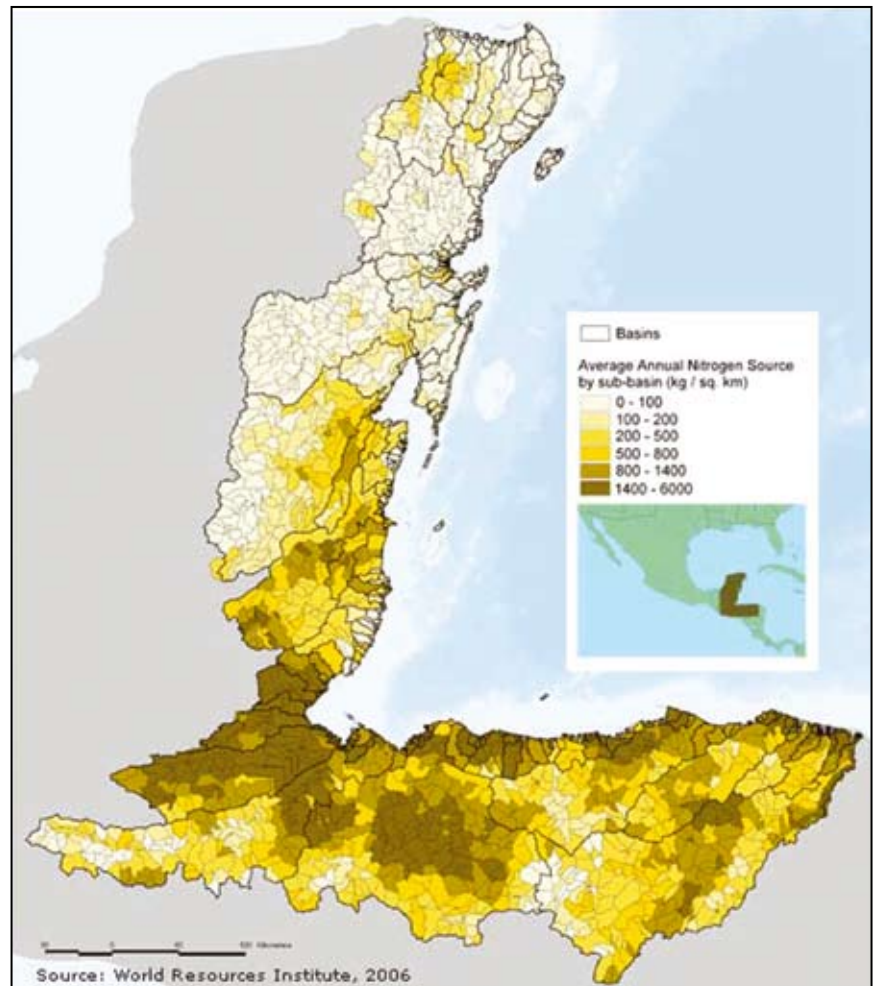
Sediment Delivery by Catchment. The GIS analysis of the major catchment areas in Central America shows the average annual sediment delivery to coastal waters and out to the Mesoamerican Reef. The darker colours indicate the greatest sediment flows come from the Ulua catchment in Honduras, at more than 100,000,000 tons per year, followed by the Patuca in Honduras and Motagua straddling the border of Honduras and Guatemala. Sediment flows from Belize are less, with virtually no sediments flowing from Yucatan areas of Mexico which contain predominantly limestone soils. This provides a clear indication where efforts should be focused to get maximum reduction in sediment flows to the reefs.



Vulnerability of Land to Erosion. The GIS analysis factored in slope of the land, vegetation cover and type, soil type, and long-term average rainfall for the peak rainfall month to determine the vulnerability of all land within the catchment to erosion. Areas with the highest vulnerability are shown in deep red. Areas across Honduras and Guatemala have very high vulnerability to erosion, which lead to the high sediment delivery estimates from the GIS calculations (shown as red and pink colours). These catchment areas contain steep slopes where the forests have been extensively cleared and replaced by banana, oil palm, sugar cane, citrus and pineapple farms. These areas are also exposed to high rainfall, especially during the relatively regular hurricanes; there were enormous sediment flows following the massive Hurricane Mitch in 1998. These two models show that more than 80% of sediment and 50% of all nutrients come from Honduras; Guatemala catchments contribute about 17% of sediments and 25% of the nutrient flows into the Caribbean.



Phosphorus and Nitrogen source by sub-basins. The GIS analysis also focused on many sub-basins in the catchment areas to assess the average annual flows of phosphorus (above) and nitrogen compounds (below) into the streams that drained into the major rivers. This fine scale analysis allows managers to identify the major sources of polluting nutrients at the scale of sub-basins as small as 6.25 hectares (15 acres). The nutrients are largely from fertilisers used in farming and either washed out in solution or adsorbed to sediment particles.



CaseStudy 6

CORAL REEF AND CATCHMENT MANAGEMENT IN TOBAGO: MONITORING REEFS FOR THE FUTURE

JENNIE MALLELA AND HYACINTH ARMSTRONG

The challenge

The coral reefs of Tobago (Trinidad and Tobago) are in the far south of the Caribbean and have developed naturally at the edge of the influence of large volumes of river sediment and nutrients from the Orinoco and Amazon rivers of South America. However, increased local runoff from catchment clearance for agriculture, coastal development and resultant nutrient pollution, erosion and poor land management practices have damaged these reefs. One of the main problems for reef managers in Tobago was that there was a distinct lack of good information from around the island that explained the reasons behind the problems that plagued the marine environment. Thus there was a need to create a reef monitoring programme that was rapid and relatively easy to use by all users (e.g. managers, scientists, volunteers, students), and was cost effective in a developing country, but also provided useful data for reef managers and scientists.

What was done?

The Buccoo Reef Trust (a local NGO), the University of the West Indies and Coral Cay Conservation obtained 3 year funding in 2006 under a GEF-funded Integrating Watershed and Coastal Areas Management Programme. They started a water quality and reef monitoring and assessment programme around Tobago in 2007.

The aim was to provide routine reef status information along permanent transects at key sites that were monitored using video cameras. They focused on measuring sedimentation rates, turbidity and light, live coral cover and macro algal cover, and the occurrence of disease and bleaching. They also put out tiles to measure coral recruitment and bioerosion at 6 sites around the island to assess rates of reef growth and destruction. This is important because pollution can reduce or stop coral recruitment and slow reef growth.

Coral Cay Conservation brought in volunteers to map the reefs around the island and provide a detailed baseline of the main resources; corals, fishes and invertebrates to support the long-term monitoring programme.

A critical assessment was done of water quality and the populations of near-shore filter feeding and grazing organisms, especially in intertidal sites. Funding also allowed them to collect samples to measure carbon and nitrogen stable isotope content to determine where sewage enrichment was coming from and to identify other sources of nutrients.

How successful has it been?

The reef assessments were a great success and yielded a vast and ongoing data set that is enabling a thorough assessment of reef health in Tobago. This allowed the scientists and resource managers to determine where the major problem areas were and the sources of the pollution that were resulting in poor water quality and damaging the reefs now and into the future. A Reef Check monitoring programme, using local dive operators, Fisheries and BRT staff, was established at initial survey sites to ensure that changes in reef health are captured over time and in a timely manner. Most importantly, the data are being used to raise awareness in the public and illustrate, using GIS based products, the far reaching consequences of poor management practices and the need to be vigilant in adjusting activities to ensure the reef environment is maintained.

An exciting initiative that highlights the positive impact of raising awareness is the construction and installation of an artificial wetland system in the Bon Accord area. This will treat wastewater discharged from a local fish processing plant that would otherwise discharge directly over the Buccoo Reef. Local communities have also been trained and are now actively involved in reforestation projects to reduce the damage from sediments from inland soil erosion. Additionally, the Tobago House of Assembly, the local governing body, has recognised the value of the information provided by these assessments and has drafted the 'Tobago Environmental Management Plan' which gives a more coordinated framework for management of Tobago's natural resources.

Lessons learned and recommendations

- It is essential to have reliable data to assess reef status and adjust the management procedures;
- In the small island of Tobago, the collaboration between NGOs, volunteers and scientists enabled them to gather a lot of data in a rapid and cost effective way;
- The techniques used were suitable for people with limited technical training and were also cost effective, however, they needed a scientist for the initial design, training, final analysis and interpretation;
- It was particularly beneficial to perform a rapid baseline survey of the reefs and key resources. The partners were able to use volunteers with limited technical experience, and give them rapid training to gather good baseline data around the island at the same time;

- However, rapid baseline assessments must be followed by long-term monitoring at key sites to demonstrate changes over time;
- Assessment of coral and algal cover and measuring sediment fallout provided good information on reef status, and the assessments of coral recruitment, calcification and bioerosion gave an indication of future reef health, which is also useful to managers;
- The use of stable isotopes can be beneficial, even if there are no analytical laboratories in country. If necessary, the samples can be collected, stored and sent away for analyses at a later date when the costs of these analyses become more affordable.
- Engage and empower local communities to take charge of and action in addressing island-wide issues from a local perspective.

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Contacts

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Death of *Mussismilia hispida* coral after arrival of the autumn sediment flows following heavy rains in Tamandare No Take Zone in Brazil (Case Study 14).



These satellite images of the Coral Coast Environmental Protection Area in northern Brazil show clean waters flowing over the Tamandaré No Take Zone (marked in red dots) in the dry season (left) but large sediment flows covering the reefs and threatening the corals in the wet season (Case Study 14).

The Coral Reef Initiatives for the Pacific (CRISP) program developed informative posters to illustrate the value of effective catchment management. Maintaining healthy rivers (top) ensures that many fish species can move between fresh and salt water for breeding (important in island food: emphasised in Case Study 18). Healthy natural forests (bottom) act as a sponge for heavy rain, and release it slowly to ease the threat of flooding. (From Leigh Anne Buliruarua, buliruarua_l@usp.ac.fj).



This view from the sea shows revegetated coastal forests in Houma, Tonga that now protect villages and farms from salt spray and erosion. Salt tolerant *Tournefortia* scrub grow in front, then *Pandanus* with rapid growing *Casuarina* at the back (Case Study 14).



Sediments flowing over coral reefs from small scale farming in Rarotonga Cook Islands; note the traditional fish traps on the reef flat (Case Study 19; photo Keri Hemman).



These two photos show red soil runoff from the Henan River mouth in Okinawa (right) and the same location before the pollution started (left) (Case Study 27).



Forest destruction on steep hillsides in Pohnpei, Federated States of Micronesia to grow sakau, a narcotic plant of the kava family. Sediments from these hillsides have damaged coral reefs in the lagoon (Case Study 8). Forest loss of 70% was measured using satellite images from 1975 to 2002 (Page 55).



This shows unintended damage from large scale engineering modification of catchment areas in Puerto Rico. Drainage from a nearby catchment area was diverted into the Guanica Bay Rio Loco catchment to improve water flows and generate electricity; however, sediments from the modified catchment have damaged some of the best reefs in Puerto Rico. These sediments have washed off steep hillsides (right) cleared for sun grown coffee (Case Study 7).

Case Study 7

THE GUÁNICA BAY RIO LOCO WATERSHED PROJECT IN PUERTO RICO

PAUL STURM, ROBERTO VIQUEIRA, TOM MOORE AND BETH DIEVENY

The challenge

Engineering and agriculture projects constructed to bring water and hydroelectric power to the south coast of Puerto Rico have artificially increased the Guánica Bay/Rio Loco watershed area by more than 50%. Now the watershed which drains into Guánica Bay is one of the largest in Southwest Puerto Rico and covers nearly 151 square miles (390 km²). This area includes the town of Yauco and part of the Lajas Valley agricultural region; offshore are some of the most extensive coral reefs in Puerto Rico. However, the status of these reefs have significantly declined over the past 30-40 years with estimates of live coral loss greater than 50%, including more than 90% of sensitive and federally listed *Acropora palmata* (elkhorn) and *Acropora cervicornis* (staghorn) corals. Nutrient and sediment pollution has increased 5-10 times since pre-colonial levels and several times more in the last 40-50 years.

A series of inter-watershed water transfers constructed in the 1950s are the primary reason behind the increase in drainage area. There are now 5 reservoirs including 4 that are not naturally part of the watershed as well as 2 hydroelectric plants. These systems bring drinking and irrigation water to the arid south coast from the high rainfall watersheds of the central Cordillera mountains. Urban development dominates the area surrounding the town of Yauco while agriculture dominates the Guánica and Lajas Valleys. Sun grown coffee and subsistence cropping are common on the highly erodible steep hillsides. The key task of this project was to reduce threats to the downstream coral reefs from this human altered watershed.

What was done?

The first actions were to assess historical watershed conditions to understand how the area has changed, including almost complete deforestation in the early 1900s and large areas of land dedicated to sugar cane agriculture in the 1950s and 60s. The team applied the Unified Stream Assessment and upland assessments methods developed by the Center for Watershed Protection and used water quality data and land use coefficients to develop GIS models of the catchment area. These efforts were assisted by detailed knowledge of pollution sources of local farmers and resource managers in the community.

These extensive contacts with the community helped develop trust amongst the local partners and assisted with access to important lands and identifying major point and non-point sources of pollution. GIS analysis was used to show the major areas of exposed soils and farmland; they also employed the Watershed Treatment Model to estimate nutrient and sediment budgets based on land use and anticipated benefits of control measures for improving water quality.

The Guánica watershed has extensive mountain forests in the north and extensive dry forests in the south. In the 1950s, engineering for the Southwest Water Project greatly increased the drainage area for the Rio Loco and included large areas of highly erodible soils where coffee was grown. The original Guánica lagoon (historically the largest body of freshwater in Puerto Rico) and wetlands were drained in the 1950s, which removed most of the nutrient and sediment filtering capacity of the watershed before the river flowed into Guánica Bay. Sediment flows were exacerbated when the steep slopes were cleared exposing soil to tropical rainfall and major hurricanes which occur every 10-20 years. Thus the export of sediment, nutrients and other contaminants has increased 5-10 times above natural levels; all this flows out to Guánica Bay and the nearshore coral reefs without the prior filtering by the wetlands.

Additionally, increasing sea-surface temperatures and resulting increases in coral bleaching and disease also threaten the area. These reefs have been significantly damaged by Caribbean wide coral bleaching in the past. However evidence suggests that coral reefs are more resistant to warmer waters if they are not exposed to high concentrations of inorganic nitrogen; increasing the importance of corrective actions in the face of climate change and higher ocean temperatures.

The fieldwork, GIS analysis and modeling showed the following:

1. Most of the upland erosion and reservoir sedimentation has come from highly erodible soil washing off high mountain coffee growing regions where high rainfall events dominate. This was made worse when government subsidy programs encouraged the replacement of shade grown coffee, to varieties grown with full sun in cleared areas;
2. Clear evidence of sediments being transported from historically adjacent watershed areas as a result of the engineering modifications;
3. Erosion of 'Legacy' sediment from stream channels where sediment was transported and deposited from the upper watershed during massive post-colonial deforestation, coffee and subsistence farming on steep slopes and recent urbanization. The extent of sediment deposition in Guánica Valley associated with the Rio Loco was partially due to past use of surface irrigation and low head dams which exacerbated deposition behind these obstructions;

4. The extent of the loss of historic wetlands and filtering capacity of Guánica Lagoon which originally covered 4-5 square miles (about 11.5 km²); and
5. Much of the nutrient load was due to sewage effluent from traditional wastewater treatment plants, leaky infrastructure, or non-existent systems. Many of these sources flow directly to the coast.

The first systematic report in 2008 showed large areas of seriously degraded coral reefs around Puerto Rico. This is largely due to increased sediment and nutrient discharge from human modified watersheds, eutrophication from sewage and agrochemical discharges, dredging, increased water temperatures and global warming. The worst damage was immediately offshore of large populations.

The project to restore nearshore coral reefs in Guánica, develop models for effective watershed management and build local capacity was established by the NOAA Coral Reef Conservation Program, and the Puerto Rico Department of Natural and Environmental Resources (DNER). The NOAA Center for Coastal Monitoring and Assessment (CCMA) has gathered baseline data on biological resources (e.g. fish, corals), chemical contaminants, nutrients and sedimentation rates, prior to proposed restoration activities. This baseline is essential to measure success of the project in restoring the coral reefs. The next steps include capacity development and project implementation. These activities to restore and protect the Guánica Bay/Rio Loco Watershed were initiated through the formation of partnerships between federal, state, local and NGO partners. The design and implementation of appropriate watershed restoration activities will be led by the Center for Watershed Protection (CWP) including local staff in Puerto Rico and the U.S Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS), Fish and Wildlife Service (FWS), National Fish and Wildlife Foundation, NOAA's Restoration Center, and the NOAA Coral Reef Conservation Program. The following tasks are to be undertaken to address critical issues:

- Converting sun grown to shade grown coffee with 650 acres converted in the first year, greatly reducing exposed soil cover;
- Developing stream buffers by re-establishing vegetation along the banks;
- Stabilizing eroding legacy sediments from the Rio Loco (funded by NRCS);
- Restoring the Guánica Lagoon, historically the largest freshwater wetlands and lagoon in Puerto Rico;
- Adding a wetland treatment system to the current waste water treatment plant in Guánica; and
- Developing smaller projects to correct problems through identifying and correcting sources of sewage and septic tank contamination.

Implementation of projects will be undertaken progressively as a multi-year, multi-partnership effort which combines federal resources, with NGOs, local resource managers and farmers to effectively deliver restoration practices often supported and driven by outreach to landowners and residents. This project is designed and funded within the objectives of the NOAA Coral Reef Conservation Program and the U.S. Coral Reef Task Force.

Lessons learned and recommendations

- Correcting problems resulting from major engineering modifications of the watershed are often complicated and very expensive. It is far better to avoid such problems by careful planning and consideration of all potential damage in the future by conducting effective Ecosystem Impact Assessments;
- Increasing local capacity by employing local collaborators, and developing trust through partnerships was a major contributor to project success;
- Developing multi-agency partnerships is essential to bring financial and technical resources to implement complex projects;
- A comprehensive approach is required for effective management including on-site best management practices (BMPs) and ecosystem scale restoration to restore lost ecosystem services through riparian reforestation, wetland and lagoon restoration, and reforestation associated with shade grown coffee;
- Baseline monitoring is needed to establish existing conditions and compare to future conditions; and
- Ongoing monitoring is needed to help identify source areas of pollution and determine success in reducing pollutant transport.

Contact

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For more information and a copy of the watershed plan and associated references; request access to the USEPA: Environmental Science Connector, specifically the Puerto Rico Coral Reefs page
http://oaspub.epa.gov/portal/page/portal/GENERAL_PAGE_GROUP/IAM_Self_Registration_Page

Case study 7

Case Study 8

CORAL REEF POLLUTION AND SEDIMENTATION REDUCTION IN POHNPEI: THE PROBLEM OF SAKAU AND UNSUSTAINABLE DEVELOPMENT

PATTERSON SHED

The challenge

The mountainous Micronesian island of Pohnpei has lost approximately 70% (based on 3 surveys conducted in 1975 at 42% loss, 1995 at 15% additional loss and 2002 at 13% more loss) of its native forests in the last 30 years because of population growth and an expanding cash economy. One of the biggest causes of loss is the commercial production of the plant kava or sakau (*Piper methysticum*), once used only for traditional ceremonies, but this mildly narcotic kava-like plant is mass-grown for recreational use by clearing old growth forests on steep mountain slopes. Therefore, large volumes of sediment are carried by the rapid flowing streams into the lagoon and onto the coral reefs. Already there is clear evidence of damage to the reefs, the lagoon waters are no longer clear and blue, and there is increased sediment on the floor of the lagoon.

Rapid population growth is also increasing organic pollution because untreated human and animal wastes pollute the lagoon and cause many gastrointestinal infections. Thus, the Conservation Society of Pohnpei (CSP) obtained funding from the National Fish and Wildlife Foundation (USA) to: raise awareness and develop community partnerships; improve forest management and enforce sustainable forestry practices; and stabilize the ground and reduce erosion by controlling invasive species.

The Wildlife Forest Reserve on the land is a significant conservation area protecting important biodiversity, and food and cultural resources that are important for all Pohnpeians. This reserve will continue to be a high priority area covering 15% of Pohnpei terrestrial resources (5,100 hectares). Effective conservation of the reserve will make a major contribution towards the goal of the Micronesia Challenge (MC) declared by the five Micronesia jurisdictions (Palau, FSM, RMI, Guam and CNMI) to conserve 20% of the terrestrial environment and 30% of near-shore marine resources by 2020.

What was done?

CSP's first task was to improve existing educational programs and train community volunteers to explain the environmental problems to schools and communities and get them involved in a small pollution reduction project. They specifically targeted the youth to improve chances of long-term and sustainable success. Posters were developed in English and Pohnpeian languages to educate the public. This had other benefits because it allowed CSP to expand into other avenues of nature conservation. The CSP developed the 'Green Road Show' to alert youth to environmental principles and provided mini-grants that challenged communities to address their specific pollution problems, such as watershed and forest management, and coral reef management.

The CSP trained 20 forest rangers and 2 contracted police officers to monitor forests to improve forest management and enforcement. The early monitoring was unreliable because the estimations of clearing size were inaccurate. Therefore the rangers were trained to use hand held GPS monitors to map forest clearings to improve enforcement. All the identified illegal forest clearings were notified to the Pohnpei State enforcement agency (Attorney General's office) for enforcement action.

A Pohnpei State Invasive Species Taskforce was organized in 2001 and they identified the 9 most invasive plant species in Pohnpei that invade abandoned forest clearings. Many of these plants rapidly invade abandoned forest clearings, however their weak root structure leads to soil instability and increased run-off. The Taskforce has successfully eradicated more than 85% of the most invasive species (*Piper auritum* or false sakau) which was resulting in considerable soil erosion. Following each forest monitoring exercise, the CSP field assistants visited each cleared area in the 5 municipalities and sprayed the invasive species with target specific herbicides. Through partnership with SPC plants and a pest expert Konrad Engleberger, CSP applied biological control for one of the species, *Chromolaena odorata* (Siam weed), which can be controlled using *Cecidochares connexa* (gall fly).

How successful has it been?

Efforts to enforce laws banning the clearing of forests were ineffective. While some progress was made to identify people who were clearing forests illegally, when the cases went to court, the punishment was minor. The monitoring by CSP identified many repeat violations in protected areas and provided details to the office of the Attorney General. But frequently no punitive or control action was taken; this was a critical reason why the legislative mechanism failed to stop forest clearing.

Therefore an alternative approach was attempted. The extent of information communicated to the public and stakeholders was the highlight of the project, with the community/youth outreach program reaching 6 communities and youth groups around Pohnpei. Each outreach group averaged 55 people, and the youth-to-youth environmental fair

brought together 400 primary school students, teachers, parents and government officials in 2006, and more than 500 people in 2007. There was extensive coverage of the environmental problems on radio stations and the local television channel, with more than 20 radio programs on watershed management, organic pollution, invasive species, mangroves and coral reefs. The CSP printed 247 posters about organic pollution in English and Pohnpeian languages for schools, partner agencies, and public places. This way they were able to reach almost 100% of the population of Pohnpei, as well as people in neighboring islands.

Thus awareness of the need to protect watersheds and support forest and coral reef conservation is increasing, and more communities are taking sincere interest and paying attention to reverse the threats and pressures that are occurring in the Wildlife Forest Reserve. As a result of the CSP project, a community (Pehleing, south of Pohnpei) recently approached CSP with a concept project that seeks support to reduce deforestation and sediment runoff due to forest clearing for sakau planting. Their aim was to begin by replanting native flora to re-establish the natural forest.

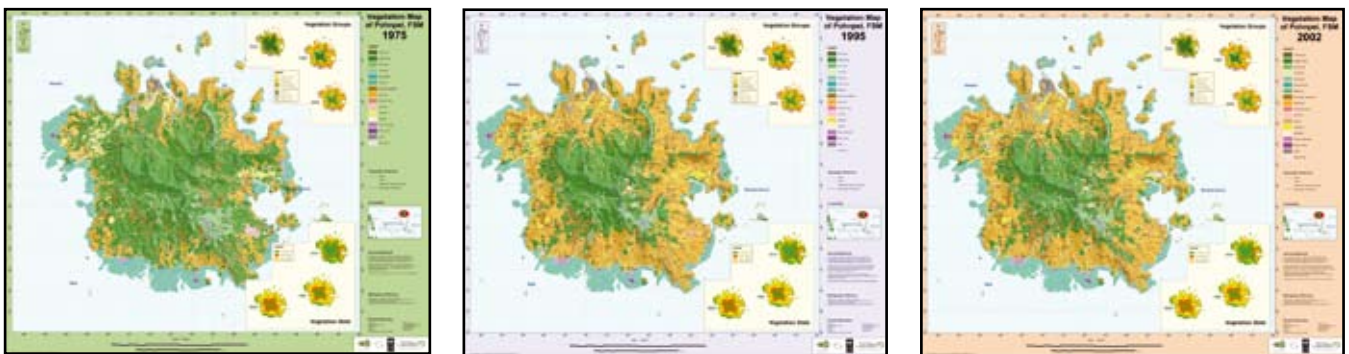
The recently declared Micronesia Challenge provides a mechanism to support greater control over illegal forest clearing, especially in protected areas. Under the Challenge, Micronesian countries have declared that they will effectively conserve 20% of their land resources by 2020. Thus, this should ensure that the Wildlife Forest Reserve is effectively conserved as it will assist FSM reach their 20% target. Similarly the Challenge declares that 30% of nearshore resources will also be conserved. Controlling sediment and other pollution will ensure that Pohnpei reefs and lagoons are in a sufficiently healthy state to warrant such protection.

