After the Tsunami:
Restoring coral reefs and rebuilding communities in SE Asia

An assessment of coral reef damage and recommendations for restoration to rebuild the marine environment and communities devastated by the tsunami

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August 2005

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TSUNAMI REEF ACTION FUND

ABOUT TSUNAMI REEF ACTION FUND (TRAF)

The Tsunami Reef Action Fund provides scientific and economic relief to local communities to help them rebuild their lives and the coral reefs on which they depend for food and tourism income. The Fund provides a hand up and not a hand out, which gives people an opportunity to re-establish their lives with dignity and manage the reefs for the long term. An important goal of TRAF is to raise awareness of the interdependence between humans and their marine environment; when both are damaged healing one heals the other.

TRAF provides scientific and economic support by:

- Providing economic assistance to local individuals and organizations that suffered great loss in the tsunami, to assess, clean up, and restore their marine ecosystem.
- Providing scientific expertise by sending scientists to work with local communities.
- Training local people in assessment, debris removal, and restoration techniques.
- Assisting local scientists with much needed equipment, supplies, and expertise.

Coral broken by the tsunami.

Currently, TRAF is supporting six major efforts in Thailand and Sri Lanka, and several other smaller ones. The Fund has supported local people who were left homeless and without income by the tsunami. TRAF has sent scientists to help these communities with clean up and restoration and has sent divers to assist with debris removal. It has provided scientific knowledge and appropriate techniques to restore damaged and broken reefs.

Divers remove debris from coral.

At a project site in Thailand, scientists and divers removed 150 tons of debris off the reefs — and that effort continues with more debris removed every day in a slow and painstaking effort under difficult conditions.

Reef assessment and clean up efforts in Sri Lanka would not have happened without TRAF's support to local conservation and dive groups. The Center for Conservation Research called TRAF's support of its efforts to monitor the tsunami-destroyed National Park "a God-send." But much work remains in the clean-up and restoration phase and TRAF is fully committed to rebuilding livelihoods and reefs and to raising awareness of these efforts.

Fund History

The Tsunami Reef Action Fund was started with a major donation by Dr. Deborah Brosnan (SEI, President). This was her way of giving back to the oceans and to people who helped her when her 747 flight to Los Angeles crashed in SE Asia when she was returning to the U.S. from a coral reef conference in Indonesia. TRAF provides scientific and financial support to local communities in reef clean up, restoration and management. The goal is to help individuals, communities, and the coral reefs get "back on their feet." Dr. Brosnan traveled through Asia after the tsunami to help restore coral reefs, meeting, working with, and supporting scientists and local communities. While there, she seeded several local projects. TRAF works in partnership with PADI Project Aware. Many individuals and corporations now support TRAF, including the Disney Corporation, SEI, scientists and divers. TRAF has sent scientists, divers and economic support to assist the communities rebuild their own lives in SE Asia.

Clown fish live among coral reef anemones.

About Sustainable Ecosystems Institute

TRAF is sponsored in part by Sustainable Ecosystems Institute (SEI). SEI works to sustain species and ecosystems and the people who depend on them by applying science and cooperative solutions. Since its inception, SEI has become a leader in convening scientists, governments, and private and public sectors to solve ecological issues. SEI has won the support of all groups for its integrity, scientific excellence, and commitment to sustainable solutions. SEI is supported by a Conservation Science Network of 250 scientists who provide their expertise on a wide variety of habitats and issues including Northern Spotted Owl conservation, Everglades restoration, Missouri River management, California Redwoods research, and Columbia River management. SEI staff have provided expert testimony to U.S. Senate and House committees, convened panels and workshops on species and habitats, and written scientific papers and reports.

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Front Cover: Large coral head overturned by the tsunami, Thailand.