Lessons learned and recommendations

- The Conservation Society of Pohnpei recognized that they must identify the major point sources of organic pollution from unsustainable coastal and hillside development that are causing damage to the coral reef lagoon;
- The failure of the legal enforcement mechanisms have demonstrated that the protocols to manage Pohnpei State's land use need to be reviewed and enforcement strengthened in the protected areas, especially in the upland forest areas;
- Some of the catchment damage occurred during approved development projects which commenced without proper environmental impact assessments;
- Education and awareness programs are essential parts of any conservation project to ensure long-term and short-term outcomes, especially by targeting schools;
- The environmental awareness education programs can effectively build support for conservation and resource management among citizens, especially the youth;
- It is essential to inform, and, where appropriate show, government officials, and especially traditional leaders, the extent of forest clearing for temporary agriculture and encroachment into declared protected areas. Frequently, however, little action follows;
- Unless the legal system cooperates by imposing appropriate penalties on people who knowingly and willfully break the laws, conservation measures to stop forest clearing and unsustainable agriculture will be ineffective. Making laws without applying adequate enforcement is counterproductive; and
- Co-management of resources and alternative income schemes are absolutely critical to conservation success.

Contacts

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These satellite images from 1975, 1995 and 2002 were used to measure approximately 70% loss of forest cover on Pohnpei in Micronesia; much of this was to grow sakau during the last 30 years.

Case Study 9

POHNPEI WATERSHED MANAGEMENT: RECONCILING TRADITIONAL AND MODERN LAW FOR SUSTAINABLE OUTCOMES

JUSTIN ROSE

The challenge

About 66% of the catchment area forests in Pohnpei have been degraded since the mid-1970s. This has caused severe downstream impacts with erosion on the steep hillsides sending sediments to smother the mangroves and coral reefs, as well as contaminate water supplies and threaten biodiversity. Pohnpei, the largest of the 4 states of the Federated States of Micronesia, has a population of around 30,000 in 200 villages within 5 municipalities. The primary cause of forest loss has been clearing of land for kava (sakau) production. Kava consumption has expanded beyond traditional ceremonial use to being a popular recreational substance and a major cash crop.

The problem was how to reduce the downstream damage to the forests and coral reefs, which are also very important in the Pohnpeian culture, while also recognizing traditional land ownership. This required a major education and awareness raising campaign that had to start with rethinking who was responsible for decisions about land use in communities.

What was done?

The first task was to understand the traditional authority structure in Pohnpei. There are 200 villages (kousapw) and 5 traditional kingdoms (wehi) where customary authority resides with the traditional titleholders. Their roles and responsibilities are allocated and organized within complex hierarchical systems that manage activities on land and along the coasts. The nahmwarki (paramount chief) is the symbolic owner of all land within a wehi, but the kousapw is the centre of social organisation and culture. Other men have traditional titles which are either hereditary or earned through community service or by demonstrating traditional skills and knowledge. Traditional titles are of great symbolic cultural value to Pohnpeians and can be lost if the leaders do not perform their duties adequately. There are also traditional titles concerning the management of natural resources (Sou Madau, 'Master of the Ocean'; and Souwel Lapalap, 'Great Master of the Forest').

With the coming of independence in the early 1980s, the new Pohnpei State Government maintained the western-style legal system introduced by the United States after World War II. This reflected the need for Pohnpei to operate within modern economic and political contexts, to focus on providing good governance and democracy, implementing effective administration and developing a respect for the rule of law. However, this resulted in direct conflicts with the traditional titleholders who have the authority for decision making over land use, and conservation and natural resource management. The paramount chiefs are often considered as the undisputed leaders of their wehi and decide all land use within the catchment forests, however these are notionally state government property.

The early attempts by government to mark out watershed boundaries failed. The villagers welcomed the 'Pohnpei Watershed Forest Reserve and Mangrove Protection Act of 1987' with 'guns and machetes'. They considered that this was "a government land grab in direct conflict with traditional Pohnpei resource use and authority". The subsequent response was to engage in extensive consultation and participatory planning to develop partnerships between government and communities for effective catchment management. This resulted in the 'Pohnpei Watershed Management Strategy 1996-2000' and the 'Pohnpei Community Conservation and Compatible Management Project 2000-2004' which were developed with support from the Global Environment Facility and the Nature Conservancy (TNC).

In 2001, the attempted legal reform at the state level collapsed due to a lack of consensus. So a co-management approach was attempted in the Madolenihmw Municipality, which resulted in the 'Madolenihmw Protected Areas Act' (MPA Act). This was a 'bottom-up' approach to forest, coastal and marine conservation. One of the senior titleholders reported "the greatest legacy of this process is that Pohnpeians are regaining control of their own resources".

The MPA Act was modeled on Samoan legislation which recognized village by-laws within the Samoan national fisheries law; this recognized a mix of traditional management arrangements and western approaches to fisheries management. In general, this MPA Act was found to be too complex for Pohnpeian municipal local governments with limited capacity, and it only functioned when TNC guided and facilitated the listing process.

How successful has it been?

The attempts at making formalised agreements for co-management between municipalities and the state government were abandoned; but the traditional leaders agreed that something had to be done and they marked out a critical watershed boundary line in Madolenihmw. As a result kava planting above the line has been significantly reduced. A similar watershed boundary line was marked in U Municipality, where there has been a remarkable reduction in upland kava farming. Monitoring in 2001 showed there were 1741 new forest clearances for kava plantings; however in 2004 there were fewer than 100 new clearings. This showed clear success in returning authority to the traditional leadership; the paramount chief declared that “any man who planted kava above the watershed boundary line will lose his title, or if he has no title the father will lose his title, or if the father has no title, the soumas (village chief) will lose his title”. This edict resulted in a 95% reduction in forest clearing.

This change demonstrated how traditional authority and state law could be reconciled to reduce clearing upland forests. Pohnpeian people like to retain alternative sources of authority to justify their alternate courses of action, such as balancing authority between the leaders of the village and the ‘kingdoms’. Now, the alternative structure seeks to retain both traditional and state rules to manage resource use. The threats from the state government against kava growers planting in the uplands were less effective than the threats from traditional leaders to remove title and bring shame to wrong doers in the village. This unwritten act has reduced forest clearings, and reinforced the position of traditional leaders in making decisions about land use.

Lessons learned and recommendations

- All critical stakeholders need to be well informed and consulted before any legislation is developed about managing forests, catchment areas and coastal resources. This is especially true when dealing with islands where much of the traditional culture remains intact;
- When the state government attempted to introduce ‘western’ and centralized control over these resources, the traditional land owners resisted very strongly, and ignored the legislated acts of the State Government;
- Sound scientific monitoring is valuable in demonstrating to community leaders and key stakeholders the damage caused by poor land use. This monitoring clearly showed the downstream effects of the upland forest clearing;
- Co-management partnerships that involve traditional leaders in natural resource management and combine traditional with ‘western’ approaches can prove very effective;
- The State Government failed to exercise control over land management because it lacked capacity and authority to enforce regulations to stop damaging practices;
- The authority of traditional leaders was able to disrupt a State Government Act, but it was also able to enforce local control over damaging land practices;
- The co-management partnerships have reversed the clearing of forests in the catchment area and also reinforced Pohnpeian traditional authority. This use of authority would not be visible to outside observers as nothing was written in statute books. The strong wording in State Government legislation may appear effective, but the unwritten traditional authority was the reason for success (although it took longer);
- Two people closely involved in the reform process summarized this story as: “Most importantly, the [recent watershed management reform in Pohnpei] has provided a bridge between the Western conventional, centralized approach to resource management adopted by the young government and the Pohnpei traditional community resource management system, characterized by decentralization and consensus-based decision-making based on thousands of years of traditional knowledge. In a sense, the approach is an act of reconciliation, reconfirming those aspects of both political systems that are considered legitimate”.

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Case Study 10

A REVEGETATION TECHNIQUE TO PREVENT SEDIMENT DAMAGE TO FRINGING REEFS IN VANUATU

DON MILLER AND JAMES COMLEY

The challenge

The steep weathered volcanic debris slopes of Aneityum, the most southern inhabited island of the Vanuatu archipelago, have suffered severe sediment erosion over the last 3,000 years. The original inhabitants, 'Lapita Man' (named after the distinctive Lapita pottery found throughout Melanesia), started exploiting hill slopes after clearing them with fire. The indigenous pioneer plant species, *Acacia spirorbis*, had evolved in the absence of fire and was regarded as the ideal plant to revegetate its slopes. However, the constant uncontrolled burning that had destroyed the forest also resulted in unstable soils, which readily eroded during tropical rains and resulted in the formation of very deep gullies.

These increased sediment flows were transported to the coastal environment from the exposed gully walls and coated fringing reefs and beaches with thick red mud. This threatened the future of the coral reefs which were a particular attraction for tourists, especially those from the cruise ship industry which brought considerable economic benefits. The challenge was to develop sustainable and non-damaging procedures to stabilise the hill slopes and not damage the local agriculture.

What was done?

A substantial New Zealand funded rehabilitation (afforestation) program using an introduced pine tree, *Pinus caribaea*, commenced in the 1960s. While the new forest growth prevented the formation of new large gullies, the pine seedlings being planted could not survive in the hostile environment of the eroding gullies, which continued to increase in size.

A new approach started in 1995 after field tests showed the soil to be acidic, strongly weathered ferrallitic material with toxic levels of Aluminium and Manganese. Moreover it was effectively devoid of available plant nutrients. When these soils dried in direct sunlight, the top layers shrank and flaked off which resulted in up to 50 mm of surface soil being lost each year.

Attention turned to a tough, infertile, non-invasive plant (Vetiver grass – *Chrysopogon zizanioides*), that had already existed on Aneityum island for nearly 100 years. This showed promise as a mechanism to trap sediment on these eroding slopes. Initial trials over several years showed that, despite the hardy nature of this plant, it needed some non-soluble fertiliser to allow it to grow in this 'soil' and a specific fertiliser mix was developed that would not threaten reef health.

The Vetiver plants were produced in large nurseries using vegetative propagation methods from a small number of older plants. The nurseries eventually produced more than 100,000 plants per year ready to be planted out on the hill slopes. The young plants were placed close to each other in rows along the contour across the bare eroding ground and these contour 'hedges' immediately started trapping moving sediments.

After one year, young seedling *Acacia spirorbis* trees were planted in the collected sediments and these rapidly grew to shade the soil. The roots of the Vetiver are host to a beneficial mycorrhizal fungus which can extract tightly bound nutrients from the soil and the *Acacia* fixes nitrogen which in turn benefits the Vetiver grass. If in the future the fires can be controlled, it appears that the *Acacia* forest will be permanent on these slopes. If there is an accidental fire, the Vetiver quickly regrows and carries on its original function. This allows time for new seedling trees to establish in the trapped sediments.

How successful has it been?

Where the work has been completed, there has been a highly significant reduction in the amounts of sediment washing off these slopes and out to the reefs. Up to 1 metre depth of sediment has been retained in the floor of one wide gully, with lesser quantities in other gullies. More importantly, the production of sediment from the replanted gully walls has effectively ceased and the stream running onto the beach from one particular catchment is now flowing clean, even during the wet season.

An unintended benefit of the long term reforestation program has been the increased fertility of the soils on which the pines had grown for about 40 years. Land which had been regarded as quite useless for gardening when the pines had been planted now supports gardens of healthy and productive Cassava food crops after harvesting of the trees. This is almost certainly due to the activity of mycorrhizal fungi growing on the roots of the *Pinus caribaea*, which can mobilise phosphate from aluminium/iron compounds present in the soft rock. The fallen needles from the pines have also improved the carbon content of the small gullies in the forested areas and the trees have provided shelter from wind, both factors that have allowed these small eroding areas to be stabilised without further intervention.

Unfortunately, the project lapsed in 2003 when funding stopped, but it was reactivated with incorporation into the project *Towards Coastal and Watershed Restoration for the Integrity of Island Environments* (COWRIE) being implemented in Fiji and Vanuatu under the Coral Reef Initiatives for the Pacific (CRISP) programme. New large Vetiver nurseries have been established and field planting will be extended in the next wet season.

Lessons learned and recommendations

- Planting Vetiver grass and Acacia trees around hill slopes and especially in erosion gullies has dramatically reduced sediment flows out to the coral reefs;
- This revegetation technique could be used on other Pacific Islands that have similar problems in deeply weathered red acid soils;
- For example, Micronesian islands like Federated States of Micronesia, Guam and Palau are examples where erosion is on a similar scale to Aneityum;
- The erosion on some Hawaiian islands is on a larger scale, but the basic processes appear to be the same, and the benefits to the south coast of Molokai in particular could be substantial;
- However, careful planning and planting of grass and trees is essential to gain success, as the technique is probably site specific;
- It is important to have a long term project so that successive plantings of Vetiver followed by larger shade trees, like Acacia, can be undertaken;
- A particular advantage is the combination of Vetiver, as a non-invasive species (as designated in the USA), and a tough nitrogen fixing tree species like Acacia. Other hardy nitrogen fixing shrubs or trees could be substituted for *Acacia spirorbis* where that plant is not indigenous.

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A gully wall with Vetiver hedges in 2001



A footprint on the uplifted reef in 1995



The same gully wall with Vetiver and *Acacia spirorbis* in 2008



The same section of uplifted reef in 2008 showing absence of mud.

Case Study II

LINKING WATERSHED MANAGEMENT AND CORAL REEF CONSERVATION IN THE WESTERN CARIBBEAN, SAN ANDRES ARCHIPELAGO, COLOMBIA

ELIZABETH TAYLOR, OPAL BENT AND MARION HOWARD

The challenge

The reefs around the Archipelago of San Andres, Colombia, are the foundation of local tourism and fishing industries, a primary source of food and beach sand, and aid coastal protection. This area contains the Caribbean's largest open ocean coral reefs, atolls, lagoons as well as mangroves, and seagrasses and algal beds. The Colombian government declared San Andres a free port in 1953, and 40 years of unplanned development and unregulated tourism followed. This transformed the artisanal farming and fishing economy to one based on tourism, with rapid deforestation, urbanization and loss of farmlands. Waves of migration from mainland Colombia resulted in unprecedented population growth and unsustainable exploitation of coastal and marine resources, over-extraction of freshwater, pollution from inadequate solid and liquid waste management, soil erosion and loss of agricultural productivity, and the emergence of slums and shantytowns. This resulted in a spiral of increasing poverty and environmental degradation. A comprehensive and integrated approach to watershed management was required to conserve the coral reefs and other resources.

What was done?

Colombia established a decentralized National Environment System in 1993, and created autonomous environmental management corporations. Thus CORALINA was formed in 1995 to manage the land and marine resources of the San Andres Archipelago. CORALINA strived to integrate land, coastal, and marine management through ecosystem-based, holistic projects with active community participation in decision making. The Archipelago is now protected as the Seaflower Biosphere Reserve and Marine Protected Area (MPA). CORALINA developed MPA management plans including integrated groundwater management with active involvement of the communities. The plans include multiple-use protected areas and proceeded with the assistance of many national and international partners including the Seaflower MPA International Advisory Board, GEF, World Bank, UNEP, UNESCO, DFID, Ocean Conservancy, Florida Keys National Marine Sanctuary, Heriot-Watt University, and Colombia's Ministry of Environment and Office of National Natural Parks.

CORALINA and the community obtained volunteer help from international experts to strengthen conservation and management of the Seaflower protected areas, and produce a Water Quality Action Plan to focus on the relationship between freshwater and coastal water quality and identify the threats from land-based sources. The NOAA International Coral Reef Program assisted with the development of this Action Plan to conserve and recover coral reef ecosystems by implementing adaptive, participatory watershed management. Activities focused on: improving monitoring; controlling sedimentation and pollution into the marine environment from poor agriculture, construction, and waste disposal; and building the capacity of local scientists, managers, stakeholders, and communities to manage their environment.

How successful has it been?

Monitoring. Effective monitoring of ground and coastal waters was essential, so an evaluation focused on determining capacity gaps and training needs, especially on: selecting sites; implementing field methods; testing parameters, laboratory analysis and data management; and raising public awareness. Substantial effort went into strengthening the water testing laboratory to ISO certification level to measure saline intrusion into the aquifer. Staff and community volunteers were trained in monitoring and management, especially to spot threats to the watershed, undertake basic enforcement and communicate via two-way radios. Workers from businesses that sell, bottle, or distribute water and those in hotels with wells were trained to monitor their freshwater. Students were trained in water quality analysis at the local national technical institute. A quarterly bulletin with tips and monitoring results was given to the largest fresh water users (owners of commercial wells and tourist hotels).

Land-based pollution. Pollution sources were mapped, and 4 different problems were selected for pilot projects using low-tech, low-maintenance methods. Project 1 tackled the problem of inadequate household sewage treatment by installing a community septic wastewater treatment system to connect 19 residences with more than 70 people. Project 2 focused on runoff into coastal waters by implementing coastal clean-ups and gully maintenance. Bad practices were identified with the community, such as direct dumping of solid waste, poor management of household waste, and unsustainable methods of agriculture and land clearing. CORALINA, volunteer inspectors and villagers joined with public institutions and schools during coastal and gully cleanups and set up village programs to promote best practice. The Project 3 problem was severe soil erosion, with the solution being low-tech abatement structures designed and built by the community. They used readily available materials such as old car tires, fallen trees, and cane trash to stabilize slopes and control erosion. Project 4 attempted to minimize waste from animal farming by constructing waste management treatment beds based on artisanal designs and methods. Farmers were trained in their construction and use, and demonstration beds were built at 10 pig farms.

Construction sites. A partnership was initiated with government and the private sector (contractors, engineers, and architects) to reduce pollution and sedimentation from construction sites. Stricter EIA requirements were put in place for large constructions and enforced immediately in major construction projects including the new hospital, stadium, and road construction. Regulations were enacted with standards for housing projects, septic tanks were strengthened, a guide was produced for these standards, and surveillance of construction sites was improved.

Agriculture. All farms were examined for practices, crops, animals, and issues facing the farmers. The farmers were given on-site training in sustainable technologies for them to choose the best methods. New practices included: use of manure, natural fertiliser, composting, and worm culture; application of biological controls and natural pesticides to control pests and disease; and crop rotation and cover cropping to improve production. Farmers tried new erosion control methods such as stabling cattle, pastoral forestry, and selective land clearing. They also learned efficient water use and storage to cope with dry seasons. Information on agricultural burning, deforestation, and erosion and on ways to improve land clearing and tree management was delivered to all houses before the rainy season.

Neighborhoods. Field technicians trained households to reduce pollution from poor disposal of solid, liquid, and oily wastes. Rainwater harvesting was improved to increase freshwater resources and for climate change adaptation. Schools were targeted with special events such as adopt a beach or mangrove forest or participate in coastal clean-ups. Bilingual education was distributed via the radio, interviews, posters and flyers. These were distributed at meetings, workshops, and house-to-house visits.

Overall. Protecting San Andres' coral reefs required a broad-based program that reduces or prevents pollutants from the land such as erosion, agriculture, urban runoff, and wastewater. Since this project was completed, coastal water quality monitoring has found reductions in suspended solids and reduced discharges from pollution sources. In addition, the visiting experts report that efforts to educate farmers in better farming and field management practices to reduce agricultural pollution, including erosion, have been comprehensive and successful.

Lessons learned and recommendations

- Conservation and poverty alleviation need to go hand-in-hand, so strategies are needed to improve livelihoods, promote food security, and generate income;
- Multi-disciplinary approaches are essential for integrated watershed and coastal management. Outside experts were invaluable to bring in new techniques, strengthen CORALINA as an institution, and develop substantial capacity in the community;
- Best practices cannot be imposed; stakeholders must choose their solutions, however, people need training, information-sharing, and capacity building to make informed decisions and change practices;
- Institutional jurisdictions to control land and sea actions overlap. CORALINA worked with all interested stakeholders, other public institutions, civil society, and the private sector to produce better results and promote empowerment, compliance, and extensive community involvement;
- Linking similar programs such as groundwater management, climate change, MPA management, laboratory and GIS functions, and environmental education was effective in strengthening watershed, coastal, and marine management throughout the islands;
- Sustainable agriculture is part of the island heritage, so socioeconomic and conservation benefits were gained by empowering communities and integrating traditional and low-tech methods;
- Pilot projects to reduce land-based pollution at different locations were successful in providing accessible demonstration sites. Communities readily took 'ownership' of their projects and encouraged other communities to follow;
- Long-lasting programs are fundamental to achieving sustainable development. Public and private partners can reduce threats from poor construction; neighborhoods and schools can assume responsibility for ecosystem health; farmers can introduce best practices; and stakeholders can monitor water quality alongside the authorities.

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Case Study 12

BEST PRACTICE FARMING IMPROVED WATER QUALITY AND HELPED REEF PROTECTION IN CENTRAL AMERICA

CHRIS WILLE

The challenge

Sediments, pesticides and nutrients were damaging reefs in the Gulf of Honduras and the damage was spreading North to the Mesoamerican Barrier Reef. The pollution from massive banana, coffee and citrus farms in the watershed (or catchment) areas of Honduras, Guatemala and Belize was threatening endangered species, such as sea turtles and manatees. The pollution was also threatening important commercial and sport fisheries, and growing ecotourism. However, the farms are major national economic resources and employ many people. The task was to reduce the pollution while not reducing economic benefits. This project in the Gulf of Honduras built on previous projects including those by USAID, PROARCA, the Mesoamerican Biological Corridor commission and the Mesoamerican Reef System Commission.

What was done?

The Rainforest Alliance, acting as the international secretariat of the Sustainable Agriculture Network (SAN), was funded by the National Fish and Wildlife Foundation of USA to introduce best practice to coffee, citrus and banana farmers to reduce sedimentation and agrochemical use to aid coral reef conservation, while retaining the economic benefits for the farmers. They introduced the SAN **Best Management Practices** to farmers, grower associations and large agricultural companies, and included farmer-friendly information to illustrate the downstream effects of sediments and pesticides on coral reefs and other marine ecosystems.

The first targets were the banana farmers as the largest group. The Rainforest Alliance and local NGOs, such as the Fundacion Interamericana de Investigacion Tropical in Guatemala and the Instituto para la Cooperacion y Autodesarrollo in Honduras met repeatedly with banana, coffee and citrus farmers to convince them of the economic and environmental benefits of best practice.

The SAN standards for responsible farming include a requirement for large-scale growers to monitor water quality. Water samples were taken from streams running through the farms and analyzed for contaminants in independent laboratories. It takes years of expensive monitoring to prove cause and effect, but the monitoring program helped show the farmers that they were making a difference.

Farm progress was evaluated annually by experienced auditors using the SAN standards, and successful growers gained the Rainforest Alliance Certified **Green-Seal of Approval**. These growers can sell their crops to retailers and consumers prepared to pay more for such sustainable products. The approval was used in marketing to improve the prices, company management practices and pride in their products. To gain certification, farmers and the companies were assessed on 200 specific indicators that guided them towards improved farm management. Many of the criteria relate to soil and water conservation, pesticide management and pollution control; which all benefit downstream coral reefs.

How successful has it been?

SAN is a unique coalition of similar NGOs aiming to increase the community benefits and reduce environmental impacts of export agriculture. The success was in: raising awareness; aggressively enrolling farmers in the SAN certification program; providing guidance in best practice management; minimising social and economic losses; providing the certification seal as an incentive; improving water quality; and ensuring that all people along the chain from farmer to large marketing companies were fully informed and involved. The Rainforest Alliance linked with 8 other NGOs to help farmers understand the unseen impacts of their farming, especially the effects of sediments and agrochemicals on coral reefs.

The best management practices and certification standards developed by the SAN aimed to eliminate, reduce or mitigate the negative impacts of farming on the environment and to increase and diversify social benefits for farm workers and their families. The SAN standards are the most comprehensive and complete criteria for sustainable agriculture available, based on the 10 principles below. Activities included: reductions and restrictions in the use of pesticides; stopping deforestation and planting and protecting forest reserves; planting buffer strips of native trees and other vegetation along streams; planting ground cover especially along drainage canals to reduce erosion; collecting and recycling plastic; recycling organic by-products (e.g. banana bunch stems); managing solid wastes in specially constructed landfills; installing sewage and wastewater treatment facilities; controlling pollution from houses, shops and storage areas, especially fuels and other toxic substances; stopping channelization; making farms more flood proof (especially after Hurricane Mitch); and providing environmental education to farm managers and workers, including good business practices and how to protect wildlife, coastal ecosystems and reefs. The SAN standards in English and Spanish are on www.rainforest-alliance.org/agriculture.cfm

More than 30 large banana farms in the Gulf of Honduras area covering 20,000 acres have reduced agrochemical use, planted groundcover and buffer zones along streams, improved soil conservation, reduced erosion and point-source pollution from banana packing plants, shops and houses. Farms in Guatemala have made remarkable progress with all Chiquita farms being certified. A surprise audit of the Tela Railroad (a Chiquita subsidiary) farms in Honduras after 4 years by SAN staff found some farms had regressed to some former bad habits after Hurricane Mitch. This audit stimulated dramatic progress by farms to keep their certification, and Tela subsequently won awards for corporate social and environmental responsibility.

The main problem with coffee farms was the change from traditional, relatively benign, agro-forest systems to planting coffee trees in dense hedgerows in full sun. This temporarily increases production, but requires more fertiliser and pesticide and destroys wildlife habitats. Farmers were encouraged to conserve traditional forested coffee farms to reduce costs, which is essential when prices are low. They also introduced 'clean technologies' to reduce water pollution and grow quality coffee for better prices.

Water monitoring was not coordinated across many agencies including The Nature Conservancy, UNEP, WWF, the EARTH School, the Wildlife Conservation Society and PROARCA. The Rainforest Alliance held meetings with banana company and NGO scientists to assess what monitoring was occurring; the companies are obligated to share water quality data, but NGOs were more reluctant to share data. However, progress was made in having the agencies share data and coordinate water quality monitoring.

Lessons learned and recommendations

- Improved information flow to farmers was particularly valuable. An attractive poster explaining that 'good farms are good neighbors' was distributed by SAN to many communities;
- Early success on model farms using SAN Best Management Practices allowed the Rainforest Alliance to introduce these to many farms, and train more auditors, extension workers and scientists in best practice and reef conservation;
- Convince the leaders and others will follow. When Chiquita, the most progressive banana company, integrated the SAN standards, other companies and independent farmers signed up;
- SAN and the NGOs formed a collaborating network to share information, training and motivation with farmers, and now this network includes the whole supply chain for effective and long-lasting watershed management;
- Formal monitoring and evaluation of SAN guidelines was essential to ensure that farms and companies apply best practice to improve land use practices, promote better business methods and change consumer awareness and behavior to improve the conservation outcomes. Communicating the monitoring results to farmers, funding agencies and policymakers allowed them to assess progress and raise compliance;
- Focusing on reducing threats is more effective than trying to measure all the apparent, but immeasurable, levels of contamination in streams flowing onto the reef;
- Similarly, more effort and resources should be put into preventing water contamination than expensive, complicated and often inaccurate monitoring. Improved farm practices will naturally reduce water pollution;
- Assessing current water quality monitoring and seeking cooperation to share data and design is particularly effective, especially when it involves government, academic, NGO and company water monitoring experts;
- Linking projects to long term programs (more than 10 years) is valuable to assess objectives of reducing poverty, pollution, deforestation and destructive land-use practices as well as developing alternative livelihoods. This project benefited by being part of the Rainforest Alliance/SAN agriculture certification program which changed consumer attitudes and raised farm incomes;
- Good training is essential. The project benefited from SAN's experience in training biologists, agronomists and other experts to evaluate farms based on certification standards;
- Working with the major exporting companies was very productive once their confidence was obtained and they cooperated in sharing information.

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Principles of SAN Best Management Practices

1. Social and Environmental Management System
2. Ecosystem Conservation
3. Wildlife Protection
4. Water Conservation
5. Fair Treatment and Good Working Conditions for Workers
6. Occupational Health and Safety
7. Community Relations
8. Integrated Crop Management
9. Soil Management and Conservation
10. Integrated Waste Management

Case Study 13

INSPIRING AGRICULTURAL INNOVATION IN THE MESOAMERICAN REEF: REDUCING PESTICIDE DAMAGE TO CORAL REEFS

DAVID MCLAUGHLIN

The challenge

Sediments from inland deforestation, and pesticides and fertiliser washing out of large-scale banana, pineapple, oil palm, citrus and sugarcane plantations in Honduras, Guatemala and Belize were threatening the Mesoamerican Reef (MAR) the largest coral reef in the Caribbean. In 2003, coral reef animals and plants downstream were shown to be accumulating toxic pesticides that could affect them and also poison people eating the fish. The challenge was to reduce the damage caused by the use of the most toxic agricultural pesticides to conserve the downstream coral reefs, but not threaten these major agricultural industries. The overall goal was to improve agricultural practices so that less of the most toxic pesticides flowed onto the reefs, and also result in economic advantages. The first step was to gather convincing evidence and carefully raise awareness of the problems with the major agricultural companies.

What was done?

WWF (World Wildlife Fund) staff in Central America collected seagrass, invertebrate and fish samples from reefs off Honduras and Belize. They analyzed these samples locally and found higher concentrations of toxins than previously imagined, including some chemicals that were last used 20 years ago. High concentrations of the toxic compounds were accumulating in marine organisms and persisting longer than was previously considered possible.

WWF quietly approached the major agricultural producers and chemical companies like Dole, Chiquita, Fyffes and DuPont with the data hoping to get their cooperation to reduce damaging pesticide use. These were the main strategic partners in the production and marketing of citrus, sugarcane, and oil palm which grow on 80% of agricultural land in the MAR region. The companies agreed to undertake a detailed study with credible protocols for sampling, and analysis to determine which chemicals were causing the impacts on the animals and plants offshore.

The data were presented confidentially to scientists from DuPont and major agricultural companies (Chiquita, Dole, Fyffes), to NGOs, and government officials. They were unaware of pesticide accumulation downstream and the chemical companies were not fully convinced. So together they developed detailed and strict protocols to collect and test samples at internationally recognized laboratories in Hawai'i and Virginia, USA.

With such good scientific evidence, the companies and WWF were able to develop methods to reduce damaging chemical effects, and further improve the collection of samples for chemical analysis. The focus shifted to conch, corals and one fish, the 'white grunt', as well as collecting river sediments. Two big agricultural companies helped determine where the most toxic pesticides were coming from and identify inappropriate agricultural practices. When these results came back, the growers and companies were surprised at the amount of toxic pesticides accumulating on the coral reefs and realized that their efforts to reduce pesticide runoff had not been effective. When regular monitoring of runoff from agriculture was in place and the data analyzed, the partners could trace the source of most of the toxic pesticides and develop 'best practice' growing methods. Farmers were also interviewed about when and why they used pesticides. They developed 'Best Management Practices' and built partnerships between the growers, the chemical companies and WWF to reduce toxic pesticide use and also save money; a win-win situation.

At the start WWF explained their experience in identifying problems with other agricultural companies, reducing environmental damage, and how best practice produced real economic benefits to farmers. When the companies recognized the problems, WWF developed MOUs[#] with the top managers, emphasizing a partnership approach and guaranteeing strict confidentiality about meetings and data. As the trust between the partners increased, the large chemical companies started sharing their data on pesticide use and together they developed a 'toxicity model' on the use of these chemicals in producing bananas and pineapples. This was based on a model developed by WWF in the late 1990s for potato growers. The success of this project allowed WWF to take the messages to sugarcane producers in Mexico, citrus growers in Belize and oil palm producers in Honduras.

How successful has it been?

The best international scientific methods and analyses were used to demonstrate that agrichemicals (fertilisers, pesticides, herbicides, and fungicides) and sediments (from soil erosion, loss of organic matter and agricultural processing waste) were accumulating in animals and plants on downstream coral reefs. With this evidence, WWF and the stakeholders, especially the major chemical and agricultural companies, examined current farming practices identified the practices and sources of the polluting high risk and environmentally damaging pesticides, and developed 'Best Management Practices'. They field tested these in pilot plots with the farmers, monitored the plots and showed reductions in pesticide runoff and real economic benefits for the farmers. The changed practices reduced soil erosion (e.g. cover crops, mulching) and fertiliser loss with a lower amount applied each time.

Lessons learned and recommendations

This project was successful because WWF recognized that the farmers and chemical companies were not intentionally causing damage, therefore they formed partnerships and collaborated carefully over several years. The goals were to reduce damage to the coral reefs by implementing best practice without causing economic losses. There are several clear messages:

- Ensure that credible science information is gathered and presented confidentially to the farming and company partners. This way they gained their confidence to collaborate to reduce the harmful impacts;
- The first analyses of pesticides were made in local laboratories which were not considered to be highly accurate. The partners collaborated to get more accurate results by sending samples to independent laboratories in Hawai'i and Virginia; this avoided unscientific criticism of the companies;
- Maintaining confidentiality was essential. They made one mistake when confidential information about pesticide toxicity from one company was disclosed to farming participants. It took almost a year to regain their trust;
- Another critical success factor was employing the right people to talk to industry. WWF employed a person who had worked with banana growers for 18 years; whereas an inexperienced NGO person would probably not understand the industry position and 'speak the right language' to gain the trust of the agricultural companies and farmers;
- It takes time to achieve success. Agricultural and chemical companies are nervous of NGOs and could see little value in working with them. Therefore patience and persistence was required to determine economic benefits of collaboration and ensure confidentiality of data exchanges. WWF developed legally binding MOUs[#] with these partners to demonstrate good faith;
- Success was achieved by making this a collaborative process, with WWF and the companies working together to find innovative solutions. For example, the companies developed new ways of reducing sediment and pesticide runoff by mulching pineapple waste, and putting sediment traps and vegetative covers on drains (Case Study 12).

MOUs are Memoranda of Understanding usually drawn up by legal people and signed by all parties agreeing to a set of conditions and promises. These MOUs focused on confidentiality and agreement on communications protocols.

Contacts

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References

The following publications are on the website below:

- Promoting Better Management Practices Among Citrus Producers in the Aguan River Valley of Northern Honduras
- Promoting Better Management Practices Among Oil Palm Producers in the Coastal Plains of Atlantida Department of Northern Honduras
- Implementation of Best Agricultural Practices for the Production of Sugar Cane
- Promoting Better Management Practices Among Oil Palm Producers in the Sula Valley Region of Northern Honduras

www.worldwildlife.org/what/wherewework/mesoamericanreef/publications.html

The homepage for the *MAR Linking Ridges to Reef* project is on www.wwf-mar.org/Home/

Case Study 14

THE IMPORTANCE OF WATERSHED MANAGEMENT FOR COASTAL CORAL REEFS IN BRAZIL

EDUARDO MACEDO AND MAURO MAIDA

The challenge

The threats to coastal reefs of Brazil are mainly from human impacts and date back to the colonization process. Over the last 500 years, there has been increasing sedimentation from soil erosion caused by deforestation of the Atlantic Tropical Forest, and the changes to timber plantation and sugar cane growing. Over the last 45 years, the so called 'green revolution', based on more intensive 'industrial farming' with greater use of fertilisers and pesticides, has allowed a vast increase in agricultural production, especially in lesser developed countries like Brazil. This, combined with less respect for environmental laws, is clearly evident in the drainage basins that flow to the Brazilian coast and then out to nearshore coral reefs. The practices that have contributed to increases in erosion and to the poor water quality in the region are easily identified: deforestation of riparian forests; cultivation on steep slopes (areas with a slope greater than 45°); illegal mining of sand from the stream banks for construction work; agricultural activity right up to river banks; forest fires following the sugar cane harvest; and indiscriminate use of pesticides and fertilisers. Many Brazilian coral reefs are in close proximity to the coast and river mouths, therefore the conservation of these ecosystems is directly related to combined management of the catchments (watershed) and coastal zones.

What was done?

The first initiatives towards conserving Brazilian coral reefs occurred in the 20 years between 1971 and 1991, with the creation of 4 Marine Protected Areas (MPAs). Previously, the only MPAs (or Conservation Units as they are locally named) occurred around islands that were relatively far from the coast and less exposed to pollution from the land. It was only in 1993 that 7 MPAs were created which encompassed the coastal coral reefs within the adjacent coastal ecosystems. Special attention was paid to the physical impacts directly generated from fishing and tourist activities, because the proximity of these environments to large populations made them more vulnerable to many forms of pollution. Among those MPAs, one is particularly important: the Coral Coast Environmental Protection Area (APA), created in 1997. This is the largest Brazilian marine conservation unit, extending along 135 km of coastline and covering an approximate area of 414 000 hectares that contains the greatest range of coastal coral reefs in Brazil.

The Coastal Reefs Project was created as a partnership between the local fishing community, the Federal University of Pernambuco, and the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA). The designation of the Coral Coast APA in 1999 initiated the largest long-term, controlled experiment on the recovery and conservation of coastal reefs. In the Tamandaré No Take Zone, research has been the only activity permitted since 1999. This research focus was particularly aimed at supplying scientific information for municipal, state and federal public policy developments for the protection of these ecosystems in Brazil.

With the goal of better understanding the relations between the best practice use of the surrounding catchments and their land uses, and the conservation of Brazilian coastal reefs, the Coastal Reefs Project conducted studies in the Tamandaré No Take Zone from 2005 to 2009, on the dynamics of suspended sediments and their ecological consequences. They used the following strategies for data collection to achieve that objective:

- Historical, seasonal and spatial description of land use in the catchment area;
- Analysis of 58 satellite remote sensed images obtained over the last 30 years for a spatial description of the terrestrial runoff over the coastal coral reefs and lateral migration of the river mouth through time;
- Meteorological and oceanographic data were added to the information base to permit analyses to determine which environmental parameters and activities contribute most to the input of sediments into the studied area;
- Gathering suspended sediment samples each week for 3 years using sediment traps on the reefs of the Tamandaré No Take Zone;
- Quantification and qualification of the collected sediment samples; and
- Seasonal follow up of the rate of coral mortality during the time of the study.

As a result, the researchers in this study concluded that the river flows cover the reefs annually with high levels of terrestrial sediments, with the maximum peaking at about 37 times the critical amount in which some species of corals can survive. In addition to the physical impacts, the sediments also function as vectors of agricultural chemicals. In the catchments, some chemicals such as diruon, ametrin and 2,4D are used in sugar cane farming and applied in large concentrations extensively during the early growing stages when the soil is still unprotected prior the first annual rains. Combined with the lack of riparian forest along the stream banks, this facilitates the transportation of these chemicals that are toxic to coral reef organisms. Increased coral mortality was observed especially in the autumn months, when higher water temperatures that stress the corals are combined with the first rains. These rains wash out the ponds, wetlands and streams across the catchment and nutrient and pesticide rich sediments are washed over the reefs. These

effects are exacerbated by occasional extreme precipitation events, such as the big floods of 2000 and 2010. The impacts and consequences of such events are not yet known, but it should be recognized that climate change may result in more extreme events.

How successful has it been?

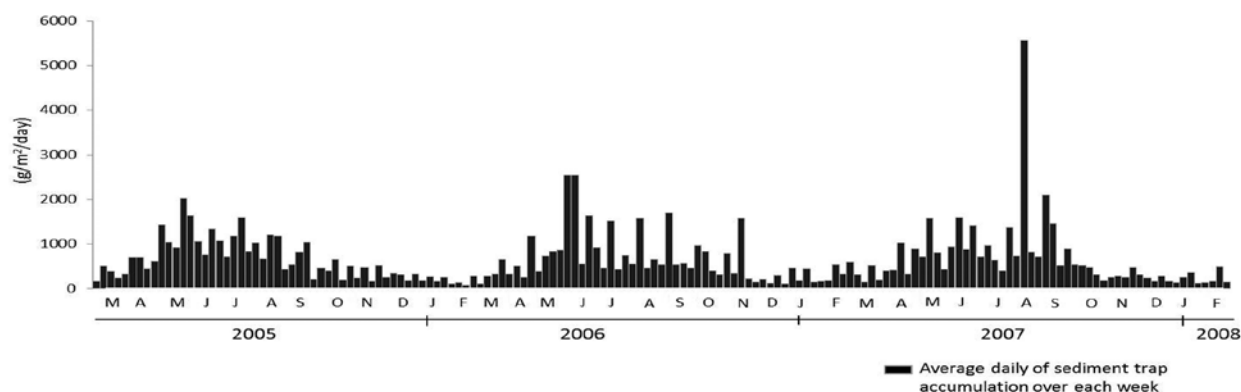
A key feature of this project was the extensive scientific collection of data on sediments and water flows. These data were communicated to the public through the press and publicized by government agencies responsible for the management of the MPAs. The National Policies for Hydric Resources in Brazil has been developing guidelines on the need for integrated catchment management that includes rivers, estuaries and adjacent coastal zones. However, further efforts to reconcile land use and conservation of coral reefs are still needed.

Lessons learned and recommendations

- Riparian forests in Brazil are legally considered Permanent Protection Area (PPA) and the width to be preserved is proportional to the river width. The conservation and restoration of PPAs would certainly contribute to reducing the amount of sediment, pollutants, pesticides and nutrients that flow out to the coastal coral reefs;
- Sound scientific data must be obtained to show that land-based activities in the catchments damage downstream environments. Therefore, activities on land should be managed according to the resilience capacity of the surrounding ecosystems, including the coral reefs;
- Frequently, the anticipated environmental benefits of declaring MPAs can be reduced by a lack of scientific knowledge, i.e. determining acceptable pollution levels for rivers that flow towards reefs and assessing the impacts on reef biota of various levels of pollution;
- The National Council for the Environment Resolution 357 in 2005 recognised that acceptable water quality in ecosystems should be based not only on the present condition, but also consider water quality that would cater for community needs; the resolution states “the government may, at any moment, determine new conditions and quality standards for a determined body of water; or even restrain the standards due to local conditions based on technical inputs”;
- Brazil has previously not assessed water quality in catchment areas that are likely to impact on coral reefs. Management of coral reefs must be integrated with models of best practice in agricultural production in parallel with environmental needs;
- Brazilian watersheds are managed in part by the Watershed Committee, which is composed of representatives from government and civil society. Their actions include the implementation of monitoring programs of water quality. The expansion of these monitoring programs for coral reef areas adjacent to watersheds would provide a better integrated management of these ecosystems;
- It is important to include predictions of likely impacts of extreme climatic events;
- Scientific research that measures the persistence and real impacts that pesticides and increased sedimentation cause to coral reefs, and unravelling the mechanisms of such damage must be encouraged. This would contribute to the elaboration of public policies on watershed management that are appropriate to the conservation of coral reefs; and
- The enforcement of existing laws, combined with advances in scientific knowledge that permit adaptive management changes to existing legislation, are among the most important measures that would lead to the improvement of reef conservation.

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The graph shows the average daily sedimentation rate for each week over 3 years in the Tamandaré No Take Zone. There is clear evidence of increased suspended sediment over the reefs during the rainy seasons (Southern autumn and winter), which represent the most damaging time for coral reefs (see Page 50 for an example of a killed coral). This increase can be seen in the difference between the satellite images on P. 50 of dry and wet season runoff.

Case Study 15

CORAL REEF POLLUTION REDUCTION IN AMERICAN SAMOA

MICHAEL KING

The challenge

Nutrient pollution from the catchment area was causing algal blooms on the coral reef flats, fringing reefs and seagrass beds in front of 4 villages in American Samoa, including the rich seagrass lagoon of Aofau, the largest village. These reefs have more than 200 species of coral, hundreds of fish species, and are important foraging and nesting habitats for endangered hawksbill and green sea turtles. The Aofau, Amaua, Auto and Afulei villages on Tutuila the largest island in the United States Territory of American Samoa faced a challenge: to identify the sources of pollution from the catchment; raise community awareness and develop a community project to tackle the problems; and build teams to locate funds to solve problems outside their immediate capacity. However, no local agencies had the resources to conduct the necessary testing and there are few conservation organizations, therefore a project was developed with the long-term goal of restoring the coral reef, mangrove and seagrass habitats to a more productive and healthy state.

What was done?

The 4 villages have community fisheries management programs, and 3 (Aofau, Amaua and Auto) participate in the Department of Marine and Wildlife Resources (DMWR) Community Fisheries Management Program (CFMP). However, this department does not assess water quality or clean up pollution. The American Samoa Environmental Protection Agency (ASEPA) monitors water quality in several streams, but not in these 4 villages. The Land Grant program at the Community College measures nutrients and fresh water algae in one creek in the Aofau watershed, but does not determine the nutrient sources. Their first results, however, showed elevated levels of phosphate from unknown sources.

A local NGO, the Coalition of Reef Lovers (CORL), obtained funds from the National Fish and Wildlife Foundation of USA to form a partnership program with government agencies and the American Samoa Community College. Although 3 villages already had management plans stating that reducing land based pollution is important, none had the capacity to undertake such activities. The first major task was to identify the pollution that was the cause of these algal blooms, then build capacity and community support for coral conservation. Local community members completed surveys to help pinpoint sources of pollution, participated in stream and coastal clean-ups, and helped monitor the growth of algal mats. The project used the *Stressed Stream Analysis* (on www.CORL.org) and created a GIS pollutant source map based on GPS readings. They also surveyed each village to determine the nature and extent of sewage disposal facilities, and to identify pollution sources. Local youth groups and community members conducted the surveys with the emphasis on solving problems and not attributing blame.

The Stressed Stream Analysis has been widely used for community planning and watershed ecosystem management because it is simple and reliable, and the results are easily understood by community members. The analysis uses GIS or Google Earth maps to assist villages with planning and future development. The water quality monitoring in streams, springs, and set points in the sea focused on ammonia, nitrite, nitrate, phosphate in fresh and salt water, chemical oxygen demand, dissolved oxygen, pH, oxygen reduction potential, and included waterborne pathogens.

The study showed that imported high-phosphate soaps and detergents were major nutrient pollutants across the island. The American Samoa Government responded immediately and banned the importation of these high-phosphate products from October 2007. The other major sources of polluted water were outflows from piggeries and inadequate sewage treatment with septic grey water being dumped into the streams.

CORL set about raising awareness and increasing community involvement as the key to correcting the problems and preventing them from recurring. After the clean up activities, CORL put on a village barbecue with short talks for participants (food is a big crowd attracter in Samoa). They also produced several videos to help other Polynesian communities correct similar problems.

How successful has it been?

CORL realized that for conservation to succeed in American Samoa, they needed to involve the village chiefs and mayors. If the leaders are convinced of the value of protecting reefs and provided with solutions, they will lead the process. The 2 or 3 clean up activities in each village surpassed expectations; but litter pollution did not stop. Not all community members participated, and many outsiders showed up for the barbecues, but not to pick up litter. Many participants proudly wore T-shirts which carried clean up messages.

The extensive algal bloom has not returned to Aofau lagoon in the 3 years since high phosphate detergents were banned (those with more than 11% phosphate content); but mostly due to the voluntary removal of them from local stores. Blooms of different algae (*Dictyota*) have occurred on near shore reefs of other villages. Nutrient levels should decline dramatically in the future when the American Samoa Customs Department is able to enforce the ban on high phosphate

detergents. Detergent testing and creation of a detergent identification guide will be undertaken by CORL in 2010-2011 with funding from NFWF. Some of the 20 identified pollution sources were corrected during the project; but the total list was too large and expensive for the project. However, other village mayors have requested assistance to clean up their waters and 2 additional streams were mapped in 2008-2009 in preparation for clean up activities.

Lessons learned and recommendations

- Stressed Stream Analysis was particularly useful in determining pollution with 59 point sources identified in 4 villages. The GIS analysis using a picture of the catchment area and structured walks around the villages was helpful to raise awareness;
- The major pollutant was the high-phosphate soaps and detergents; importation was banned in October 2007;
- Similarly, piggeries and inadequate septic systems were other main sources of pollution, especially ammonia, nitrites, and nitrates; ASEPA has closed many piggeries within 50 feet (15 m) of streams (Case Study 16);
- Many households dump 'grey' water directly into nearby streams and ditches; septic tank emptying facilities and larger scale sewerage systems are required to treat these wastes;
- It is essential to convince the village chiefs and mayors of the problems and possible solutions. Villagers will follow when Chiefs, Mayors, titled men, youth group members, work together with NGOs on clean-up activities. However, the death of a high chief can interrupt village participation, so the whole village council should be involved;
- Be careful not to schedule workshops and training activities on the same day as other events. Poor attendance in one village was because the local team was playing in the cricket final, and in another it was because of school graduation day;
- Enforcement may eventually be necessary to reduce the amount of litter dumped in streams and the sea. Similarly enforcement by Customs is needed to prevent the importation of high phosphate detergents;
- Providing a gift to the village is the usual custom for all activities, including visits by NGOs; Chiefs may waive this if the activity will benefit the village; and
- Evaluation and monitoring plans should not be over-ambitious, but developed knowing the capacity and resources available. Simpler methods that yield results and can be continued are better than very detailed monitoring that is not sustainable.

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Case Study 16

PIGS WE CAN LIVE WITH: A CASE STUDY FROM AMERICAN SAMOA

PHILIP WILES, CHRISTIANERA TUIELE, BRIAN RIPPY AND FA'AUUGA LAITITI

The challenge

Raising pigs has been an integral part of American Samoan culture for almost 3,000 years. In the past, pigs were kept communally and the Village Matai (Chief) decided who was responsible for them and when they were eaten. However human populations and personal wealth have expanded rapidly during the past century, with the result that many more pigs are raised in private farms across American Samoa. Much of the waste from these piggeries was washed into streams and out to the nearby fringing coral reefs, thereby damaging important marine habitats and a source of food for Samoan people.

The effects of untreated pig waste on the coral reefs did not raise local concern until it was linked to the Leptospirosis disease. In 2003 a construction worker required an urgent medical evacuation to New Zealand, where the illness was identified as Leptospirosis, a relatively rare bacterial disease carried by pigs. The diseased worker was involved in a stream project that carried runoff from several piggeries. The bacteria are passed from pigs through the urine into waterways where they can infect people, especially through cuts in the skin. In 2004, the US Centre for Disease Control (CDC) showed that 17% of adults in American Samoa were hosts of Leptospirosis. These results indicated that contact with pigs or stream water contaminated with pig wastes were correlated with positive Leptospirosis cases. Additionally, the very porous geology of American Samoa means there is insufficient filtration of surface water before it reaches drinking water wells and streams, making them susceptible to bacterial and nutrient pollution from piggeries. Several drinking water wells in the vicinity of piggeries consistently tested positive for the faecal contamination indicator bacterium *E. coli*.

An American Samoa Environmental Protection Agency (AS-EPA) survey in 2006 showed there were 8,373 pigs in 1,017 piggeries in American Samoa. Of these farms, 82% discharged directly into streams, used open bottom cesspools or had improperly constructed septic tanks. Most piggery owners had never experienced enforcement of existing piggery laws, but the majority (80%) wanted to comply with local anti-pollution laws.

What was done?

The direct impacts to human health, threats to drinking water supplies and damage being caused to the relatively pristine coral reefs of American Samoa prompted AS-EPA to initiate a 'Piggery Compliance Program' (PCP), with 3 main components:

1. Educate pig owners about the impact of their piggeries on the environment and human health. They explained the regulations and the reasons behind them to the owners along with suggested solutions to prevent pollution. Demonstration piggeries at the American Samoa Community College Land Grant extension were built to show compliant piggeries;
2. Develop piggery designs that effectively manage the waste using composting systems: portable dry litter (now phased out); dry litter; and controlled wash-down. Each basic design can be tailored to individual needs. Pig waste is composted or the liquid waste is processed through a septic system while the separated solids are composted. The compost is a valuable agricultural product. Funding from the Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) and from the Veterans Affairs (VA) made it financially viable for pig farmers to upgrade their infrastructure;
3. Enforce regulations if efforts to work with the farmer are not effective in bringing the piggery into compliance with the Piggery Compliance Program. Failure by farmers to respond to the citations will result in legal processes, which can result in fines and/or confiscation of the animals.

A dedicated piggery compliance program team at AS-EPA interacts closely with farmers and responds to calls from the public on piggery matters. A follow up survey of piggeries by the team in July 2010 showed that their efforts had reduced the pig numbers from 8,373 to 3,500 housed in 430 active piggeries.

How successful has it been?

The education effort played a major role in the success of this program, which is shown by the large number of piggeries that voluntarily closed or came into compliance. Initial discontent from the public about the closing of piggeries (and sometimes a hostile reception from farmers) has changed to a favourable view of the Piggery Compliance Program and efforts to increase environmental quality and human health.

The funding support from NRCS and VA has provided farmers with a cost effective mechanism to bring their piggeries into compliance. By December 2010, there were 30 fully compliant piggeries housing about 300 pigs and 60 compliant piggeries are expected to be built in the next 4 years. A system to supply wood chips to the piggeries and a market to sell compost is being created with financial spin offs to the local economy. The sustained high temperatures (>55°C) developed during composting kill the Leptospirosis bacteria in the pig waste.

Bacterial (*E. coli*) counts in streams within two priority watersheds have been monitored over the education and enforcement period. There have been dramatic decreases of at least 90% in bacterial counts in both watersheds. Preliminary results from a second Leptospirosis study in 2010 by the University of Queensland in collaboration with the American Samoa Department of Health showed that 15.5% of the population had Leptospirosis antibodies in their blood, compared to the CDC study in 2004 CDC of 17%; this is lower but not statistically significant because of inherent difficulties in sampling.

Lessons learned and recommendations

- This case study is relevant for many other tropical islands with similar conditions to American Samoa and large pig populations. Leptospirosis was only found in American Samoa because of one case of severe illness in 2003. Since then, testing kits have been given to local hospitals and the widespread incidence of Leptospirosis is now apparent. Poorly managed animal waste disposal on other islands may also lead to decreased human and environmental health;
- The Piggery Compliance Program faced fierce initial resistance from local governments and pig farmers; perseverance was required to make it successful;
- A comprehensive education campaign has helped the farmers comply with the regulations, and made enforcement much easier;
- Financial assistance from the NRCS EQUIP program and VA made it possible for farmers to build new, compliant piggeries to the AS-EPA designs;
- Waste treatment in the new piggery designs has significantly reduced the bacterial and nutrient loads flowing into American Samoan streams and out to the coral reefs;
- The compost by-products are sold as fertiliser and add value to the improved pig farming;
- A current limitation is the inadequate supply of wood chips to the piggeries. Securing a consistent supply needs to be solved; this will require grants to supply wood chipping equipment until stable markets for wood chips and compost are established; and
- The major value of the program is seen in protecting valuable resources such as drinking water, human health and the resilience of coral reefs.

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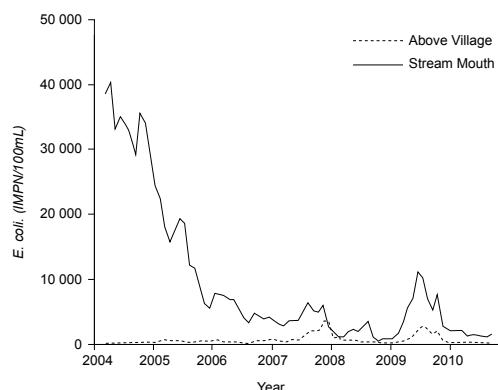
An example of a piggery discharging waste directly into a stream.



The waste and woodchips from this dry litter piggery are trodden down a 6% slope into the trough, then composted in the bin.



Wash down piggery system with waste washed into the trough. Solids are filtered off and composted; liquids are treated in a septic system and discharged to a drain field.



*There has been a dramatic reduction in *E. coli* counts at sampling points downstream of Papa watershed pig farms compared to an upstream site (dashed line).*

Case Study 17

INTEGRATED COASTAL MANAGEMENT IN VANUASO TIKINA, GAU ISLAND, FIJI

JOELI VEITAYAKI

The challenge

Three critical issues threaten Pacific environments: rapidly increasing populations; widespread coastal development and resource use; and addressing climate change and sea level rise. In Vanuaso Tikina, Gau Island, Fiji, coastal resources were degrading because of coastal flooding, erosion, habitat damage and pollution, over-fishing, salt water intrusion and increased storm damage. These problems were compounded by climate change and sea level rise. Although the communities in Vanuaso Tikina (district) have traditional knowledge and experience living on small islands, they are now required to address a whole range of environmental issues, including some which are unfamiliar. This is why the people applied the integrated resource management approach to address their environmental challenges.

What was done?

The villagers were involved in a series of meetings before they were convinced to preserve their environment resources by managing fisheries resources, banning fish poisoning and lessening the impacts of land-based activities such as poor land use and waste disposal (Table). The villagers then formulated their resource management plans, worked to rehabilitate their natural habitats and communicated these activities to publicise and seek support for their actions. The people put in place locally appropriate resource management activities including:

- conserving parts of their fishing grounds using their traditional rights;
- prohibiting the use of destructive resource use practices;
- protecting and rehabilitating mangrove forests and coastal vegetation;
- promoting sustainable and best land-use practices;
- arresting deforestation and wild fires;
- promoting good drainage and protecting their water supplies;
- caring for domestic waste disposal and waste water;
- managing their domesticated animals, especially pigs and cattle; and
- setting up advocacy and support network – Mositi (care for) Vanuaso

Since 2001, regular follow-up visits by the development partners from the University of the South Pacific (USP), the International Ocean Institute - Pacific Islands Operational Centre (IOI-Pacific) and the Japanese International Cooperation Agency (JICA) were made to validate village resource management plans and development activities. Short training workshops were also given in: monitoring; community leadership; project planning; project preparation; composting toilets; smokeless stoves; fish aggregation devices; and post harvest processing.

The communities were assisted with their self-determined resource management and development activities that emphasised their strengths because of their situation and location. The villagers were encouraged to learn from each other and to foster closer social linkages to benefit them and their communities. The goal was to develop an environmental ethic in the district to improve conservation and the wellbeing of the people. The women and youth were involved to ensure the sustainability of the initiative, as they constitute a powerful social force. If properly coached and supported, they will maintain project goals. Both groups were happy with their new-found role and were working on self-determined initiatives to improve their lives and those of their families. While much support was promised by the partners, project leadership was expected to come from the local people to determine the major environmental and development issues that were addressed. Although the traditional leaders in Vanuaso Tikina were supportive, the long term community support would only be assured if the leadership was fair, transparent and inspirational. Good community leaders were expected to make consistently good decisions. The people recognized the need to secure alternative livelihoods and agreed on developing different income-generating activities to support their resource management arrangements.

How successful has it been?

Some of the accomplishments of the Vanuaso Tikina initiative included:

- Declaration of long-term, no-take managed marine areas in 6 villages;
- Building of stone breakwaters to protect the coasts in Naovuka and Lamiti from cyclones and tidal waves;
- Replanting and management of native hardwood and coastal forests in all villages;
- Monitoring and banning of wild fires;
- Restocking protected areas in 2006 with juvenile giant clams provided by Fiji Fisheries;
- Protecting and replanting mangroves because of their importance for fisheries and coastal protection;
- Promoting efficient smokeless stoves to reduce firewood use and smoke inhalation by the villagers;
- Protecting water catchments that are critical to community health;

- Managing hazardous wastes such as pesticides, batteries and waste water;
- Improving husbandry of domesticated animals, which previously damaged the best farming areas, especially the care of pigs to encourage lowland farming;
- Promoting better waste management, such as sorting and composting;
- Planting pandanus trees to guarantee supply for mat making, which is a new income source that has contributed about \$1,000 per month to the villages;
- Planting a village taro garden in Lamiti village to provide income;
- Malawai Village Youth Council operating a cattle farm for which they provided the land, labour and the posts. The French Government provided the cattle, wire and staples; the income is held in a Unit Trust account;
- Operating a youth store in Vanuaso village;
- Increasing villager involvement in decision making, with women and youth taking a more active interest in village development; and
- Enhancing trading amongst the villagers through a number of micro-economic ventures in different villages.

Lessons learned and recommendations

- The wishes of people to improve their living conditions and look after their long-term interests must be recognized; people need to find a balance between development and environmental management;
- Outside partners assisting local communities must realize that communities are under pressure to make a living;
- New and improved sources of income that complement people's resource management activities are essential to support resource management initiatives;
- Proper planning supported by social and economic assessment of needs and benefits is essential and must include clear benefits for local communities,;
- Sufficient time is needed to permit people to learn from conservation efforts and inspire others;
- Enforcement of management decisions in locally-managed marine areas is a huge challenge because the biggest threats come from outside the communities;
- Traditional authority and institutions are no longer appropriate for enforcement in the contemporary context;
- Conservation and management aims must reflect the need to manage marine resources and involve people in the process; and
- The goals of international resource management conventions require that marine resource management be successful at local to global levels.

The 2001 Vanuaso Tikina Resource Management Plan workshop identified these issues

	Lekanai	Vanuaso	Nacavanadi	Malawai	Lamiti	Naovuka
Rubbish dumped on the shore	✓	✓	✓	✓	✓	✓
Pigs roaming freely	✓	✓	✓	✓	✓	✓
Unnecessary tree cutting	X	✓	✓	X	✓	✓
Burning vegetation	✓	✓	✓	✓	✓	✓
Protection of water source	✓	✓	✓	X	✓	✓
Protection and maintenance of drains	✓	✓	✓	✓	✓	✓
Upholding communal lifestyle	X	✓	✓	✓	✓	✓
Education issues	X	✓	✓	✓	✓	✓
Sources of food and income	X	✓	✓	✓	✓	✓
Cutting mangroves	X	X	X	X	X	X
Prepared to participate in development	X	X	X	✓	X	✓

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Case Study 18

IMPLEMENTING ECOSYSTEM-BASED MANAGEMENT AT THE DISTRICT AND SEASCAPE LEVEL IN FIJI

STACY JUPITER

The challenge

Increasing levels of exploitation of coastal resources were threatening the high biodiversity of the Fiji coral reefs. However, these reefs are particularly important for Pacific Island people who depend on the coastal fisheries for economic development and food. By 2035 the human demand on these fisheries will exceed natural production rates and potentially cause a collapse of stocks. In the Fiji Islands, more than 17% of the traditional fisheries management areas are already considered over-exploited while more than 60% are currently at maximum levels of exploitation. Fisheries resources in Fiji are also being damaged by changes in land cover use in the catchment areas. Major sediment flows coming from the clearing of forests are directly linked to a loss of freshwater fish diversity in Fiji streams. This is also affecting many coral reef species such as bull sharks, snapper and mullets that migrate into these streams to feed and breed. The major effects are during the wet season when there is pulsed runoff of poor quality water from the degraded catchments. Because of increasing pressure from the Fiji government to expand mining and logging in Fiji catchments, there is urgent need to manage commercial activities within and adjacent to healthy biodiversity-rich habitats. Community-based management offers the best opportunities to protect coral reef biodiversity, since there are gaps in legislation and limited resources at the national scale to establish and enforce legally mandated protected areas.

What was done?

For hundreds of years, Fijians and other Pacific Islanders used customary governance systems (*qoliqoli*) to manage the use of terrestrial and marine resources. However, these traditions have recently been eroded with increased urbanization and access to commercial markets. Local villages began reviving customary bans on harvesting coral reef resources within their traditional fisheries management areas in the 1990s to stop perceived resource declines. By 2001, these local practitioners, in partnership with government and non-government organizations, had organized the Fiji Locally Managed Marine Area (FLMMA) network, which aimed to share information about best practices for resource management. The main tool of the FLMMA network has been the use of traditional no-take closures (*tabu*) that are harvested periodically at the discretion of local chiefs and community managers. Although these closures are typically small, with a median area of 1 km², they are generally easy to manage because they are within the secure, customary tenure of a single village or clan and usually within sight of the village.

In 2005, the Wildlife Conservation Society (WCS), partnered with Wetlands International-Oceania (WIO) and the WWF South Pacific Programme, initiated an alternative, complementary approach by implementing ecosystem-based management (EBM) within the Vatu-i-Ra and Cakaulevu seascapes of Vanua Levu, the second largest island in Fiji. They worked with representatives of the 10 communities in the Kubulau District of the Vatu-i-Ra seascape to design a network of 17 traditional-style periodic closures with 3 large, permanent, no-take marine protected areas (MPAs) that covered more than 30% of the traditional fisheries management area. These were placed to maximize both biodiversity and fisheries benefits. WCS consulted with the Kubulau chiefs, resource users and many stakeholders from government and NGOs to assist the Kubulau Resource Management Committee, made up of representatives from each village in the district, to create the first EBM plan in Fiji to manage the catchments and adjacent waters. The plan was built from information gained through extensive biological and socioeconomic assessments, which included collection of traditional and local knowledge. All this information was presented to the stakeholders at a large, participatory planning workshop in February 2009, where facilitators used conceptual modelling techniques to define conservation targets, threats and management strategies for terrestrial, freshwater, coastal and marine habitats to show how a MPA network could be included into total area management. The Kubulau EBM Plan includes best practice guidelines for catchment agriculture, logging and waste management, as well as management rules for all habitats with options on how to enforce the rules backed by either national legislation or traditional authority.

WCS created a generalized template of the Kubulau EBM Plan that was presented to community members throughout Fiji during FLMMA annual 'lessons learned' meetings in late 2009. The release of the plan in English and Fijian resulted in many requests from communities to help them implement EBM plans in their areas. Another 4 districts of the Vatu-i-Ra seascape have started to develop their own catchment management plans and WWF is using the template to help 4 districts of the Cakaulevu seascape form a consolidated plan. The guiding principles and lessons learned have been incorporated into a handbook on how to implement EBM in the tropical, Western Pacific. This has been distributed throughout the region.

How successful has it been?

There have been notable successes in the first 5 years after implementing the EBM plan, as well as areas earmarked for improvement. Socioeconomic surveys conducted in Kubulau indicate that communities now consider that the availability of reef resources has increased and there have been improvements in the habitats. This indicates strong likelihood that communities will continue participation in management activities. Biological monitoring of reef fish populations indicates that fish biomass has increased between 2007 and 2009 at nearly all control sites open to fishing. However, not all of the MPAs and traditional closures have been equally effective. Low fish biomass within some MPAs and traditional closures may be related to poaching by residents of Kubulau and adjacent districts or opening the traditional closures too frequently. Further, recent conflict among resource users has resulted in deliberate fishing within the Namena Marine Reserve by traditional fishing rights owners who feel that they have not been adequately compensated for restrictions on their fishing grounds. Thus, WCS and research partners at James Cook University and the University of Queensland are currently using decision support tools to investigate alternative configurations for the Kubulau MPA network that maximize biodiversity benefits and reef resilience while minimizing conflict among resource users.

Catchment freshwater surveys in the Vatu-i-Ra and Cakaulevu seascapes show that community bans on harvesting and clearing forests within riparian zones (beside the streams) can be effective at maintaining fish diversity, even where forests have previously been extensively cleared. However, these benefits are rapidly removed if the ban is lifted. WCS and WIO are now investigating links between the width and condition of this riparian belt and the ecology and composition of the streams to be able to advise communities in Kubulau and adjacent districts on where to place freshwater protected areas and implement broader stream management recommendations. Results from these surveys will be presented to the Kubulau communities at the same time as considering options to reconfigure the MPA network as part of adaptive management of the natural resources.

Lessons Learned and Recommendations

- Management of coastal resources should always commence with an understanding of traditional practices and open communication with communities via contact with their leaders;
- Ecosystem management processes should respect the needs, interests, rights and aspirations of local communities and contribute to local as well as national goals;
- MPAs need to be placed in a broader ecosystem management framework to reduce disturbance from outside the MPA boundaries (e.g. from land-based activities or commercial fisheries operating in adjacent waters);
- EBM requires close collaboration between upland and lowland communities, as well as active, participatory engagement of stakeholders from all relevant sectors, which can include fisheries, forestry, agriculture, tourism and culture;
- Management should be adaptive and iterative as new information becomes available; and
- EBM provides a cost-effective approach for reducing vulnerability to climate change impacts.

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Case Study 19

BUILDING CAPACITY FOR BETTER MANAGEMENT OF THE TAKITUMU LAGOON, RAROTONGA, COOK ISLANDS: HOW STUDY TOURS CAN BUILD KNOWLEDGE AND EXPERIENCE

TAKITUMU LAGOON STEERING COMMITTEE, GEOFF DEWS AND MELANIE KING

The challenge

Historically, the Takitumu lagoon was an integral part of the community of Rarotonga providing many resources for the people. They traditionally harvested seafood, including reef fish, octopus, rori (holothuroids), kina (sea urchins), patito (sea slug), giant clams and more. Until the late 1980s and early 1990s, there was always an abundance of seafood, and the lagoon was where people could relax, swim, snorkel, and sail safely at Muri and Tikioki.

The Takitumu lagoon was characterised by clean, clear waters, live coral and abundant fish life near the shore and protected by the outer reef. The lagoon attracted many tourists to Rarotonga who supported the accommodation and leisure industries. These values, however, have been eroding due to the increasing pressures on the Takitumu lagoon due mainly to: human development adjacent to the lagoon; unsustainable land management and agricultural practices in the lagoon catchments; gradual sea-level rise and changes in ocean conditions; and increases in storms. The lagoon still provides some limited seafood and remains a major benefit to the tourism industry, but the sustainability is threatened.

The key symptoms of declining water quality in the Takitumu Lagoon Management Plan were: the occurrence of the 'syndrome' (believed to be from an algal bloom) in the Titikaveka region of Rarotonga; and the prevalence of ciguatera toxins in some lagoon fishes. The drivers for environmental decline raised by the community included: continuing development of the foreshore lands by tourist resorts; many old septic systems; poor agricultural practices in some parts; and increasing numbers of residents and visitors, many of whom fish and collect marine resources for their own consumption. Concern was also raised about the shallowing of the lagoon because of increased sediment inputs, and the increased layers of mud from the catchment covering coral sands and damaging corals and fish life.

What was done?

The Takitumu Lagoon Management Plan was developed after considerable consultation between the former TakitumuVaka Council, National Environment Service, Ministry of Marine Resources and NGOs, with technical assistance from the NZAid-funded Cook Islands Marine Resources Institutional Strengthening (CIMRIS) project to address the issues and guide the local and national governments in activities to respond to the threats.

The Management Plan was based on a pilot site for the Takitumu lagoon (although its principles can be expanded to a 'whole-of-island' approach) and is based on the principles established through two other national strategic plans: the National Sustainable Development Plan 2007-2010 (NSDP); and the National Environment Strategic Action Framework 2005-2009 (NESAF). These are focused on actions at the local and national level. The Plan provides for three new functions:

1. A mechanism for community, business and voluntary group representatives to work with the government to discuss concerns and identify and prioritise actions to resolve environmental problems in the lagoon;
2. Procedures for gathering technical information to resolve the issues effectively and keep the community well informed about the health of the lagoon, the activities being undertaken to address any issues, and the expected outcomes; and
3. A mechanism to coordinate and integrate government, business and land-owner activities affecting the lagoon so that resources may be committed efficiently to resolve the most pressing issues.

A principal purpose of the Plan was to provide the structure, arrangements and a neutral forum for all interested stakeholders to discuss and decide how the lagoon should be managed in the future. In particular, this involved agreeing on the most pressing issues to be resolved, what options may resolve these issues, and then determining what actions should be taken by specific agencies, businesses, groups, householders and individuals. Prior to the Plan's development, there was little coordination between agencies or NGOs, and disputes over management boundaries and responsibilities between agencies could not be resolved without an effective management plan. There was also no demand for the country to develop 'best practice' for site-based management to reduce impacts into the lagoon from the land.

The Plan was proposed as a voluntary instrument, and although it is operated and managed by the Takitumu Vaka Council (local government council) on behalf of the Takitumu community, activities in the Plan are the responsibility of the nominated group, mainly the Government Agencies and the Vaka itself to implement, including reporting of activities and outcomes. The Vaka Council is responsible for maintaining the Plan, including organising relevant committee and public meetings established under the plan, and preparing the annual reports upon advice from the Agencies. Whilst the Plan is a voluntary instrument, many actions under the workplans do carry the force of law, since they are largely implemented by Government Agencies operating within their respective Acts and Regulations.

How successful has it been?

The Plan demonstrated success after 4 years, particularly in increasing technical knowledge by Government Agency staff and local community members, and in building the capacity of the stakeholders to deal with issues and solutions facing them in an integrated manner. Success is also seen in developing awareness of issues and solutions through:

1. Increased technical knowledge and skills, which have led to changes to the environment;
2. The pilot site being expanded to a 'whole of island' approach;
3. Capacity building study tours have led to an increase in knowledge of issues and potential frameworks; and
4. Exploration of a 'co-management' model to implement future sustainable programs across Rarotonga based on the approach under the Takitumu pilot site.

The capacity building tours aimed to increase the high level of technical capacity in the agencies by adding policy development skills and ways to implement actions to support the Management Plan. Three mentoring and study tours were undertaken for National Environment Services (NES) and Marine Resources and Health staff with a focus on ecosystem-based management. Senior managers visited the Coral Reef Targeted Research Program at the University of Queensland, and one member was trained in legislative drafting in the UK. Management and practitioners attended the Coastal Resources Management course at the University, where they increased their knowledge of integrated coastal management. After the Vaka Councils in Rarotonga were disbanded in 2008, additional training was added to examine the models used by local governments in New Zealand and Australia to build partnerships for integrated management.

Lessons learned and recommendations

The main lessons learned from this project include:

- Ensure enough time is allocated to transfer experience and skills;
- Mentoring is highly recommended to reduce the need for constant 'workshops' that are often focused on international issues rather than local solutions;
- The best method to demonstrate issues and drivers is by initially focusing on small studies;
- Effective management of the study site should include commitments from local communities and Government. Community commitment is an important element for overall ownership;
- Demonstration sites should be based on current issues that do not require additional research and data collection (but may require scientific verification);
- Government engagement is needed from the start and constantly reinforced throughout the program;
- Results of 'best practice' should be presented consistently and not over stated as a 'fix-all';
- Solutions need to be cost effective and replicable, and relate to priority issues;
- Communication early in the program is essential; and
- The program needs to continually adjust the subject and methods of delivery in response to requests for assistance and capacity building by Pacific Islanders.

Compiled by members of the Takitumu Lagoon Steering Committee, Cook Island Marine Institutional Strengthening Program (CIMRIS), Geoff Dews and Melanie King from the Coral Reef Targeted Research & Capacity Building for Management Program. The Lagoon Management Project is part of CIMRIS funded by NZAid and implemented by ANZDEC Auckland, which began in 2006.

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Case Study 20

TRADITIONAL CATCHMENT MANAGEMENT IN TAKUVAINA, COOK ISLANDS

DEYNA MARSH AND TAURAKI RAEA

The challenge

Drinking water for Rarotonga, the capital of the Cook Islands, is collected at 12 water intakes constructed on pristine mountain streams radiating from the central volcano. This is surface runoff water and the streams can run dry during droughts. The untreated water is filtered through a gravel and sand system, and either gravity fed to users, or pumped into elevated storage reservoirs. Historically the people of Rarotonga have consumed this water without significant cause for concern since most water catchments are either untouched or protected by traditional systems.

The Takuvaie watershed is on the north side of capital island Rarotonga and flows through the main town. About 50% of the 161 hectare watershed feeds into an island water supply network linking all of the Rarotonga water intakes. Until the late 1970s, the Takuvaie catchment was also the main food growing area for the Takuvaie community and nearby districts. 'Utu' or crown bananas grow naturally, and taro (*Colocassia esculents*) is grown in man-made swamp patches filled with diverted stream water. This catchment also has a popular trail to one of Rarotonga's highest peaks, the best scenic lookout.

The Takuvaie catchment water has consistently recorded the highest faecal coliform levels for the Cook Islands; far higher than the other catchments on Rarotonga. Taro is still grown in the catchment, and tourists and trekkers still venture unguided up the mountain. While there are water quality risks associated with these activities and some 'unwritten' laws prohibiting and controlling some activities, such as the use of chemicals and bush toilets within the catchment, taro growers have resisted any attempts at relocation and there is no monitoring or control of activities.

Current legislation governs the use of the water catchments: the 'Rarotonga Waterworks Ordinance 1960' aims at the safe delivery of water and services to its users; while the national 'Environment Act 2003', provides for the protection of natural resources. The Waterworks Ordinance designates that water catchments are 'crown' property for the establishment of piping and treatment to ensure safe water for the public.

The Environment Act is broad and provides for the protection of salt and fresh-water resources. For example, any development within 5 km of streams or 30 m of the mean high water mark requires Environment Authority approval. Fortunately, the Environment Act allows for the development of management plans or bylaws at the community level, as well as the development of regulations to protect areas of concern or interest. The traditional tribal groups still own land and are spiritually and emotionally attached to their land.

What was done?

During the 1970s, crop harvesting in the catchments was controlled by a women's organization called the 'Au Vaine', which gave the women the right to confiscate excess harvest as it passed their hut at the entrance to the water catchment area. Offenders were also required to carry out community services such as clearing the stream or the track, or even cleaning other people's plantations. The punishments and swift monitoring of the catchment earned the women respect from the community; however the organization ceased to exist when factory jobs allowed women to join men in the paid workforce.

In 2002, the International Waters Project (IWP) aimed to address the root causes of water degradation in 14 Pacific Countries. In addition to the oceanic component, there was a focus on implementing integrated coastal and watershed management actions to address priority concerns. This kind of project aimed to strengthen or build the capacity of communities and governments to improve the management of natural resources and ensure its sustainability beyond the IWP and not to fund million-dollar infrastructure development.

The Cook Islands project focused on freshwater quality and the protection of water catchments, with Takuvaie water catchment as the pilot site. This was an enormous undertaking on its own, particularly as it was to be replicated in the 11 (of the 12) other water catchment areas on Rarotonga. A management plan was developed and legislated in 2006 following a detailed 3-year community consultation process. This involved presentations from government ministries such as the National Environment Service (NES), Agriculture, Marine Resources, Public Health, Aid Management, and Water Works on the need for effective action to improve the quality of water in the catchment. This improved community acceptance of the final management plan. The root cause analyses helped identify possible solutions and corrective actions. The Management Committee formed under this plan was given the authority by an incorporation of landowners, to implement the plan on private lands.

How successful has it been?

The biggest challenge to this project was getting community support; it took one year of consultation before a core voluntary committee was established to develop the management plan. The major contributing factors to these challenges were:

- Politics and the unstable state of government;
- The Government's poor track record regarding community projects, which were often incomplete because funds were diverted to other projects;
- The land tenure system where the lands are owned by the people and not by the crown; and
- Development ideas where members of the community may have conflicting ideas about developing the area. As land becomes scarce on the coast, more people move in-land and up the mountain.

During consultation, a number of solutions were discussed.

- Installing water tanks for every home to reduce reliance on the public water supply;
- Prohibiting or controlling activities, such as wetland taro growing and other activities within the catchment;
- Relocation of the intakes upstream of the main wetland taro terraces (agricultural areas), but this would significantly reduce the water catchment area; and
- Installing treatment systems, but chemical treatment and spending millions of dollars was resisted. Previous attempts at a user-pays system failed.

Reviving traditional conservation practices and systems, such as the raui (a taboo system), and empowering the community to protect and conserve their land and its resources came out strongly as the best solution. Involving communities to practice and promote better land management practices would be the ultimate action to provide good water quality and have other good environmental spin-offs (protecting biodiversity).

The project initially targeted people living in Takuvaine Village, however, during the endorsement of the Management Plan it was discovered that the majority of the major landowners (thus, decision-makers) lived outside the village. After a lengthy re-examination of the Management Plan, a Management Committee was selected (consisting of major landowning representatives) who endorsed the Plan. Those landowners elected to the Committee unfortunately were not part of the initial development. Coupled with this was the nature of the committee members, where out of traditional respect, families elected the elders, who may have been more appropriate on a decision making committee rather than a working committee. In 2007, during a planning workshop, more landowners and catchment users came onboard and developed a workplan and working committees to implement the Management Plan.

Lessons learnt and recommendations

Community engagement throughout this project has demonstrated that:

- The community must be presented with convincing information or data to speed up the 'buy in' process;
- A long laborious process should be anticipated when seeking community buy-in on new initiatives;
- Ensure a community-based approach; a highly respected community member should be asked to lead the process of community consultation;
- A small committee of committed members is better than a big committee with no determination to accomplish anything, but occupy positions;
- The terms of reference should be made clear before the election of any committee;
- When electing a committee, the expertise and representation of members should be stressed. Senior leaders should be asked to endorse decisions, whereas other community members may be more appropriate in developing work plans;
- An economic valuation should be conducted at the start to be used as a rallying tool;
- Include the youth of the community as they will be taking the project forward into the future; and
- Regulations should recommend adequate monitoring and enforcement of any community-based management plan.

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Case Study 21

COMMUNITIES PROTECT FRESHWATER SOURCES AND REDUCE SEDIMENT DAMAGE TO CORAL REEFS IN PALAU

STEVEN VICTOR, ADELLE LUKES ISECHAL, JOYCE BEOUCH, UMIICH SENGEBAU AND YIMNANG GOLBUU

The challenge

When the Republic of Palau became independent in 1994, the USA agreed to build a 50 mile (32 km) ring road around Babeldaob Island, the largest volcanic island of more than 500 Palauan islands. It was hoped this would bring economic benefits to this tiny Pacific Island nation. The construction of the road involved extensive land clearing such that there was massive soil erosion into the streams, which ended up in coastal areas and degraded mangroves, seagrass beds and coral reefs. The completion of the road in 2006 has increased access to both public and private properties in much of this 330 km² volcanic island. The desire for economic development raises concerns that more land will be cleared leading to increased soil run off and damage to marine resources. Already the increased sediment flows have damaged freshwater sources, degraded downstream marine habitats and contributed to declining fish stocks and other marine resources used by communities. Thus, there was an urgent need for better land management and conservation practices to safeguard these resources.

What was done?

Past conservation efforts in Palau have largely been focused on the marine environment. The concern for the decline in reef fish stocks coupled with the potential for a marine-based tourism industry helped fuel marine conservation. Conversely, terrestrial conservation, for the most part, lagged far behind or was non-existent. In 2003, Palau International Coral Reef Center (PICRC) launched scientific studies in Airai Bay to quantify sediment input and to document the impacts on coral reefs and other habitats. They documented losses of corals and degradation of reefs as a direct result of sediment from the land. Subsequent studies at other sites in Babeldaob reported similar sediment damage to the corals reefs. These findings became the basis of awareness campaigns targeted at Babeldaob communities that emphasized the link between land-based activities, the quality of rivers and freshwater drinking supplies, and the habitats that support the fish, clams, mangrove crabs and many other resources that communities rely on for daily living.

When PICRC scientists presented these findings in Airai and elsewhere in Babeldaob, the communities were motivated to protect the mangroves that were trapping sediment, and the Airai State initiated a ban on mangrove clearing. The improved understanding of the impacts of sediments and concern for the health of ecosystems that supported community livelihoods helped mobilize communities and conservation practitioners to work together.

Biodiversity conservation in Palau had mainly focused in the past on the marine environment, especially the decline in reef fishes which are the main source of animal protein for Palauans, and the basis for marine-based tourism. Thus it was difficult to convince Palauan communities that biodiversity was important as they have much less affinity for forests and terrestrial systems than they have for the sea. Water quality and quantity, however, proved to be a key conservation target as clean water was fundamental to Palauan culture. Thus the conservation focus shifted from species and ecosystems towards protecting community culture and their way of life.

This quality of life emphasis on conserving freshwater resources transcended the discussion beyond the political boundary issues for neighboring States and focused instead on ecosystem boundaries to effectively conserve water sources. This approach allowed States with political boundary issues to collaborate to guarantee that their freshwater resources continue to be clean and abundant, and able to support economic development.

After a series of meetings with key elected and traditional leaders of two Babeldaob States and a group of young conservation practitioners, including the Community Conservation Coordinators of Palau Conservation Society, the first meeting of the Babeldaob Watershed Alliance (BWA), was convened during which the two States of Melekeok and Ngaremlengui signed a 'Master Cooperative Agreement', a document that articulates the states' commitment to protect and manage critical watershed areas. With the leadership and guidance from renowned conservationist and congressman Noah Idechong, High Chief Reklai of Melekeok State and Chief Ngirturong of Ngeremlengui State, BWA has grown to include 9 of the 10 Babeldaob states and has attracted the support of key government agencies and NGOs, such as Micronesia Conservation Trust (MCT) and US Fish and Wildlife Service.

How successful has it been?

The Babeldaob Watershed Alliance has grown to be an informal yet effective network of communities, government agencies and NGOs. The forum has allowed communities to individually or collectively request assistance and for agencies to better coordinate and streamline the delivery of that assistance to address local priorities. The non-binding, voluntary 'Master Cooperative Agreements' between States, agencies and NGOs provided incentives for States and agencies to make progress towards the collective goals by a series of small steps. Progress of the alliance includes very tangible conservation outcomes that protect livelihoods and conserve biodiversity, including:

- Establishment of 4 new terrestrial protected areas;
- Completion of conservation action planning in 8 communities;
- Completion of 2 management plans in 4 communities that are now completing their plans;
- 9 out of 10 communities in Babeldaob have joined the Alliance.

Lessons learned and recommendations

- *Relevance to livelihood:* Conservation targets must be linked to quality of life. When the focus shifted away from species and ecosystem conservation towards protecting water which is the base of community culture and their way of life, the Babeldaob Watershed Alliance found natural allies in the traditional chiefs who, despite the modern democratic government, are still widely recognized as stewards of all commonly shared resources and defenders of the Palauan culture and way of life.
- *Leadership:* Identification of an individual who can act as project champion is key. The charismatic leadership of High Chief Reklai added credibility and authority to BWA's message and engaged the traditional leaders of other states to rise to the same challenge.
- *Relevant and sound science:* Availability and effective communication of sound scientific information is essential. The scientific data documenting the negative impacts of sediment on coral reef communities increased awareness in some and empowered many others by validating and understanding what they were already seeing on their reefs.
- *Awareness of social, cultural and political context:* Palau, like other small cultures in a modernizing world, has complex, sometimes subtle but often intersecting social, cultural and political landscapes. Understanding and navigating through this complexity is rarely given enough emphasis in conservation projects. The BWA included young local conservation practitioners who understood the science and the culture, and were able to communicate the scientific information to leverage community support.

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Members of the Babeldaob Watershed Alliance Steering Committee during the first leadership summit at TNC to raise awareness of the Alliance and the need for better management of water resources. Initially the Alliance had 5 member States, but this has grown to 9 States.

Case Study 22

COASTAL REFORESTATION IN TONGA TO PROTECT COASTLINES

RANDY THAMAN, ANDREW SMITH AND TEVITA FAKA'OSI

The challenge

The coastal lands of many small island states are seriously threatened by coastal erosion and increasing salination, which are exacerbated by rising sea levels. The erosion can be particularly serious if the natural coastal vegetation has been removed, which leads to seawater contamination and increasing wind damage to coconut plantations, food gardens and particularly freshwater wells. Accelerated erosion also damages nearby coral reefs.

Most of the original forest cover in large parts of Tonga has been removed for timber, firewood or agricultural expansion. This was exacerbated because of the small land holder allotment system in Tonga, with very little land available to cater for increasing populations and expansion of export agriculture. The deforestation has exposed shorelines, accelerated sand erosion, reduced suitable timber for construction and firewood, and resulted in the loss of medicinal and other useful plants. Coastal forests are also major habitats and nesting grounds for threatened seabirds, crabs and turtles.

Tongan farmers traditionally protected coastal forests as a buffer between their farms and the sea to reduce salt spray, saltwater intrusion and wind damage from storms and cyclones. However, during the past 25 to 50 years, these forests have been cleared to extend farms seaward and take valuable timber. This was particularly serious around Houma on the southwest coast of Tongatapu, the main and most populated island in Tonga, where farms and grasslands expanded towards the coast, and traditional agroforestry trees were removed. Cattle, horses and especially pigs, and the indiscriminate use of fire to prepare gardens have also damaged these forests. These losses have resulted in drastic declines in agricultural productivity and diversity; some farms have been abandoned due to the increased salt. The Prime Minister of Tonga, who was from Houma, focused on the problem in the early 1990s; thus the Ministry of Agriculture and Forestry (MAF), with support from Australia, SPREP and The University of the South Pacific (USP), implemented the Tonga Coastal Protection and Reforestation Project in the mid-1990s to address these problems. The primary objectives were to: develop and implement an effective model for coastal reforestation near the Blow Holes at Houma; and develop effective community-based programs to promote coastal reforestation and protection at community and landowner levels. There were 3 other objectives: to supplement Tonga's declining timber and multi-purpose tree resources; rehabilitate areas of degraded coastal lands to prevent shoreline and saltwater damage; and develop a model for coastal planting and produce seedlings for sale to the public.

What was done?

The MAF assessed many indigenous species to find the best local trees and shrubs to plant along the coastal zone. They examined previous propagation projects looking for salt- and wind-tolerant plants, particularly important food and timber trees, or others with cultural significance e.g. used medicinally or to build canoes.

The project site was Houma (southwest Tongatapu); a rocky, uplifted windward limestone area, with a raised limestone terrace and a fringing coral reef that drops off to the deep ocean. Large waves crash on the shore creating spectacular blowholes and high volumes of salt spray which blow inland onto farms and houses. The remaining coastal vegetation was very degraded, with most of the larger coastal trees removed to expand farms or make banana shipping crates in the 1960-70s, or damaged by fire, salt spray and firewood collection.

The site was marked out and manually cleared, especially to remove Guinea grass (*Panicum maximum*) and other shrubby vegetation to reduce wild fires, which damaged previous vegetation projects in Tonga. A 5 m wide firebreak was cleared along the land side and planted with cassava (manioke) and other crops to keep out the grasses, and prevent people from trampling or driving over the young trees. Unfortunately free roaming pigs dug up some cassava and damaged young trees; therefore a fence was needed to keep animals out.

They used a 3-phase approach: 1. fast-growing pioneer species were planted to provide shade and shelter from the wind, with Casuarinas planted in two rows five metres apart on the land adjacent to farms. Large numbers of Casuarinas can be grown easily from seed, they fix nitrogen, are useful as firewood and grow rapidly to form effective wind breaks. They also planted 30 indigenous coastal tree species on the seaward side of the casuarinas. 2. after about 6 months, less-tolerant, but preferred, species were planted in the shelter of the pioneers. 3. finally they focused on hard to propagate species to increase diversity towards that of the original forest.

The original strategy was for co-management between the Forestry Division and the community, but there was little early cooperation because the Houma Town Officer was absent for most of the time. However, the people played a very positive role in preparing, planting, and maintaining the project; something they are very proud of.

How successful has it been?

About 25,000 seedlings and saplings from 30 indigenous species were planted along 2 km of coastline in 2.4 hectares; mostly in a narrow band 12 m wide. Approximately 80% had survived after 2 years. MAF undertook a concerted awareness raising program on coastal reforestation with the local community, especially on the maintenance of the newly planted trees. Frequent weeding was essential to prevent overgrowth by grasses, shrubs and vines, and to reduce the fuel for fires. Firebreaks were also maintained and mature trees protected during the development. Control of free ranging livestock, particularly pigs, cattle and horses was also essential.

A limiting factor for re-forestation on Tonga is the legal definition of the coastal area: “the area between high tide and 50 feet (15.4 m) inland”, but local boundary markers can vary considerably. This is virtually the only land owned and controlled by the Government; thus part of the Houma site was within the coastal zone, and the rest within the estate of village chiefs. No re-forestation land was in farmers’ allotments, but the coastal forests were considered to be common property for firewood, medicinal plants, wood for carving and building. Thus the community and chiefs had to agree to the tree planting project and allow the forest to grow.

The coastal planting in Houma was very successful in re-establishing viable forests and windbreaks, and even Cyclone Hina in March 1997 cause no damage to trees, except snapping off the upper crown of some *Casuarinas*. By 2011, the forest was fully grown with the double row of *casuarinas* forming a wall along the coast and protecting the farms, and many other coastal trees in this multi-species forest.

Lessons learned and recommendations

- Coastal forest protection should be high priority for small island communities, particularly with the threat of sea level rise and increasing extreme events;
- Using local salt-tolerant species is a cost-effective, low-tech method for coastal re-forestation to protect coastal lands and communities from natural disasters and sea-level rise, and to increase food production;
- Success was enhanced because it was proposed by a traditional leader (who was also the Prime Minister), illustrating the need to involve traditional leadership and to have a ‘champion’ to raise awareness in communities;
- National legislation is needed to support community projects in the coastal commons to reduce shoreline erosion, reduce sedimentation on reefs and protect threatened marine and land animals;
- Before starting, it is essential to understand traditional ownership rights and customary (‘usufruct’) rights to resources on common land;
- Planting cassava and other food crops in the fire break was successful because people were less likely to damage food crops, and moreover they provided multiple benefits from labour and weed control;
- Selecting the best trees is important to gain community support; this project used over 30 indigenous species. *Casuarina equisetifolia* was extremely successful as a windbreak; other very successful trees included coconut palms, *Pandanus tectorius*, *Hibiscus tiliaceus*, *Excoecaria agallocha*, *Calophyllum inophyllum*, *Hernandia nymphaeifolia*, *Terminalia catappa*, *Tournefortia argentea*, *Barringtonia asiatica* and *Neisosperma oppositifolium*. Other indigenous species that show promise for enrichment include the high- value carving wood and multi-purpose trees, *Thespesia populnea*, *Cordia subcordata*, *Guettarda speciosa*, *Xylocarpus moluccensis*, and sandalwood (*Santalum yasi*), which have all been historically selectively removed from Tonga’s coastal forests
- Provide enough time to allow a three-phase coastal reforestation (pioneer species; non-pioneer species; and high forest biodiversity enrichment planting). Short-term projects often fail, which results in a lack of confidence and support from local communities;
- Regular maintenance is essential to prevent grasses, weeds and smothering vines, and to reduce the amount of fuel for fires. This was done by the Forestry people assisted by the Houma community;
- Protection from free-ranging livestock is essential; this may require fencing; and
- Coastal reforestation is a very practical activity for communities to protect their land from sea-level rise, climate variability and extreme events (such as tsunamis and cyclones). Protecting original coastal forests is easier and more cost-effective than re-establishing a degraded forest.

Contacts

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Case Study 23

SEWAGE POLLUTION CONTROL IN KANEOHE BAY, HAWAII IN THE 1970S AND 1980S

DON KINSEY

The challenge

Kaneohe Bay is a large, elongated embayment (14 km long) that runs SE to NW on the windward side of island of Oahu in Hawai'i. It is roughly enclosed by a barrier reef about 5 km long. The enclosed waters are about 2.5 km wide on average, but there is a 4 km wide lagoon-like area in the southern Bay. There are many patch reefs of very variable size throughout the Bay and the lagoon has a relatively uniform depth of about 15 m. Ocean water is driven in by the dominant trade winds through a 2 km wide channel south of the barrier reef. The seawater circulates through the southern Bay then moves out the northern end several kilometres north of the barrier reef with a typical residence time of about two weeks.

Throughout much of the last 6,000 years, the reefs have been subject to occasional damage by freshwater flowing off the land and 'floating' to about 1 metre depth over the seawater after major rainfall events. This often results in the death of reef communities, but this was usually temporary and good recovery occurred over the following few years. The northern inshore end of the Bay has long received diffuse nutrient and sediment inputs from low-level agriculture and semi-rural settlement, especially septic tanks, such that the reef flats are almost totally 'dead' with virtually no corals and colonised mostly by thick algal growth. These conditions have not changed recently, except to be slightly more aggravated with increasing population pressures in the Bay.

The southern end of the Bay is predominantly urban, being the outer suburbs of Honolulu, the largest city in Hawai'i. Poorly controlled land clearing and building activities have resulted in serious runoff of the lateritic (volcanic) red soil. There have been many periods of more concentrated fresh water flows with elevated nutrient concentrations after storms. Thus, there has been considerable and increasing damage to surface reefs from this pollution. The most significant input was due to the rapid increase in human populations with the release of large volumes of partially treated sewage through a major point-source in the southern end of the Bay. By 1975, the mostly non-toxic domestic sewage from 100,000 people was pouring out. This high-level nutrient pollution was almost all immediately taken up by plankton near the entry point. When nutrients were measured in the southern Bay, the levels were only moderately elevated but there were very elevated concentrations of organic matter (plankton). For some decades, the coral reefs tolerated this 'abuse' with some loss of normal reef organisms and major increases in organisms that could benefit from filter-feeding on the organic matter. The elevated nutrient levels also caused substantial overgrowth by the massive green bubble alga (*Dictyosphaeria cavernosa*). The central section of the Bay retained an almost natural reef community, but with larger amounts of the bubble alga and some filter feeders.

In 1965, there was a major rainfall event that killed large areas of the reef; there was virtually no recovery of any remaining reef organisms in the southern third of the Bay after that event. The remaining reef flat communities consisted almost entirely of organic feeding organisms such as zoanthids, sponges, barnacles, feather duster worms etc. The bubble algae continued to thrive, but more towards the centre of the Bay as the water in the southern part was too turbid to allow enough light to penetrate.

What was done?

Virtually nothing significant was done to modify the low-level diffuse, but chronic, pollution inputs to the northern Bay. During the 1970s, more stringent controls on urban development came into effect in the southern part, and by 1980 sediment runoff from careless developments had been substantially reduced. Fortunately, much of the suburban development in the more coastal areas of the catchment had already been completed. Although localised stormwater runoff increased with the increased population and larger areas of sealed surfaces, nutrient input generally was more controlled and stable.

The most significant change occurred in late 1977 after recognising the major problems for reefs in the southern Bay were due to sewage effluents and their high nitrogen and phosphorus content. This was reinforced by ecological studies from the late 1950s and facilitated by the Hawai'i Institute of Marine Biology, University of Hawai'i in Kaneohe Bay. With this knowledge, the major sewage outfall was diverted totally to a deep ocean outfall off the southern end of the Bay and a lesser outfall from the Marine Corps Base was also diverted in mid-1978.

How successful has it been?

The most dramatic response followed the diversion of the sewer to the deep ocean. The immediate stop in the point-source nutrient release deprived the plankton community of food. Almost immediately, the water clarity improved from the decrease in plankton growth, and within a few weeks the major populations of filter feeding communities died, especially the barnacles and sponges. This left much of the dead reef substrate available for new coral colonisation.

However, an unexpected outcome was that large concentrations of nutrients were still held within the sediments of the Bay, and slowly released over a very long time. Thus there was no immediate or large drop in nutrient availability in the Bay, even though the sewage was gone. The newly exposed reef substrate was colonised by thick algal growth (mostly foliose red algae), and this continued for at least 4 years until 1982, when rapid recovery of corals and other reef biota started on these clear reef-flats. After 7 years (1985), coral cover was well established in areas formerly covered by the filter feeders.

The effect of better control of suburban stormwater flows was also very obvious. By 1982, large areas of the southern Bay still showed evidence of red mud covering the bottom, but water clarity had improved markedly. By 1985, most of the red mud had disappeared from these former degraded areas and some limited growth of corals and other reef biota was happening. The central Bay which was already in quite good condition, showed further improvement with less bubble algae and fewer filter-feeders. But, there was virtually no improvement in the degraded reef-flats of the northern Bay, because of the continued diffuse pollution; there has been no evidence of recovery since.

Sadly, the occasional serious rainfall events still occur. A particularly severe flooding event in 1987 killed large areas of the new reef-flat coral communities. However, the well-recovered deeper reef-slopes were not particularly affected by the freshwater flows and provided new coral larvae. Recovery from these severe flooding events should be much better now that the sewage has been removed and the urban development at the southern end is essentially complete. However, the situation throughout Kaneohe Bay is not stable. There are continuing threats with a probable increase in frequency of extreme weather events due to climate change and growing human populations which will mean larger areas of sealed surfaces.

Lessons learned and recommendations

- Extensive research studies were needed to identify the major issue i.e. the sewage. Somewhat fortuitously, many studies of coral reef ecology were already occurring in Kaneohe Bay to document the declines;
- Kaneohe Bay was threatened by 3 major pollution threats: increasing human populations with more clearing of land, and hardening of surfaces; a major point source of sewage pollution at the southern end; and diffuse domestic and agricultural pollution throughout the Bay, especially in the north;
- The large nutrient point source from the sewage outfall caused major damage to the coral reefs and water quality, but this was relatively easily fixed by diverting the outfall away from the Bay into deeper water (although at considerable financial cost);
- While there was a rapid plankton and filter feeder die off, the nutrients buried in the sediments were slowly released and these delayed coral recovery;
- Four years after the diversion of the major sewage point source, the coral reefs recovered relatively rapidly following the gradual removal of sediment nutrients;
- This showed that coral reefs are able to survive and grow next to highly urbanised environments provided there is good planning and control of sewage pollution;
- However the diffuse nutrient and sediment inputs have continued and caused significant damage that will require very careful and often difficult catchment management to control. This is a general rule; diffuse pollution is always more difficult to manage than point source pollution;
- Periodic extreme weather events are natural and very serious, but the damage involved can only be minimised with major and expensive catchment modification, such as extensive replanting of lost vegetation, a decrease in sealed surfaces, significant changes in stormwater systems through the use of more natural and artificial wetlands; and
- Climate change will probably result in more extreme weather events with periodic flooding and coral die off. Better management of the catchment will provide these reefs with more resilience, particularly if corals in the deeper parts of the Bay remain healthy.

Contact

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Case Study 24

A MULTI-AGENCY RESPONSE TO SEDIMENTATION DAMAGE TO HAWAIIAN CORAL REEFS

RISA ORAM

The challenge

Sedimentation events have devastated Hawai'i's coral reefs in recent decades. The islands are recent in origin with steep mountain slopes and unstable soils. The coral reefs that grew up around the islands were able to cope with relatively high levels of natural sediment flows; however, recent massive increases in sediments washing off the land have smothered reef flats and fringing reefs. While the evidence for increased sediment concentrations is easy to see, the causes of these events are often not well established and their impacts on coral reefs are not well characterized or quantified. Detailed responses and assessments of sediment damage to coral reefs are limited because of limited funds, low staff capacity, jurisdictional limitations of government resource agencies and unclear lines of responsibility between different regulation agencies. The principle sources of sediment flows are from forest clearing, urban development and building of roads, pineapple growing, and golf course construction.

Management of resources in Hawai'i is based on the principle of *ahupua'a*, which is the principal land division that runs from mountains to the sea. It is also the basic unit of Hawai'ian socio-economic organization, therefore any consideration of coral reef health must include all the lands to the top of the mountains and all the catchment areas for the waters.

What was done?

A Sediment Response Network Workshop was held in May 2010, developed within the Hawaiian Coral Reef Land Based Sources of Pollution Local Action Strategy and supported with funds from the NOAA Coral Reef Conservation Program. This workshop brought the appropriate government agencies together to: seek commitment to create a sediment response framework; identify potential multi-agency team members; and develop a sedimentation response protocol and investigation methodology.

Three sedimentation case studies: Pila'a, Kaua'i; North Kohala, Hawai'i; and Hokulia, Hawai'i, were presented to demonstrate damaging land-based activities, to describe the nature and extent of agency investigations, and to highlight the lessons learned to improve the response and resource protection. Each case study was described based on the 'land' response from the U.S. Environmental Protection Agency (USEPA) and State of Hawai'i Department of Health (DOH) and the 'water' response from the Department of Land and Natural Resources, Division of Aquatic Resources.

The Pila'a, Kaua'i case study showed an effective, coordinated agency and citizen response where legal action was taken and civil and criminal enforcement occurred. There were many violations of county, state and federal laws after extensive earthwork was done without permits, appropriate engineering design or erosion control. Large sediment flows in 2001 from a 378 acre (150 ha) property on Kaua'i entered Pila'a Bay damaging streams, beaches and coral reefs. Penalties were levied by State and Federal governments for civil (\$2M fine) and criminal violations (\$500K fine plus public service payment of \$200K upgrade coastal cesspools at Kalihiwai). This violation required years of land stabilization, restoration work, and monitoring of the Pila'a environment; a total cost of \$5.3M. All un-permitted work and land sub-division was stopped.

The lessons included: coordination with state, county, federal agencies, and citizens was effective; technical experts from both sides collaborated on the restoration and settlement; press coverage resulted in new information being offered; diligent oversight/monitoring of stabilization, operations and maintenance by citizens and government was critical; and there were large dollar, time, and reputation penalties for the violator. The USEPA identified several improvements in procedures, including: identifying and implementing land stabilization measures more quickly; requiring technical consultants with erosion control qualifications; and establishing a conservation easement to protect restored streams, stabilized slopes and native plants from future development.

The North Kohala, Big Island of Hawai'i case study highlighted 'un-coordinated' agency responses. This coast is generally undeveloped except for three sparsely developed subdivisions drained by several steep ravines from the Kohala Mountain Range. Notification of a large sedimentation event in South Kohala, stimulated inspections between in 2006 and 2007 that showed: urban development in the watershed contributed to the pollution and several un-permitted construction projects and permit violations were found; an earthquake in October 2006 followed by heavy rainfall contributed to large sediment discharges; non-point source discharges from deforested and overgrazed land were major contributors; and pollution was primarily from poor land management practices and poor regulatory oversight. DOH changed the homeowner's association rules, without assigning responsibility for the sediment discharges. USEPA used Clean Water Act enforcement to address un-permitted alteration of a dry streambed and DOH prevented damaging construction. Possible violations and

specific point sources were identified from a helicopter. However, inadequate regulations and inadequate land grading and stormwater requirements in Hawai'i prevented effective enforcement and remediation. A major lesson was to improve communication between regulatory agencies e.g. between National and County of Hawai'i roads departments.

In the Hokuia, Big Island of Hawai'i, environmental damage still occurred even though all construction was conducted using the required permits. Pollution from a 1,540 acre (600 ha) property between Kailua-Kona and Kealahou on Hawai'i occurred after a heavy storm in September 2000 polluted Class AA coastal waters (water with the highest degree of protection under State water quality standards). The developer had failed to implement best practice erosion control measures and the management authority had not checked the development. The development was designed for a 10-year storm in compliance with County of Hawai'i stormwater control measures, but this storm was excessive. The major lessons learned were that best management practices are essential and better interagency communications are needed to protect sensitive areas. This large area was opened for development before best management practices could be implemented.

How successful has it been?

A sediment response notification framework created at the workshop was as follows;

- Identify scenarios that need a response (major/minor events);
- Develop standardized notification protocols for the entire state to ensure consistency;
- Separate land and water frameworks and ensure linkage;
- Contact State of Hawai'i Department of Health, Clean Water Branch as gatekeepers rather than Counties;
- Notify county agencies where and when an event has occurred; and
- Consider development of different notification systems for each county.

A separate response framework was created for each County that included contact names and information for each County, and the way each County should respond. They developed a sedimentation notification framework with all agencies cooperating.

Lessons learned and recommendations

- A small core planning team of critical players should attend workshops to develop sediment response protocols, form alliances and determine responsibility via a clear chain of command to respond to sedimentation events and prevent future damage;
- Responses and remediation efforts should be multi-agency, multi-disciplinary and take a whole of watershed approach by identifying erosion sources, and tackling them;
- Lack of funding and/or expertise can slow or stop a response, but forming partnerships allows the use of all partner resources;
- Current voluntary control of non-point stormwater management systems should be replaced by stronger regulation in recognition of the pace of land development;
- Public education for ridge to reef pollution prevention is important and should target homeowners, agricultural workers, the media and county councils;
- Timely interagency communication during or just after an event is important with a 7day/24 hr notification system;
- Participatory workshops provide richer understanding of the capacity, needs and authority of each agency;
- Existing statutes should be reviewed to determine if they will withstand court processes and still be effective;
- Relevant agencies need improved capacity to monitor water quality, locate point source and nonpoint sources of pollution and apply the regulations based on agreed response thresholds;
- Similarly coral reef site identification, assessment methods, sedimentation measurement, effective data archiving and analysis need to be standardized;
- Comparable response networks around the world can provide valuable lessons on best practice, levels of compensation and remediation methods;
- Where funding permits, 'neutral' experts should be consulted to advise on regulation breaches and any required remediation;
- Enforcement of regulations is essential and violations must be pursued by State or National authorities.

Contacts

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CaseStudy 25

PRACTICAL CORAL REEF MANAGEMENT ON A SMALL ISLAND: CONTROLLING SEDIMENT ON KOH TAO, THAILAND

RADDA LARPNUN, CHAD SCOTT, PINSAK SURASAWADI

The challenge

Koh Tao is a small, 21 km² island north of Koh Samui in the Gulf of Thailand. It attracts 300,000 to 400,000 tourists every year to enjoy the climate, clean beaches and coral reefs. It is the hub of scuba diving instruction and certification for Southeast Asia, and diving forms the base of the local economy. Tourism generates US\$ 62 million each year from clean, healthy coral reefs. All this is threatened by rapid development and over-exploitation of the fisheries and coral reef resources. There are few waste water treatment systems on Koh Tao, so nutrient and sewage pollution is increasing in the bays where algae out compete corals. Reef resilience is decreasing and there has been little recovery from recent bleaching. Rapid deforestation has released excess sediment during rain events and this has reduced light for photosynthesis and slowed coral growth. Some coral reefs have been buried completely.

The largely 'top-down' Government promotes tourism development with policies that appear to favour unchecked growth. The over-development is threatening the livelihoods of local stakeholders who have no influence on development. The problem is further compounded by poorly planned projects that seek to facilitate island growth. The challenge is to match human needs for clean water with the potential ecosystem damage from building reservoirs and dams. An example was the construction of a reservoir in the pristine forests above Tanote Bay, which failed because it was put on the summit of a mountain with no catchment area to collect rain or ground water. The topsoil was removed and revegetation is difficult in the nutrient poor clay soils.

In 2006, local dive companies measured 44.5% hard coral cover in Tanote Bay with 93.2% of these corals being healthy, with no evidence of silt sediments. Fish populations were healthy with 9 fish per 100 m² of Weibels and 8-banded butterflyfish, 23 rabbitfish per 100 m², and 31.5 parrotfish per 100 m². After the reservoir was built in mid-2006, changes in reef health were observed immediately. By 2008, hard coral cover had dropped to 23.5%, and 66.3% of the bottom was covered in silt. Fish abundance also dropped with fewer than 3 butterflyfish and 3 parrotfish per 100 m², and only 1 rabbitfish per 100 m². Giant clams and boring clams also decreased from 1.5 giant and 13 boring clams per 100 m² respectively in 2006 to 0.5 giant clams and 2.25 boring clams per 100 m² in 2008.

Between 2006 and 2009, approximately 1.5-2.0 metres of silt was deposited in the bay with some of the monitoring survey buoys buried and the sand areas being layered with mud. The water is dirty and the corals are either buried, diseased or overgrown by ascidians. Sediments are also flowing into surrounding bays such as y Ao Leuk and all the way to Shark Island.

What was done?

Because stakeholders had no control over the rapid development that was wrecking their coral reefs, they formed the 'Save Koh Tao' Conservation Group in 2000; and expanded it to a multi-stakeholder body to include the Local Administrative Authority, dive and resort businesses, concerned citizens, youth, and other groups. The Group consulted widely with government, academia, businesses and NGOs to identify the main problems and find solutions.

The stakeholder strategy used awareness raising through data collection and direct action to mitigate damage. Dive shop volunteers monitored the reefs using Reef Check /Reef Watch methods to convince the Thai government's Department of Marine and Coastal Resources (DMCR) to assist; they brought in technical experts to analyse the problem and help the local community find solutions. Soil conservation experts analysed the sources of the sediments and watershed experts advised on how to reduce sediment loss. More formal stakeholder consultations followed and a vision and plan for the island was developed.

The Group tried two solutions to reduce erosion: more than 300,000 vetiver grass plants (King's Grass) were planted around the reservoir by 150 volunteers to stabilize the soil; and local tree species, including coconuts, were planted along the road and around the reservoir. At the start, few volunteers were aware of the problems caused by the reservoir; but later they helped replace the 30% of grasses that died and assisted in building nurseries to supply more plants.

The Group and local businesses built a retaining wall along a degraded waterway and constructed 76 small erosion control ('check') dams across minor channels, swales, bioswales, or drainage ditches. These have reduced erosion by allowing sediments and pollutants to settle. In mid-2009, DMCR granted Save Koh Tao 0.5 million baht (USD15,000) to purchase Gabian baskets, erosion control blankets, and erosion control logs and another volunteer group with school children installed these to further reduce erosion, and further raise awareness and community support.

How successful has it been?

The major success has been the development of an 'island master plan' in partnership with many national and local government agencies. These included DMCR, Prince of Songkla University, local government, and Office of National Environmental Policy and Planning, which is now regulating Koh Tao areas as an 'environmental protection area'. The Department of National Parks is preparing to declare 27 hectares of the upper watershed as a special protected area to reduce erosion. The Provincial Administrative Authority provided 1 million baht to build more check dams.

The local communities now better understand that managing their activities on the land can improve conditions for the reefs. The Group now includes many stakeholders who are active in rehabilitation, and a local monthly newspaper shares information and knowledge amongst residents. A major challenge has been balancing the needs of individuals against the collective good of the community and the environment. The stakeholders recognise more work is needed to increase capacity and involve all stakeholders, but this grassroots initiative has shown outstanding success in just 2 years. However, land tenure and land ownership problems are complex and reduce the effectiveness of the master plan. Some key stakeholders will not permit erosion control structures on their land, therefore more advocacy is required to bring the island's population into the process.

Another complication is that the development and zoning regulations are out of date and the islands are under the jurisdiction of the Thai Department of Treasury, not the local authority, which should be responsible for land management and development. While local rehabilitation initiatives may work to get the community involved, they cannot always solve the systemic problems of poor development decisions. A better regulatory framework is needed for sustainability.

Lessons learned and recommendations

- Local stakeholders have the most interest in protecting ecosystems, therefore building their capacity to network and assess the problems and solutions is the essential starting point;
- Stakeholders need logistic and information resources to find solutions to problems, therefore outside experts in soil management and pollution control enabled the community along with the government to understand the problems and find solutions;
- Building capacity in local authorities is important for long term sustainability of project activities like implementing the Koh Tao Master Plan;
- The stakeholders gained a better understanding by being involved in the initial resource assessments and reef monitoring, and now understand how activities on land damaged marine ecosystems and their livelihoods. Changing the views of the policy makers outside Koh Tao was more difficult;
- In Thailand, most development decisions are top down from Bangkok and rarely consider the impact of developments on key ecosystems that attract the tourists who are fundamental to the tourism economy; a case of 'killing the goose that laid the golden egg'.

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Case Study 26

INVOLVING INDUSTRY AND LOCAL COMMUNITY TO CONTROL LAND-BASED POLLUTION IN BATAM, INDONESIA

SOUTH CHINA SEA PROJECT

The challenge

Rapid economic development on the Indonesian island of Batam was resulting in damage to the environment, especially to the coastal resources. Batam Island covers 1,570.35 km² with the Singapore Straits to the North and the large island of Sumatra to the West and South. Because Batam is located at the crossroads of one of the world's most important international trade routes and next to the booming economy of Singapore, it has been designated as a major centre of economic development for Indonesia. There have been enormous increases in investment across all sectors, but particularly in commerce, industry, tourism, and real estate; but the environment has suffered as have the few remaining coral reefs between Sumatra and Singapore. The health of these reefs and other coastal habitats was rapidly declining as populations increased rapidly and there were greater demands on the marine environment to provide food and recreation for people who have rising living standards. The resources were being over-exploited and heavy metal, nutrient, and sewage bacterial pollution from domestic and industrial wastes was increasing rapidly.

The project objective was to: reduce land-based pollution by promoting SUPER, PROPER and Cleaner Production (CP) systems developed by the Indonesian Government in Batam City; evaluate the social acceptability and cost effectiveness of small-scale community sewage treatment systems; and to promote co-operation and increase awareness among the government, civil society and industries about water pollution problems around Batam.

What was done?

The activities planned to achieve these objectives included: compiling and collecting baseline data and information on the demographics of the island; determining the major occupations of the people; finding the point and non-point sources of water pollution; and asking the communities how they used the coastal and coral reef resources including the importance they put on maintaining them for the future. The main objective of gathering these data were to: implement effective management; build effective and low cost facilities to manage domestic liquid and solid wastes; secure compliance of the industrial sector, especially to reduce the heavy metal content in discharges; and raise public awareness of the problems and possible solutions, and then develop their capacity to implement effective pollution control.

The responsible agency for the management of domestic waste was the 'Agency for Market and Sanitation of Batam City', which collected domestic solid waste from markets and towns and dumped them in temporary sites prior to composting, burial or burning. Bapedalda, the Indonesian Government Environment Impact Management Agency had overall responsibility for environmental management, including monitoring, control and supervision of natural resource use and environmental impact analysis.

The key challenges Bapedalda faced were a lack of compliance by industries of regulations about monitoring and pollution management, and poor awareness in coastal villages about the correct disposal of domestic wastes and the effects these were having on the environmental health of the coastal waters. A multi-sectoral management board was established to guide project activities with the hope that this management board will be maintained beyond the life of the project. This management body was not only responsible for coordinating the project, but also for integrating the planning and sustainable development of the entire city.

How successful has it been?

The project focused on actions at the scale of industry and the village level. One target was to reduce heavy metals discharged from industry by promoting the adoption of the SUPER and PROPER programmes of Indonesia that were introduced in 2002. They launched capacity building activities to improve liquid and solid waste management by holding seminars for industry, local government officers, and local community groups on the heavy metal contamination of coastal waters, sediments and fish, and the risks to human health. Awareness within the industrial sector has improved significantly and there is now much better compliance with regulations to reduce the heavy metal content of waste water. By 2007, 79 large industrial operations had signed Compliance Letters obligating them to report the results of environmental monitoring and management to Bapedalda. To follow this up, Bapedalda conducted regular assessments of the environmental performance of industrial operations (e.g. sea water quality monitoring and regular review of compliance documentation). They also: held regular seminars on the SUPER and PROPER programmes and training for stakeholders; monitored discharge and sea water quality by industry; and reported regularly on environment performance to local and national government agencies.

A village outside Batam City was selected to trial a communal septic system and demonstrate how to manage solid wastes. To improve waste collection, storage and treatment in the village, they provided 200 plastic rubbish bins for the solid wastes which were separated into organic wet materials and non-organic dry wastes. The organic wastes were sent to a waste management site and composted to produce around 300 – 400 kg of compost every month. This was a valuable fertiliser for the village gardens and was also an additional source of income. The other solid waste was buried at the solid waste dump site of the city.

They worked closely with the community to solve the problems caused by domestic sewage. The villagers were involved at the start in the planning, design, construction, and maintenance of a communal septic tank system. They installed 10 communal septic tanks with each collecting the waste from 8-10 families. The systems are being used as models to show other villages on Batam. These actions not only improved sanitary conditions in the village, but also have helped to strengthen awareness and generate support from the local community for environment management. The management teams are now expanding these domestic waste management systems throughout Batam island and developing funding mechanisms to use the money from the compost to pay for ongoing maintenance.

Lessons learned and recommendations

- It is essential to determine what are the major problems before starting projects. In Batam, they identified two major targets, heavy metals from industry and domestic sewage pollution from villages;
- A no-blame approach was used with the focus on solutions and gaining the cooperation and trust of the industry sector and the local community;
- Industry needs clear information, sound scientific data and practical guidelines to be able to implement pollution reduction measures;
- The Batam island management team had Indonesian Government regulations and experts to help advise industry which was directed by government regulations and projects;
- Building small sewage treatment systems for 8 to 10 houses is a cost effective, low tech approach, compared to a large centralised sewerage works;
- However, the sewerage pipes connecting the homes to the small systems should be compatible to be connected in the future to a centralised system;
- Solid organic waste can be composted to provide valuable fertiliser for farms and to generate income for maintenance;
- Village scale projects should be designed as demonstration projects for other villages and funding is required to bring village decision makers to view the systems; and
- Awareness raising is important with a focus on the concerns of the community for a clean environment and healthy seafood; solutions should be compatible with existing community resources and capacity.

Contacts

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Case Study 27

EFFECT OF LEGISLATION TO PREVENT RED-SOIL RUNOFF FOR CORAL REEF CONSERVATION IN OKINAWA, JAPAN

KAZUYA NAKASONE AND TADASHI KIMURA

The challenge

In Ryukyu Islands of Okinawa, large amounts of red soil sediments wash off land developments and agricultural fields into coral reef waters after heavy rain. There were rapid and large-scale public works undertaken to provide the necessary infrastructure after Okinawa was returned to Japanese administration by the USA in 1972. This included increased agricultural development, modification of rivers and other land developments; but during these activities, the rate of red soil runoff increased considerably along the coastal areas of Okinawa. Much of the soil that entered the rivers accumulated in basins only to be released as major pulses during heavy rains causing chronic damage to the nearshore coral reefs and related ecosystems. The sediment pollution, including red-and-yellow coloured soils, grey coloured soils and mudstone caused serious damage to the coastal fisheries and tourism, and became a serious social problem known as the 'Red Soil Pollution' problem in Okinawa.

What was done?

As the soil runoff was not regulated by the existing government laws, the Okinawa Prefectural government formulated the 'Red Soil Erosion Prevention Ordinance' (termed the 'Red Soil Ordinance') in 1994 and brought it into force in October 1995 to control the soil runoff from development projects and reduce water pollution of the rivers and coastal areas.

The Ordinance orders the investors who plan any constructions or land developments on more than 1,000m² area to report their construction plans to the Prefectural or local governments before commencing the projects. If the investors did not include the necessary countermeasures to prevent soil runoff in their applications, the government was able to order them to change their plans. The ordinance also established the standard concentrations in the silted drain waters (Maximum Suspended Solids: 200mg/l). The main regulations of the Red Soil Ordinance are:

- Legal obligation to prevent red soil erosion;
- Reporting project operations and engineering applications;
- Coordination and orders to change plans;
- Designation of persons responsible for the prevention of red soil runoff;
- Orders for improvements to prevent soil runoff;
- Discontinuance of the business, where necessary;
- Orders to halt an unlicensed construction;
- Management of land intended for agriculture; and
- Onsite inspections.

How successful has it been?

The Prefectural government measured annual red soil runoff before and after the ordinance was enforced using the method of Universal Soil Loss Equation (USLE) to follow progress and identify any unrecognized sources of sediment pollution. The total amount of soil runoff was estimated about 520,000 ton in 1993 prior to the ordinance being enforced. The annual amount of soil runoff after the enforcement of the ordinance was estimated about 300,000 ton from 2001 to 2002. This is a reduction in soil runoff of 57.6% due to enforcement of the ordinance, which has demonstrated that under the ordinance, soil runoff control measures had been undertaken effectively and soil losses had greatly declined. However, the 3 major sources of red soil runoff remained: 1) other development projects; 2) agricultural fields; and 3) U.S. military bases.

The runoff from development constructions was 50,000 tons after the Ordinance was enforced, being about one third of the runoff before the regulation came into force. The largest reductions in runoff were from monitored project sites for land improvement and the effective control measures introduced under the Ordinance clearly decreased runoff from exposed soils. However, the runoff from the other main source, agricultural fields was reduced to 220,000 ton after the ordinance was enforced from 320,000 ton before the enforcement. This decrease was caused more by a decrease of areas used for agriculture, rather than any major reductions from current farmland.

Lessons learned and recommendations

- The Ordinance was effective in reducing soil runoff from development projects, but much less effective in controlling soil runoff from agricultural fields. Therefore the next target should be to reduce runoff from sugar cane fields, which occupy more than half of total agricultural area. This will require:
 - Technical development of prevention methods to reduce runoff from agricultural fields;
 - Modification of the contour structure of the fields to reduce runoff;
 - Prevention of farming in inappropriate areas, and guidance for the farmers;

— Establishment of a network of prevention structures to reduce red soil runoff into streams and strengthening of the surveillance measures.

- There is a need for research on how activities on land are affecting the coral reefs such as finding thresholds of soil runoff to conserve the coral reefs; and
- There is also a need for improved cooperation between local governments and their communities, farmers, scientists and conservation practitioners to implement the required counter measures to reduce, and where possible prevent, soil runoff.

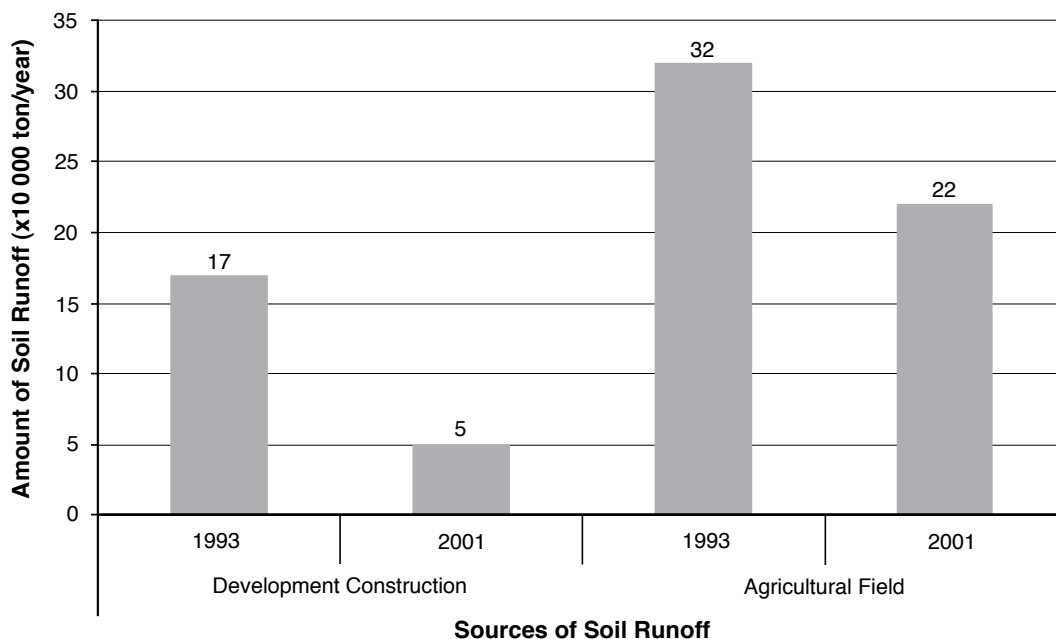
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Contacts

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There has been a major reduction in annual red soil runoff from developments after the Okinawa Prefecture Red Soil Erosion Prevention Ordinance was enforced in 1995, however there has been less success in reducing sediment loss from agricultural lands.

Case study 27

Case Study 28

RESTORATION OF A HIGH LATITUDE CORAL REEF DAMAGED BY A LANDSLIDE IN TATSUKUSHI, KOCHI, JAPAN

FUMIHITO IWASE AND TADASHI KIMURA

The challenge

The high latitude (33 degree North) coral reefs in Tatsukushi Bay, southwest Kochi Prefecture, are very rich with more than 80 species of hard corals within a small area of about 3 km². This area was designated as Japan's first marine park in 1970 within the Ashizuri-Uwakai National Park because of the beautiful underwater scenery provided by these rich coral communities. These areas are important economically with many tourists viewing the corals from glass-bottom boats and an underwater observation tower, as well it is as a major diving centre and has a popular aquarium.

However in September 2001, there was particularly heavy rain with the maximum recorded as 50 to 100 mm per hour and total rainfall of 600 mm within the southwest part of Kochi prefecture. There was severe river flooding which damaged the local town; many houses were either destroyed or flooded. In addition, there were severe landslides from the planted forests around the rivers flowing to the Tatsukushi Bay and large amounts of soil were deposited into the Bay, covering the coral communities.

The Biological Institute on Kuroshio surveyed the reefs 1 month after the flood and found that the bottom of the Bay was covered by sediments to a minimum depth of 20 cm and more than 1 m in some places. A large number of coral colonies were killed by the soil runoff, particularly around the east side of Tatsukushi Bay, near the Misaki river mouth. Later, the Ministry of the Environment also surveyed the watershed and coastal area and showed that:

- the sediment layers had been reduced rapidly in the west side of Tatsukushi Bay;
- most of the sediment flows had entered the Bay from the Misaki River, both during the rain storm and after the flood; and
- the sediments remained at the head of Tatsukushi Bay for 3 years after the flood and continued to disrupt coral recovery, because these sediments were being re-suspended whenever there was rough wave action.

Before the floods in 2001, the coral reefs in the Tatsukushi Bay had been damaged several times by sediments from the Misaki River because:

1. the mouth of Misaki river was moved through large-scale engineering from a neighbouring bay to drain into Tatsukushi Bay in 1994;
2. there was extensive land clearing for a road extension within the catchment area;
3. new port construction at the Misaki river mouth resulted in more sediments flowing into the head of Tatsukushi Bay;
4. there had been land clearing and construction for tourism developments; and
5. of re-forestation and agricultural land reclamation upstream in the catchment area.

What was done?

In an effort to help the coral communities recover from the landslide damage, the Ministry of the Environment established a 'Tatsukushi Nature Restoration Committee' in 2006 to include many stakeholders such as the Kochi Prefectural government, Tosa-Shimizu City government, governmental agencies, research institutions, representatives of the Agriculture, Forestry, Fishery and Tourism Industries, NGOs, local communities and concerned individuals; all under the law for the Promotion of Nature Restoration.

The Committee targeted three major objectives to reduce the sediments from the Misaki River which were causing most of the damage to the environment in the Tatsukushi Bay:

1. enhance the best practice management of vegetation in the planted forests to prevent future landslides from the large areas of newly planted forests;
2. stabilize the sediments on the river bottom and along the river banks; and
3. as a temporary rescue measure, remove the sediments from the bottom of the Bay to speed up recovery of the damaged corals.

The Ministry of the Environment was in charge of removing the sediments from the Bay because the area was designated as National Marine Park. Divers were employed to suck the sediments off the bottom until the original base appeared in order to prevent the secondary suspension of the sediments. In other areas where the sediments settled into coral rubble, a vacuum box was installed over the bottom to suck the suspended sediments away from the coral rubble. The mix of sea water and suspended sediment was transferred to the land to filter out the sediment particles from the seawater, which was returned to the Bay.

The Committee requested the Shikoku Regional Forest Office, Forestry Division of Prefectural Government and Forestry Cooperatives conduct an early thinning of trees and planting of broadleaf trees mixed with conifers to reduce sediment flows from the planted forests. Although the Shikoku Regional Forest Office disagreed with changing their original plans to those recommended by the Committee, they finally agreed and conducted early thinning of the trees after persistent negotiation, and completed the thinning in the planted forests by 2010. The River Policy Division of the Prefectural Government also cooperated with the Committee to remove unstable sediments and reduce soil runoff from the river bottom at several areas near Tatsukushi Bay.

How successful has it been?

Regular surveys and research have followed the progress of recovery and included physiochemical parameters in the environment and surveys of marine organisms, including the coral communities. The results of the research showed that the ecosystem in the Bay has been recovering with increasing settlement of new coral colonies and increases in coral cover and coral fish populations. Importantly there has been a major improvement in water quality in most of the areas where the soil runoff previously caused serious damage. However during this time there was a major increase in populations of the coral predator, *Acanthaster planci*, near the Bay. Control of these predators was done by the tourist operators within the Bay, but not possible outside of the Bay because of conflicts between the tourist operators and the fishers.

Lessons learned and recommendations

- A small area of coral reefs growing in a bay on one of the Japanese main islands had become a major tourist drawcard providing significant economic benefits to the local community;
- Three major developments had significantly altered the catchments of that Bay: diverting a river to drain into the Bay; major forestry operations on the steep slopes in the catchments; and extensive urban and tourism developments had cleared the land around the Bay;
- The main cause of coral destruction in Tatsukushi Bay was the damaged state of the land throughout the watershed that drained into the Bay. This was revealed when a major rainstorm resulted in landslides and massive soil erosion;
- The solution required a multi-sectoral and integrated approach to manage the environment of large areas around the Tatsukushi Bay. All the major stakeholders were consulted in depth and they all agreed on the final action;
- There were inter-sectoral problems delaying management action: the Ministry of the Environment was responsible for the National Park and only small parts of the coastal and marine areas; most of the forests were outside the parks with national forest managers, prefectural forest managers, and private forest owners responsible; local government was responsible for urban and agricultural areas; central government was responsible for national road, farming and harbour constructions; and private sector landowners including hotels, local inns and tourist facilities were suffering economic losses due to the damage to the coral reefs;
- the Ministry of the Environment was unable to conduct effective management and restoration with their existing mandate without cooperation from the other sectors which were outside the national park;
- Two years after the storm, a new law for the Promotion of Nature Restoration was enacted in 2003 aimed at repairing damaged ecosystems and other natural environments with the participation of all stakeholders, including government agencies, local governments and residents, NGOs and non-profit corporations, and people with specialized knowledge of the natural environment;
- This new law played a major role to initiate the restoration and conservation of coral communities in Tatsukushi Bay and was the key success factor in ecosystem restoration;
- However, the coral restoration process was very expensive and time consuming. If there had been less modification of the catchment area, this may not have been necessary;
- Recovery is still proceeding, but an effective and ongoing management system has not been discussed; and
- A key issue now is the establishment of long term monitoring and better coordination among the different stakeholders to promote coral conservation and avoid conflicts.

Contacts

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Case Study 29

CATCHMENT MANAGEMENT IN A DRY TROPICAL RIVER NEAR THE GREAT BARRIER REEF

ZOE BAINBRIDGE, IAN DIGHT, HUGH YORKSTON, STEPHEN LEWIS AND JON BRODIE

The challenge

The Burdekin River is one of the largest catchments (133 000 km²) within the Great Barrier Reef (GBR) catchment area. It is also the largest contributor of sediments to the Great Barrier Reef lagoon. Land use within the catchment is dominated by two main agricultural industries: rangeland beef grazing across most of the catchment area (about 120 000 km²); and intensive, irrigated sugarcane cultivation in the lower coastal plain. The annual rate of sediment delivery is now 8 times higher than it was at the time of European settlement of the catchment in about 1850; the increased sedimentation is due to increased erosion associated with low vegetation cover from dry land grazing.

With the introduction of grazing on the catchment in about 1860, initially sheep, but after 1865 predominantly cattle, erosion increased greatly as did sediment loads from the river to the GBR lagoon. The first cattle raised were British breeds (Shorthorn and Hereford; *Bos taurus*) but in the 1960s these breeds were replaced with more drought and tick resistant breeds from India, particularly those developed from Brahmin and Zebu (*Bos indica*) breeds. These newer breeds were much more adapted to tropical conditions and could survive better through droughts increasing greatly the reduction in pasture cover and increasing erosion further (see Cover photo).

There are significant areas of very fine grained sodic (sodium rich) soils in the Burdekin catchment which are naturally erodible by poor farming practices that lead to very low pasture cover. The sediments running off these lands carry adsorbed nitrogen and phosphorus nutrients attached to the particles, thereby resulting in a major pulse of sediments and nutrients into the GBR after the first rains.

The major increases in irrigated sugarcane farming with large additions of fertiliser has led to a doubling of the discharge of dissolved inorganic nitrogen. This, combined with the suspended sediment and particulate nutrients from the grazing lands, has resulted in poor water quality in Burdekin coastal waters. Levels of suspended sediment and chlorophyll (a nutrient status indicator) are outside the marine water quality guidelines set for protection of ecosystems within the Great Barrier Reef World Heritage Area. Hence, it was recognised that immediate management intervention was required to protect the ecosystems and the heritage values of the Great Barrier Reef in this region.

What was done?

Identification of sediment, nutrient and pesticide sources through long term (sometimes decades) monitoring, modelling and particle tracing activities at paddock, stream, river and marine scales has allowed scientists and managers to determine: the changed loads from the catchment through time and agricultural development stages; the loads from different land use types; and the identification of 'hot spot' contributing areas within the catchment.

Identification of suitable management practices and actions to reduce pollution discharges. These have now been implemented in rangeland grazing and sugarcane production areas where managers are confident that these changes will be successful. These included improving pasture cover through strategic fencing and rotation of cattle between paddocks; allowing natural regrowth of riparian vegetation in beef grazing lands by putting fences around stream watering points or establishing off-stream watering points to keep cattle out of the riparian areas; matching fertiliser application to local crop requirements so that losses are minimal and economic benefits are maximised.

Involvement of the community to ensure that the eventual management plan was practical and acceptable to all stakeholders. In early 2000, the Australian and Queensland State Governments began funding and supporting the establishment of community based regional natural resource management (NRM) bodies to engage in community capacity building at a regional level to address these significant natural resource management issues. This led to the setting of regional priorities in natural resource management to address these difficult land management issues. In 2005, the Australian Government funded the Burdekin Dry Tropics NRM Body to develop a Water Quality Improvement Plan (WQIP) for the Burdekin catchment. This was done through a combination of community workshops and scientific, government agency and community-based stakeholder reference panels. The final WQIP was agreed to by farmers, scientists, natural resource managers and other community stakeholders. The recognition of the need for concentrated and coordinated action across governments, industry and the community saw the introduction of the 'Reef Water Quality Protection Plan' (Reef Plan) in 2003, which focussed government resources and research on better quantifying the problem and establishing the first comprehensive monitoring programs.

How successful has it been?

The Burdekin WQIP provided the mechanism to involve the community in developing agreed environmental values and water quality objectives for the Burdekin catchment and its major tributaries. It also identified water quality targets and management actions to achieve them specific to the Burdekin Region and separate from those in other parts of the GBR catchment. In 2008, the Australian Government provided a further AU\$200 million over 5 years, through the 'Reef Rescue

Initiative', to encourage the adoption of improved agricultural management practices to reduce pollutant discharge from all catchment areas into the Great Barrier Reef lagoon. In the Burdekin region, the WQIP and its recommended management practices are now being implemented in priority areas across the catchment. The success of the improved practices in reducing pollutant discharge will take several years to become evident, due to long time lags in the response of the catchment. These time lags are due to the extreme climatic and spatial variability in this large dry tropical catchment, particularly for erosion management associated with the extended time required for interventions to become effective (e.g. it can take many years for river banks to be stabilised by vegetation regrowth or marked improvements in ground cover). The weather in this area is usually long dry periods often lasting years to decades, broken only by occasional intense rainfall and flooding events following cyclones.

The GBR catchment-wide 'Paddock to Reef' monitoring, modelling and reporting program was established under Reef Plan to determine the on-ground success of this large investment. It will start reporting progress in reducing pollutant discharge to the GBR in 2011.

Lessons learned and recommendations

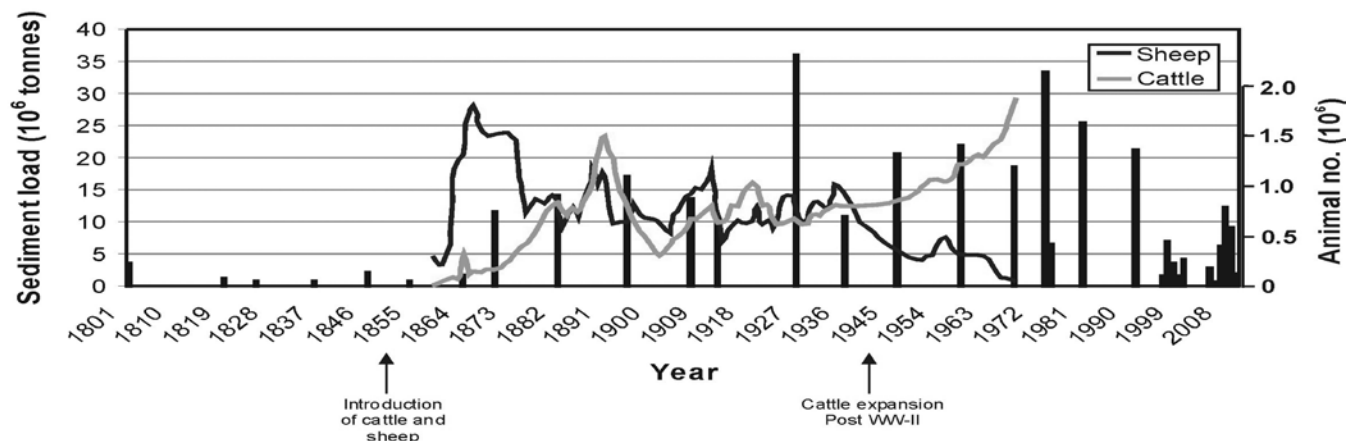
- Long-term monitoring data are required to understand pollutant dynamics, especially in dry tropical catchments with large variations in inter- and intra-annual rainfall;
- Identification of regionally specific management practices, linked to agreed water quality improvements, are necessary to ensure they suit the particular land types, farming systems and farm socio-economic factors, while still achieving the Governments' and communities' desired environmental outcomes;
- It is important to manage government and community expectations that management intervention will automatically lead to rapid solutions of water quality problems. This acknowledges the long time lags between implementing management actions and measuring water quality improvements;
- Given these time lag issues, it is essential to use a combination of monitoring and modelling tools to determine the success of the management interventions, particularly modelling that will show what is likely to happen in the next decades;
- It is important to link the desired planning outcomes and dedicated resources, especially incentive programs, to achieve general practice change in the areas of greatest risk;
- Program success is also reliant on strong community support and their continued involvement in the planning and its implementation. Therefore, transparent and frequent communication of scientific results is essential to keep the community informed and actively involved; and
- This communication requirement needs the allocation of sufficient resources for the on-going communication of results to the community. This aspect should always be included in project budgets.

Contacts

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 Reef-wide Monitoring and Evaluation Strategy www.reefplan.qld.gov.au/library/pdf/Reef-Plan-Monitoring-Eval-strategy.
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Change in fine sediment load (bars scale on left) from the Burdekin River (data from coral core analysis and river monitoring) showing the large increase following introduction of cattle and sheep on the catchment in 1860 and the large increase in cattle numbers after World War II

Case Study 30

CREEK TO CORAL I: IMPROVING WATER QUALITY IN CLEVELAND BAY, TOWNSVILLE, AUSTRALIA

JOHN GUNN, CHRIS MANNING, JASON LANGE AND GREG BRUCE

The challenge

The largest urban population adjacent to the Great Barrier Reef is the city of Townsville with a population of 182,000 and an annual growth rate around 3%. The Townsville City Council is the local government agency responsible for managing the catchment area to prevent damaging pollution flowing out to the Reef. The pressures associated with population growth and an expanding urban footprint has a flow-on effect for water quality with implications for the health of the estuarine and marine ecosystems downstream. The end point for terrestrial run-off and associated water pollution is Cleveland and Halifax Bays, which are part of the Great Barrier Reef lagoon for which there are Australian Government regulations aimed at reducing pollution from the land. These regulations recognise that to minimise the damaging effects of climate change, it is essential to minimise the release of excess sediments and other pollutants that can flow over tidal flats, seagrass beds, and fringing and inshore reefs to remain healthy in the future.

The Townsville City Council (TCC) established the 'Creek to Coral' healthy waterways initiative to minimise the impacts of urban expansion on the local waterways and improve the quality of water reaching the Great Barrier Reef.

What was done?

Since Creek to Coral was launched in 2003, there have been many adaptive planning and waterway management activities in key high priority waterways including the Gustav Creek on Magnetic Island; Louisa Creek which drains into the Town Common wetland system; and Stuart Creek. These works include:

- Strategic water management planning for water quality, water conservation and ecosystem health; and coordination of water projects across Council and with external partners;
- Creek restoration and constructed wetland maintenance works;
- Development and implementation of catchment and waterway management plans;
- Actively supporting community groups to conduct on-ground "Creekwatching" activities including water quality monitoring, aquatic surveys for fish and invertebrates, and tree planting – forming our Community based Education and Involvement (CBEI) program; and
- Conducting educational and experiential on-site tours to catchments, wetlands and water/wastewater treatment plants (see Case Study 33);

How successful has it been?

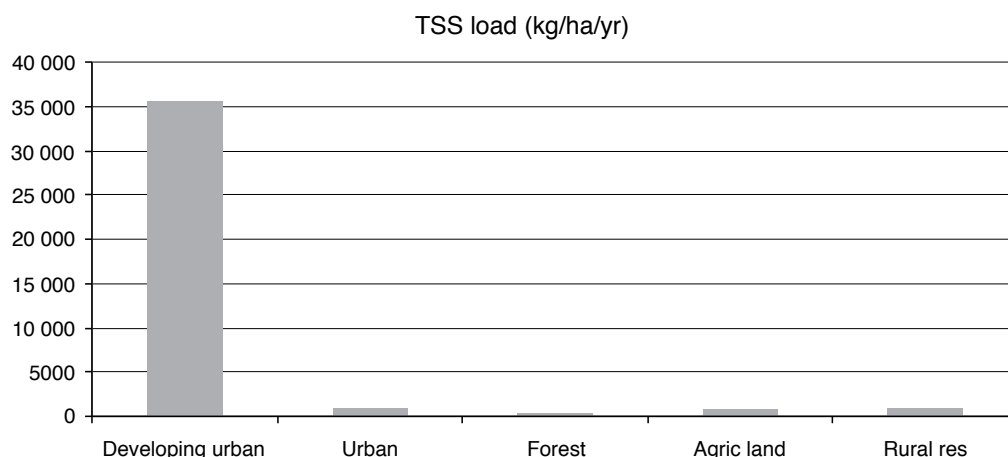
In 2006, Creek to Coral gained funding from the Australian Government Coastal Catchments Initiative to develop a Water Quality Improvement Plan for the Townsville coastal catchments between Crystal Creek (north) and Cape Cleveland (south), and Magnetic Island (east). The final Townsville Plan, along with a range of studies and supporting documents, are available on the Creek to Coral website (www.creektocoral.org).

Preparing the Townsville Plan involved a number of key tasks involving planners, engineers, consultants, developers and other community interests and included:

- Mapping and defining the catchments and the various land uses which occur in them;
- Identifying pollutant types and sources from both desktop and practical on-ground research;
- Determining environmental values and water quality objectives for waterways and waters that are consistent with State and national guidelines;
- Conducting high rainfall event water quality monitoring on-site (during wet season) and analysing the results;
- Collating and analysing all available water quality data to determine the condition of catchments; and
- Using catchment modelling techniques to determine pollutant loads entering the marine environment and be able to report on them.

A key finding of the study for the Plan was clearly identifying the impact of urban development on the amount of sediment entering waterways, compared to other land uses. Results from the rainfall event water quality monitoring were used to model the loads of sediment generated by various land uses and the results confirmed the observations that high erosion rates and sediment losses were associated with land development and construction sites.

The Council recognised early on the need to reduce the impact of development on waterways and has worked with leading professionals in erosion and sediment control and developed a suite of accredited 5 day training courses since the late 1990s that continue today. Recent updates have extended the courses by a day to include stormwater/drainage management as well as soils and vegetation.



This graph shows that the development of urban areas were by far the largest source of total suspended solids (mostly soil sediments as kilogram per hectare per year) that were being released into the creeks and waterways of the Townsville catchment area. The urban, forests, agricultural and rural residential lands released much less.

The rainfall event water quality modeling also identified the relative pollution contributions from point sources and non-point (diffuse) sources. Upgrading of wastewater treatment plants are aimed at dramatically reducing the point source contribution of nitrogen and phosphorus in the short term and take into account of likely increasing population loads over time. Similarly diffuse source loads will continue to increase as a result of land use changes and urban expansion, if measures are not put in place to improve water quality.

An important outcome of the Plan was the development of Water Sensitive Urban Design objectives and technical design guidelines for the Townsville region. These objectives will be put to the Council to guide the design of stormwater management measures in all new developments to reduce the concentration of pollutants discharged from urban areas. Some developers are already including the design guidelines in development sites. It will be important to monitor these and other sites to determine whether the Design objectives and guidelines actually work well in Townsville environment.

Adaptive waterway management and planning is another key feature of Creek to Coral activities. Urban waterways provide an interesting 'classroom for learning by doing' with actions and planning taking place at the same time. Lessons learned are then used for ongoing works and to prevent future mistakes. Two key action areas with waterway management plans are Louisa Creek and Nelly Bay/Gustav Creek (Magnetic Island).

Creek to Coral was recognised as being successful and gained additional funding for coastal habitat and waterway protection in conjunction with the community from the Australian Government Caring for our Country program.

Lessons learned and recommendations

- The best place to address waterway management issues is at the source of the problem. This is particularly relevant for reducing the amount of sediment entering waterways by reducing the amount vegetation clearing and soil disturbances wherever possible during land development phases;
- If soil erosion can be minimised then the need for sediment control both on site and downstream in the catchment is reduced. High intensity storms are better addressed through an erosion prevention approach rather than trying to control sediment movement after the storm;
- Nutrient pollution management in new developments is addressed through multiple approaches and processes, including residential behaviour and constructed wetlands and basins to filter pollutants.
- Using collaboratively based education methods, techniques and social learning approaches works best (refer to Case Study 33);
- Working together in partnerships with government, industry and community helps to share the cost and allows everyone to make a meaningful contribution to address common issues; and
- Creek to Coral recognises the importance of people in managing our natural resources. Many of the Creek to Coral waterway management actions revolve around supporting people to change their management practices to those that will result in water quality improvement.

References

Townsville Water Quality Improvement Plan for Black and Ross Rivers; and Creek to Coral Partnership
www.Creektocoral.org

Contacts

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Case Study 31

THE ECONOMICS OF IMPROVING FARM MANAGEMENT PRACTICES IN THE CATCHMENT OF THE GREAT BARRIER REEF

MARTIJN VAN GRIEKEN, JANE WATERHOUSE AND DAVID SOUTER

The challenge

The challenge of natural resource management is successfully striking a balance between securing the economic, social and cultural benefits of natural ecosystems without jeopardizing the environmental values of those ecosystems, particularly when the goods and services provided by those ecosystems are critical for local, regional and even national economies and identities. Managing Australia's Great Barrier Reef (GBR) is no different. The GBR is a World Heritage listed icon, attracting millions of tourists each year and contributing more than AU\$5 billion to the Australian economy annually. In the river catchments adjacent to the GBR, sugarcane farming, grazing and horticulture are economically significant industries. However, the health of many inshore reefs near these catchment areas have been damaged by terrestrial runoff carrying suspended sediments, nutrients and pesticides from these activities. Therefore, the challenge was to improve water quality entering the GBR lagoon, and consequently the health of inshore reefs, by altering land-use practices and improving on-farm practices without affecting the profitability of land-based primary industries.

Preliminary studies indicated that improvements in water quality can be made at no cost in some regions (e.g. there is up to 25% gain by adopting new practices to grow sugarcane in the wet tropics) but beyond that point, private costs to improve water quality rise sharply.

What was done?

The success of introducing improvements in agricultural practices is often determined by the economics associated with these changes, e.g. how much will it cost a farmer to introduce changes? Will the changes make the farm more profitable through increased yields or efficiency gains in irrigation, fertiliser or pesticide use; or make farming more expensive and possibly unprofitable?

The first task was to understand the complexity and socio-economic influences of new management practices, whether they are affordable, and whether there will be demonstrable environmental benefits. Good communication and an in-depth understanding of what needs to be done is needed to assist farming industries embrace changes suggested by management. This requires developing partnerships with individual landholders and their support networks, and good scientific knowledge of the water quality and economic outcomes of recommended management practices.

The starting point was to adopt a 4 step classification framework, originally developed by natural resource management boards for water quality improvement plans, and defines management practices from 'cutting edge' to 'old'. This 'A-B-C-D' framework was applied to sugarcane, grazing and horticulture farming systems in the catchment areas, and is defined as: D (Dated and likely degrading farming practice); C (Common practice); B (Best practice currently available); and A (Aspirational practices that are being trialled which have great potential to improve water quality, but have not been commercially validated or widely introduced). In any area, on any farm, some combination of D, C, B and A management practices may be required. The next step is to collect environmental (reduced dissolved inorganic nitrogen entering the waterways) and financial-economic (farm gross margins, i.e. income received from the crop minus the variable costs associated with growing the crops; and capital investments, e.g. in machinery) information for the classified management practices. This was used to calculate water quality and financial cost and benefits, associated with change to improved management practices.

Using this framework, case studies were developed for sugarcane and grazing in a wet tropics catchment (Tully River) and a dry tropics catchment (Burdekin River) that drain into the GBR. These were used to model the environmental and economic outcomes of improvements in management practices. The sugarcane growing case study showed that in the wet tropics and the dry tropics, the required capital investments (e.g. purchasing and modifying machinery) to improve from a C (common practice) to B (best practice) farming are likely to be offset by increased gross margins (e.g. from reduced inputs of fertiliser and pesticides). The transaction costs (e.g. the time required to learn about new farming practices or the time spent purchasing and learning to operate new machinery) were not incorporated, therefore the total costs of change are likely to be underestimated. In addition, the introduction of best practice farming (including the use of GPS for planting; reducing tillage operations; applying fertiliser based on soil tests; growing legume crops in half of the fallow area; developing a soil management plan; improving record keeping; and using climate and weather forecasts) in both catchment areas would potentially reduce DIN pollution from the paddock by 10% to 15% respectively. It must be noted that the costs and benefits with any transitions will vary between growers depending on their individual circumstances; these need to be carefully considered before changing management practices.

In both the Tully and the Burdekin catchments, the largest reductions in sediment runoff from grazing pastures could be achieved by matching stocking rates to pasture carrying capacity. In the Tully, this generally resulted in an increase in

profitability, but in the Burdekin, there was generally a cost, that is reduced benefits, although some economic benefits might be achieved by lowering costs. Investment costs were not assessed in this analysis.

How successful has it been?

The results from these case studies suggest that some farmers see the value in changing farming methods. However, there may be other non-financial motives prohibiting the adoption of improved management practices. The message from these case studies is that good economic information may be used to support the implementation of policy methods such as subsidies, extension programs and incentives; and/or regulations required to further encourage industries to develop and implement improved management practices in the GBR catchments. The Australian Government's Reef Rescue initiative (www.nrm.gov.au/funding/2008/reef-rescue.html) is supporting current improvements in management practices through a AU\$200 million incentive package over 5 years and is using these case studies and the management practice framework to guide investment priorities. In addition, these findings were incorporated into the design of a comprehensive monitoring program for the Reef Water Quality Protection Plan (www.reefplan.qld.gov.au) and the Reef Rescue initiative (Reef Plan Paddock to Reef Integrated Monitoring, Modelling and Reporting Program), and form the basis of ongoing assessment of performance against management practice targets throughout the GBR catchments.

Lessons learned and recommendations

- Good economic assessments are essential for all the major industries in a catchment before suggesting changes in farming practices. These should include quantifying the cost-effectiveness of management practices aimed at improving water quality to ensure that farmers can achieve a return on additional investment;
- Monitoring and evaluation programs are needed to assess progress in improving water quality from the paddock scale, as well as the stream and out to the ocean;
- As well as assessing the financial aspects of improving water quality, there are other non-financial factors (e.g. time and information constraints, and farmer objectives and attitudes to risk) that may delay or prevent adoption of management practices by farmers; and
- Economic assessments are useful in presenting arguments to governments and managers and provide valuable input to policy option analysis to test the cost-effectiveness of possible changes to management practices to improve water quality.

Contact

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Case Study 32

SCIENCE-BASED CATCHMENT MANAGEMENT IS EVOLVING ALONG THE GREAT BARRIER REEF OF AUSTRALIA

KATHARINA FABRICIUS, JON BRODIE, JANE WATERHOUSE AND HUGH YORKSTON

The challenge

The Great Barrier Reef (GBR) is the world's largest reef system (with about 12% of the world's coral reef area) and almost the whole area is covered by a multi-use marine park. About 33% of the Great Barrier Reef (GBR) is completely protected from fishing and exploitation. However, the GBR is particularly vulnerable to terrestrial runoff of sediments, nutrients and pesticides, especially from expanding and intensifying agriculture. The GBR is located on a shallow and wide continental shelf that traps incoming materials from 35 major river catchments along the more than 2300 km length. Therefore, reducing the damage coming from these catchments presented a particularly challenging task for management. The initial focus for management was to address the obvious direct inputs of pollutants from urban areas, such as discharges from sewage treatment plants, by regulating waste management facilities and establishing best practice standards. However, the science was beginning to identify that the discharges from agricultural lands into rivers was providing a far greater proportion of pollutants (more than 80%). Therefore, this task needed, and has since received, robust scientific evidence and strong public support to show that conservation of the GBR is important. However, there was vigorous debate until the early 2000s about whether river runoff was really a problem, and if it was, then what should be done to reduce the effects of terrestrial runoff on such a large system.

The 'Reefs at Risk Revisited' assessment by the World Resources Institute in 2011 confirmed the need for urgent action by reporting that virtually all near-shore reefs of the central and southern GBR are in the categories 'medium threat' or 'high threat from local runoff'.

What was done?

From the 1980s the Australian Government, supported by the Queensland State Government, provided considerable funding for scientific research and monitoring to trace terrestrial runoff from the catchment and the way this was affecting the downstream coral reefs. In 2003 the joint Australian and Queensland State Government's Reef Water Quality Protection Plan (Reef Plan) was developed. Reef Plan provided the 'toolbox' for addressing this complex issue. This was further supported by a government-initiated review which assessed the economic value of the GBR and concluded that the GBR contributes about AU\$6 billion dollars and more than 50,000 jobs into the Australian economy each year (2005-06). The research results provided strong evidence of the impacts of land-based runoff, including increases in macroalgal cover and decreases in coral biodiversity and number of new young corals establishing on reefs exposed to runoff. Much of this research was based on: identifying natural environmental gradients (selecting similar structured reefs along water quality gradients from turbid to cleaner water); quantifying water quality along this gradient, especially turbidity, particulate nutrients and pesticides; and simple and low-tech counts and assessments of abundance and diversity of corals and coral juveniles, macroalgal cover, and the density of larger bioeroding organisms that bore into massive *Porites* corals along these environmental gradients.

In 2004-05 the Great Barrier Reef Marine Park Authority (GBRMPA) established a comprehensive water quality and ecosystem health monitoring program, based on the indicators developed by these research programs. In monsoonal flood plumes, they measured the rate of discharge of nutrients and pesticides and determined whether these concentrations exceeded the physiological limits of coral reef organisms. Researchers also tracked the source of the contaminants back up the rivers to particular agricultural and urban development activities in the GBR catchment; sediments and particulate nutrients particularly came from beef grazing and urban development lands, while dissolved nutrients and pesticides came mostly from cropping lands (sugarcane, banana, horticulture, grains and cotton).

This research clearly showed the links between what was happening in the catchment areas and the coral reefs, some as far as 50 km from the coast. For example:

- The amount of nutrients exported to the GBR has increased by 9 times for phosphorus and 6 times for nitrogen since the first agricultural development of the catchments (in 1830). These increases are driven by applications of fertiliser on sugarcane, horticulture and other cropping areas in the catchments and losses of particulate bound nutrients from agricultural and urban lands due to soil erosion;
- The amount of sediment exported to the GBR in river discharges has increased 6 times since 1830. Intact tropical rainforests and grasslands release very little sediment; whereas overgrazed grasslands, some cropping practices and urban development activities produce high sediment loads;
- Pesticides such as diuron and atrazine were found widely in inshore GBR waters and are a risk to the plant communities of this area (coral, seagrass and algal communities);
- The majority of pollutants are exported to the GBR in high river flow discharge events and dispersed as large flood plumes over long distances in the GBR;

- The increasing concentration of phytoplankton in the water was linked to an increased probability of population outbreaks of the coral eating crown-of-thorns starfish, *Acanthaster planci*. These starfish have devastated large areas of the GBR between 1960 and 2006; and
- Scientific studies showed that macroalgal cover increased markedly and biodiversity declined in turbid water. That is where water clarity is less than 10 m Secchi depth (a simple and effective tool to assess water clarity, by measuring the water depth where a black and white disk 20 cm in diameter disappears from vision), and where chlorophyll a in the water column exceeds $0.45 \mu\text{g L}^{-1}$ (chlorophyll is a proxy for phytoplankton abundance and increases in response to nutrient enrichment).

The Governments and the GBRMPA responded by:

- Supporting ongoing research into the sources and fates of pollutants in the GBR and its catchment to better understand their impacts on the coral reefs;
- Establishing and supporting community based regional natural resource management bodies to provide community engagement and delivery mechanisms for planning, target setting and identification of management actions to address the decline in water quality. These are supported by incentive schemes;
- Developing specific GBR Water Quality Guidelines which identified clear trigger levels for key water quality parameters to maintain healthy coral reef ecosystems;
- Providing support for developing catchment level water quality improvement plans (WQIPs) that used these guidelines to establish effective water quality targets and actions to achieve them; and
- Implementing a comprehensive monitoring and modeling program to report on changes in water quality and the health of nearshore ecosystems, including seagrass beds and coral reefs.

How successful has it been?

This strong scientific evidence was provided as regular updates to the public and government leaders by GBRMPA, NGOs (particularly the World Wildlife Fund) and the scientists. Since the late 1990s there has been a significant shift in public support for action to address the problem of terrestrial runoff into the GBR. Governments at all levels became convinced of the need to halt and reverse the decline in water quality entering the GBR from coastal development and runoff from urban and agricultural lands (See Case Study 30 Creek to Coral p. 98). This was embodied through the development of Reef Plan in 2003. In 2008, the Australian Government provided a further AU\$200 million over 5 years through the 'Reef Rescue Initiative' to encourage improved agricultural management practices designed specifically for farmers' individual land types and activities. In addition, following a review of Reef Plan in 2008 and a streamlining of its actions, the Queensland State Government introduced specific new regulations in 2009 which require most farmers (especially sugarcane farmers) in priority management areas to have environmental management plans which govern fertiliser application rates and the use of certain pesticides. This is called the Queensland government's Reef Wise Farming program (www.reefwisefarming.qld.gov.au). The Reef Plan specifies that reductions in suspended sediment exports of 20% are required by 2020, and reductions in nitrogen, phosphorus and pesticide exports of 50% by 2013. Progress towards these Reef Plan targets is to be measured by a comprehensive 'paddock to reef' monitoring and modelling program and the first Reef Plan Report Cards, following the release of Reef Plan (2009) will be released in 2011.

Improved management practices are being introduced with the help of the Reef Rescue Initiative which provides financial incentives for:

- Improving pasture cover in beef grazing lands to minimize soil erosion through strategic fence building and rotation of cattle between paddocks;
- Restoring riparian vegetation in beef grazing lands by fencing, off-stream watering points and management of cattle in the riparian areas;
- Using frequent soil testing and leaf analysis in sugarcane crops to reduce fertiliser application so as to just meet crop requirements and no more;
- Managing pesticide loss by better application techniques e.g. banded spraying (i.e. spraying in narrow bands where the weeds are) rather than whole-of-paddock spraying; and
- Continuing support for trash blanketing in sugarcane cultivation and stopping burning i.e. retention of the sugarcane leaves on the ground after harvest to form a trash layer which prevents erosion.

Continuing research is helping to refine agricultural 'best management practices', develop improved and robust bioindicators for reef health and understand the cumulative effects of poor water quality and climate change on reef health.

Furthermore, GBRMPA established the 'Reef Guardians' program in 2004 to recognize and support stewardship activities taken by local councils and to develop an environment-based education program for schools. This program aims to improve water quality and land management practices in towns by building capacity in local government and developing local action plans to better manage vegetation, sewage and stormwater and engaging the community in undertaking sustainable environmental management practices. All 13 local governments adjacent to the GBR coast are now engaged in this program. Similarly, the 'Reef Guardian Schools Program' has engaged over 200 local schools across the GBR catchment by offering an endorsed curriculum that provides for outdoor environment based activities and support for on-ground projects. A pilot for 'Reef Guardian Farmers and Fishers' is now being developed with strong government and industry support.

Lessons learned and recommendations

The following actions have underpinned the success of the program to improve GBR water quality:

- The World Heritage status of the GBR has facilitated strong financial support for research over the last 30 years and has provided political strength to pursue large-scale management initiatives; this is not available in other parts of Australia;
- Strong scientific research and monitoring was needed over a long time (more than 20 years) to change public perceptions that there was a problem from increasing loads of pollutants in runoff coming from catchment areas;
- More effective management of land-based activities required sound scientific evidence, transparent communication of scientific research and monitoring results, and partnerships between authorities, industry and the community;
- Recognition that the social wellbeing of local communities and the Australian economies are significantly reliant on healthy GBR ecosystems;
- Managers recognised that sediment, nutrient and pesticide pollution reduction was necessary to help increase the resilience of the GBR to ocean acidification and coral bleaching threats resulting from global climate change;
- The authorities involved key stakeholders in delivery of 'Reef Plan' targets and engaged the public (especially schools and school communities) in an environmentally based 'Reef Guardian' program to raise and maintain community awareness;
- Engaging agricultural industries to identify the best management practices for improving water quality outcomes was critical to measure water quality improvements. However the manner in which the Queensland regulatory regime was introduced to ensure cessation of unacceptable practices led to ongoing protests by some farming interests, and a more flexible and cooperative approach to the legislation implementation is now being pursued by the Queensland Government;
- A regular monitoring program has been established to measure the effectiveness of control measures. This includes water quality monitoring and modelling, remote sensing, and seagrass and coral reef health assessment. Some aspects of the program engage the community in water quality sample collection; and
- All this required a cooperative effort from all levels of government and NGOs through the provision of a broad-based planning framework (Reef Plan) with a clear goal and targets, and supported by government funds to assist industries and communities to make the necessary changes to reduce sediment, nutrient and pesticide pollution into the GBR. This is backed by strong legislation at all levels of government.

Contacts

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Recommended Reading

Main review: Brodie J, Binney J, Fabricius K, Gordon I, Hoegh-Guldberg O, Hunter H, O'Reagain P, Pearson R, Quirk M, Thorburn P, Waterhouse J, Webster I, Wilkinson S (2008). Synthesis of evidence to support the Scientific Consensus Statement on Water Quality in the Great Barrier Reef. The State of Queensland (Department of Premier and Cabinet) Brisbane. www.reefplan.qld.gov.au/publications/scientific_consensus_statement.shtm

Environmental studies of specific aspects:

De'ath G, Fabricius KE (2010). Water quality as a regional driver of coral biodiversity and macroalgae on the Great Barrier Reef. *Ecological Applications* 20, 840–850.

Fabricius K, Okaji K, De'ath G (2010). Three lines of evidence to link outbreaks of the crown-of-thorns seastar *Acanthaster planci* to the release of larval food limitation. *Coral Reefs* 29, 593–605.

Lewis SE, Brodie JE, Bainbridge ZT, Rohde KW, Davis AM, Masters BL, Maughan M, Devlin MJ, Mueller JF, Schaffelke B (2009). Herbicides: A new threat to the Great Barrier Reef. *Environmental Pollution* 157, 2470–2484.

McKergow LA, Prosser IP, Hughes AO, Brodie J (2005). Sources of sediment to the Great Barrier Reef World Heritage Area. *Marine Pollution Bulletin*, 51: 200–211. and

Ibid. Regional scale nutrient modelling: exports to the Great Barrier Reef World Heritage Area. *Marine Pollution Bulletin*, 51: 186–189.

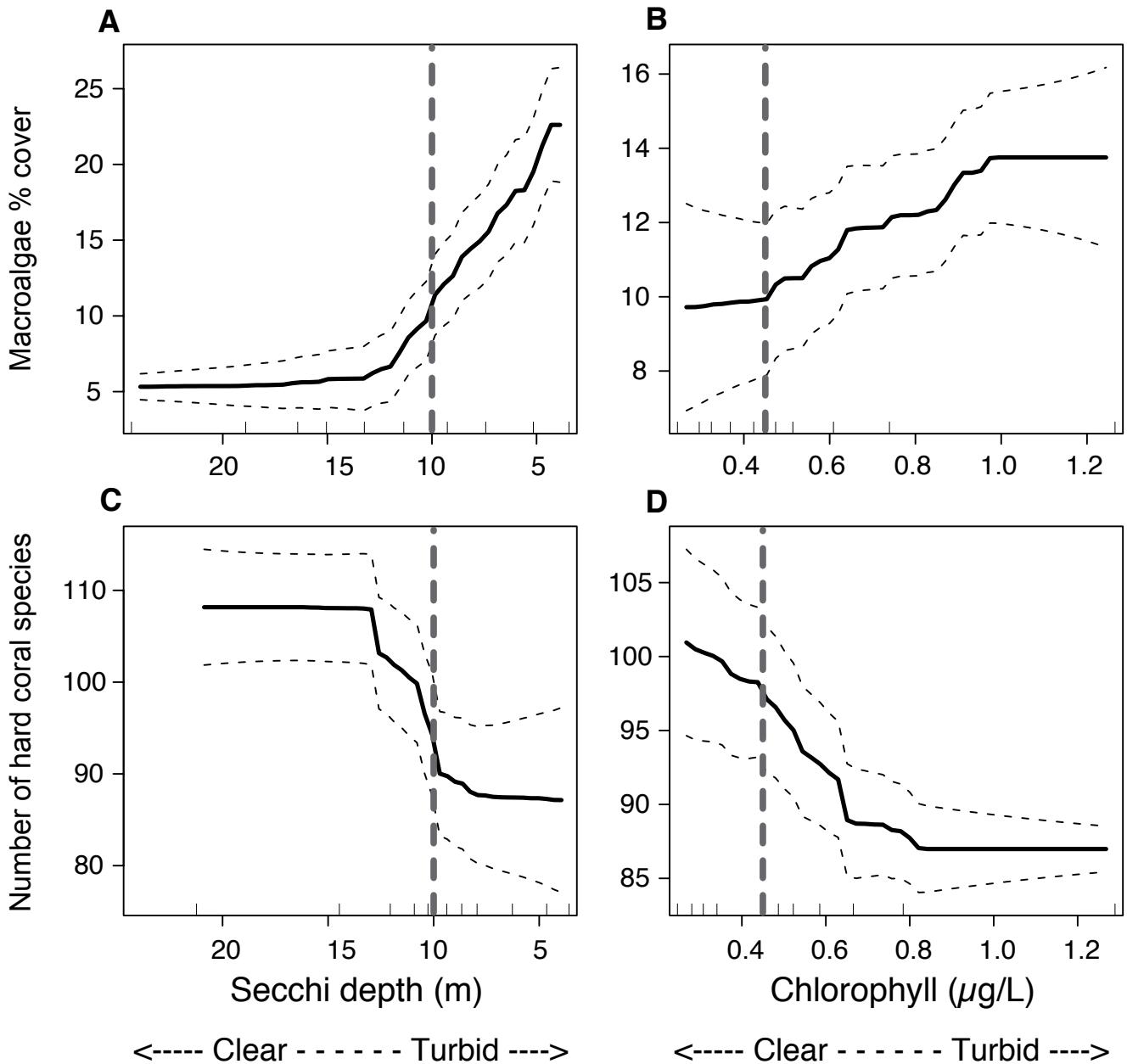
Information on government initiatives

Reef Water Quality Protection Plan - www.reefplan.qld.gov.au

Queensland Great Barrier Reef Protection Amendment Act 2009 www.reefwisefarming.qld.gov.au

'Reef Guardian initiative' - www.reefed.edu.au/home/guardians

Great Barrier Reef Water Quality Guidelines www.gbrmpa.gov.au/corp_site/key_issues/water_quality/water_quality_guidelines



These graphs show the effects of suspended sediments and nutrients on macroalgae (seaweed) and the diversity of coral communities on the Great Barrier Reef. The area of reef covered by large fleshy algae (A and B) increases significantly in more dirty water, which also contains higher concentrations of nitrogen and phosphorus nutrients. Conversely the number of coral species (C and D) growing on the reef (coral diversity) decreases significantly in more turbid and nutrient rich water.

The X-axes in A and C show Secchi disk depth, a measure of water clarity (the deepest water where a black and white disk is visible). Thus a site with 20 m Secchi disk depth has very clear water, whereas 5 m is very turbid water. The X-axis on B and D shows the concentration of chlorophyll *a* in the water, with higher concentrations occurring where there are more phytoplankton growing because of higher nutrient concentrations. Thus macroalgal cover increases where there are higher concentrations of phytoplankton, while coral diversity drops markedly in phytoplankton rich waters. Thus the macroalgae are at a competitive advantage over corals, indicating that the status of coral reefs on the GBR is clearly related to the quality of water, which is a reflection of the sediment and nutrient loads coming out of river catchments. The dotted line in all figures is the 10 m Secchi disk depth, and the $0.45 \mu\text{g L}^{-1}$ chlorophyll, which are used by the GBRMPA as water quality guideline trigger values.

Case Study 33

CREEK TO CORAL 2: SYSTEM-BASED APPROACHES TO PROTECT THE MARINE ENVIRONMENT FROM CATCHMENT ACTIVITIES, TOWNSVILLE, AUSTRALIA

GREG BRUCE

The challenge

Townsville is the largest regional city in Queensland and located where tropical savannas and rainforests drain to the coast. The key challenge is that these urban areas are next to the Great Barrier Reef World Heritage Area. Working out where to start and what to do to protect the reefs from the many and often insidious impacts of what we do on land is difficult. Many things are going on simultaneously across often mixed urban and rural catchments. The challenges include pollution, fragmented government agencies and poor community attitudes and behaviour. There are also significant time lags that can have hidden environmental feedbacks. Starting small with a big vision offers the best approach based on scientifically validated change management processes and human communication methods. These include collaborative and collective social learning to uncover hidden processes that can lead to positive impacts on catchment management. The big challenge is to create a new 'systems' approach, that is easy to understand, replicable and will become self-sustaining over time. The message is that a systems based approach can be established in any coastal area where the task is to link actions and communication between people to achieve outcomes in the environment, especially improving catchment management through simple actions.

What was done?

The 'Creek to Coral' systems approach seeks to include all major stakeholders (all levels of government, business and community) in a partnership; it started with the engineers and environmentalists talking to each other and now includes community groups and businesses. Through active dialogue and process we have built capacity in all sectors that manage water, as well as researchers and the community. This approach is the key component of the council's 'Sustainable Townsville Program' and seeks to overcome fragmentation in water governance to provide best practice in water management. Over the past 12 years, the Townsville City Council has been progressively developing and innovating this 'systems based' approach to educate the community in all aspects and practices of coastal ecosystem management; a 'Creek to Coral Partnership'. Key communication processes 'map' how individual and collective actions contribute to the big picture of ecosystem and catchment management.

Creek to Coral has managed the real impacts of land-based activities on the marine environment by helping people learn to communicate more effectively with each other, support applied science and undertake practical activities within the catchment. Actions and outcomes have been made clearer, manageable and affordable.

The UN Decade of Education for Sustainable Development 2005 has been a guide to the Council to develop and adapt innovative education programs for the community to change behaviour by collaborative learning and community development.

The Council conducts bus and walking tours to constructed systems and existing natural wetlands and drains. These have been so successful that the Townsville City Council's educational catchment tours have achieved Advanced Ecotourism Certification by Ecotourism Australia. The education program specifically demonstrates how constructed stormwater drains and sewage treatment plants function like natural wetlands, creeks and rivers. Thousands of school children have done the tours and these have been included in their schools curriculum.

The educational process expanded to consider the whole city as one system and to help people understand the link between where they live and the marine environment. This involves active learning supported by interpretative material that explains ecological processes and coastal health in provocative and meaningful ways. The project has developed functional networks and partnerships between catchment stakeholders, especially linking engineers, planners and environmentalists. This learning approach with school catchment tours is also being conducted in Phetchaburi, Thailand.

How successful has it been?

The project has been highly successful in generation of science, community involvement, and breaking down of barriers between departments in Council and government because:

1. It is locally adapted and innovative and thousands of school students have participated in ecological water catchment tours;
2. Council staff members have actively participated together in collaborative social learning processes and workshops about being a reef guardian council, learning from each other and finding actions they can take;
3. These indoor/outdoor 'learnsapes' for energy, water and nature have been developed with thematic interpretation methods and communications;

4. The program is simple:
 - a. Eco-catchment education tours demonstrate the connections between all parts of the water cycle and critical feedback loops;
 - b. The ecosystems on land include existing natural and artificial ecosystems where people live and work;
 - c. It includes students, NGOs (Conservation Volunteers Australia) as well as the utility managers and businesses; and
5. The project has improved capacity to act by getting participants and technical partners (engineers, planners, researchers) to think and act independently, rather than be instructed or taught what to think.

The project was recognised in the Australian National Environment Awards, called the Banksia Award for Achievement in Environmental Education, Innovation and Sustainability. A range of studies and supporting documents are on the Creek to Coral website (www.creektocoral.org).

Lessons learned and recommendations

- The easiest place to start is by doing something simple on the ground with other people (students and stakeholders). The 1st step is meeting and the 2nd is dialogue and learning by sharing ideas and recognising all opinions;
- Build the network with small steps and actions in parallel with developing the largest possible vision. Time, space and commitment to continuing action and building relationships will do the rest;
- Think of everything the whole community does and include these activities into a large interconnected system that may have many feedback loops;
- It is not necessary to understand everything in the system to get the community, businesses and government interested and involved. Just do something; run a workshop; conduct a catchment tour; follow water from the highest land to the ocean; visit business places, schools and homes and ask the people to share their views and perspectives;
- Don't start by asking for new resources, but instead use what you have in people, buildings and locations, as these are familiar to the people you want involved;
- Conduct more catchment tours with school children, businesses and government agencies to spread the word. If possible just walk around the area; it may be necessary to hire buses for larger areas;
- Changing human behaviour is difficult, but finding new and practical ways to start doing new things is relatively easy;
- The catchment is a complex interactive place and a 'systems approach' is valuable to see the big picture and determine actions to take. This approach is used widely in many MBA and business management programs.

Contact

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Cover Photographs

1. 'Ridge to Reef'; this photograph encapsulates many Case Studies in this book. The is only a short distance between the mountain top and the coral reef in American Samoa. In the catchment there are villages, pig farms and subsistence agriculture with the wastes potentially delivered rapidly to the nearshore coral reefs after heavy tropical rains (Case Study 15).
2. & 3. Excessive grazing by drought resistant cattle in the dry catchments of the Burdekin River in North Queensland Australia has stripped all pasture grasses off the soils, leaving them totally exposed to tropical rainfall. The satellite image shows a large sediment plume flowing from the Burdekin River and out to mid-shelf coral reefs of the Great Barrier Reef (Case Studies 29 & 32).
4. Community members sit together to discuss ecosystem-based management of the catchment areas in Vanua Levu, Fiji (Case Study 18).
5. This community run nursery in Aneityum, Vanuatu grows Vetiver grass to stabilise the easily eroded soils in the steep hillsides in Photo 9. Behind are older plants and the bush (Case Study 10).
6. This Google Earth image shows the revegetated shoreline forests in Houma Tonga that now protect the villages and farms from wind, sea spray and erosion. It also shows the value of satellite images to see the 'big picture' (Case Study 22).
7. & 8. Two inshore reefs on the Great Barrier Reef of Australia. The corals below are stressed by larger inputs of Nitrogen and Phosphorus nutrients which favour the growth of large fleshy algae that can out-compete the corals. The corals above are under no nutrient stress, and grow luxuriantly (Case Study 32).
9. A heavily eroded hillside in Aneityum, Vanuatu before revegetation started to protect the coral reefs just offshore from sediment pollution (Case Study 10).
10. This view of the Seaflower Biosphere Reserve in San Andres Archipelago, Colombia shows the large range of activities that pose pollution threats to the coral reefs that are a major attraction for tourists (Case Study 11).



Authors

Clive Wilkinson has been the Coordinator of the Global Coral Reef Monitoring Network since 1996. The GCRMN operates in 80+ countries and publishes the regular 'Status of Coral Reefs of the World' reports, with partners such as Reef Check, ReefBase, SocMon and World Resources Institute. He was formerly the Chief Technical Advisor for a coastal resource research program in 5 ASEAN countries and for an Australian project in Thailand after the massive tsunami of December 2004. He was an active field scientist on the ecology of the Great Barrier Reef at the Australian Institute of Marine Science with more than 100 papers published. He received BSc and PhD training in marine microbiology and ecology from the University of Queensland. He is based with the Reef and Rainforest Research Centre in Townsville Australia and now provides advice to governments on effects of global climate change on coastal ecosystems and potential adaptation policies.

Jon Brodie has been research scientist and leader of the Catchment to Reef Research Group, Australian Centre for Tropical Freshwater Research, James Cook University, Townsville for the past 10 years. Jon spent 10 years as an environmental researcher with the University of the South Pacific, Fiji and another 11 years as manager of the Water Quality Research and Management Program of the Great Barrier Reef Marine Park Authority. His primary research and management interests are on water quality issues for the Great Barrier Reef (GBR), including sources of pollutants in catchments, transport of those pollutants to the marine environment and their dispersal and effects on marine ecosystems. He has published more than 60 papers and 80 technical reports, with an emphasis on providing policy advice to governments on water quality issues for the GBR. He was the lead author of the Scientific Consensus Statement (2008) documenting the status of knowledge and management for water quality issues affecting the GBR for the Queensland Government.

GCRMN – The Global Coral Reef Monitoring Network, formed in 1995, is an operational unit of ICRI and operates in partnership with SocMon, ReefBase, Reef Check, NOAA, WRI, CORDIO and CRISP. The Management Group is on Page ii and major support comes from the US Department of State and NOAA. The GCRMN encourages community monitoring by local users and volunteers using Reef Check methodology, and management level monitoring at higher resolution, with equal emphasis on ecological and socio-economic monitoring data, with manuals available for both. The GCRMN produces regular 'Status of Coral Reefs of the World' reports, and other special reports. The GCRMN is a network of 17 independent Regional Nodes covering more than 80 countries and states. Contact: Clive Wilkinson clive.wilkinson@rrrc.org.au or Jerker Tamelander Jerker.Tamelander@iucn.org or Christy Loper for SocMon, Christy.Loper@noaa.gov.

ICRI – International Coral Reef Initiative is a unique public-private partnership that brings together governments, international organizations, scientific entities, and non-governmental organizations committed to reversing the global degradation of coral reefs and related ecosystems, such as mangrove forests and seagrass meadows, by promoting the conservation and sustainable use of these resources for future generations; ICRI Secretariat www.icriforum.org

RRRC – Reef and Rainforest Research Centre coordinates multi-disciplinary research on the Great Barrier Reef for the Australian and Queensland governments. It was established in 2006 and has several hundred researchers cooperating in this research; www.rrrc.org.au

UNEP – United Nations Environment Programme provides leadership and encourages partnerships with governments, the private sector, scientists, NGOs and youth to care for the environment, especially to tackle issues connecting land and sea through the GPA office. Contact: UNEP, PO Box 30552, Nairobi, Kenya; info@unep.org; www.unep.org; www.gpa.unep.org.