Executive Summary

The SE Asia tsunami claimed more than 260,000 lives in 11 countries. It left five million people homeless, without income, and in need of basic services. The socio-economic and environmental consequences are enormous. Because the coastal communities rely on the sea and its resources, the urgency for marine restoration, management, conservation, and sustainable recovery has drastically changed for all of these communities. Coral reefs are the lifeblood of the communities that depend on them for food, income from dive tourism, fisheries, and other reef related activities. Coral reefs provide 65 percent of dietary protein and dive tourism and fisheries contribute $500 billion annually to the region's economy.

The situation is severe. The reefs are damaged and the communities have been devastated. Worse still, the people lack the resources they need to rebuild and care for their reefs. By providing economic and scientific support to the communities, we can help them to rebuild their lives and restore the coral reefs on which they depend.

The Tsunami Reef Action Fund provides scientific and economic support to the communities of SE Asia to rebuild their lives and coral reefs. The central philosophy of the Fund is that people and coral reefs are inter-dependent. The Fund operates on the principle that scientific expertise coupled with sound natural resources policies and local community involvement are key to restoration and long-term sustainability. We have visited the region, carried out scientific assessments, provided scientific expertise and divers to work with local communities, and provided economic support for local people.

Damage to the coral reefs was extensive. However, it varied considerably among regions and by site. One study found that 13 percent of 174 sites suffered severe damage with 50 to 100 percent of reefs damaged. TRAF surveys found a high percentage of reefs suffered severe damage while others escaped with light damage. Location, depth, topography, reef structure, and reef health all contributed to the intensity of the tsunami damage.

The tsunami dumped debris onto the reefs. It overturned massive corals, smashed coral heads, destabilized reefs, and smothered living corals with rubble. The tsunami dragged tons of sand from the beaches and numerous coral reefs are now buried under meters of sand. Tectonic uplifting raised several reefs above water and deepened others by one to four meters.

These reefs were already under stress – scientists fear that within 20 years parts of the Indian Ocean will be without living coral. The tsunami damage has added to the urgency for coral reef repair, restoration, and management. Ironically, where reefs were intact, they protected the people from the full impact of the wave and damage and loss of life were less. Healthy reefs are not a luxury, they are a necessity.

The most urgent need is to remove the debris from the coral reefs, because it continues to damage the reefs. This is a slow and painstaking effort carried out in difficult conditions. Large and dangerous objects including corrugated iron, sheet rock, beds, bikes, as well as household items, need to be removed. Several local groups and citizens, many of whom lost everything in the tsunami, are coordinating reef cleanup efforts. TRAF is actively supporting efforts to remove debris and has developed a series of recommendations for scientific and local economic support in cleanup activities

Coral reef repair using marine epoxy or cement is a simple remedy that, if effectively used, can save corals and entire reefs which were damaged by the tsunami. TRAF has supported various

repair efforts and provided scientific expertise. TRAF has a series of recommendations for how this effort should be approached

Coral reef restoration can be effective at the scale of the individual reef or small area. It has not yet been attempted at a large scale (for example, at a scale similar to Everglades restoration). Large scale restoration requires significant funds, personnel, planning, and coordination and should not be attempted without sufficient resources or support. We recommend that scientists and policymakers evaluate and support appropriate efforts at this scale. However, on a smaller scale coral reef restoration has been carried out successfully worldwide. In certain situations, coral reef restoration is warranted in the post-tsunami environment. However, each case needs to be assessed individually and several factors need to be considered.

Recommendations

Key Recommendation

Provide appropriate economic support to the community so that they can restore their marine environment and provide the scientific guidance and training that will ensure the success of this venture and leave new skills in the community. In conjunction with this effort, develop high level, science-based, and workable policies that address the ongoing threats to the region's reefs and which are implemented through enforcement and incentives.

Specific Recommendations for Communities and Coral Reefs

Community Restoration through Rebuilding Coral Reefs

- *Economic support* – We recommend providing economic support by hiring local people to clean up, monitor, and engage in reef management.
- *Local support* – We recommend working with community organizations and individuals who have shown leadership, ability, and integrity. We recommend supporting and building the capacity of these groups.
- *Scientific expertise* – Several community efforts have great intentions and commitment but severely lack the scientific underpinnings that will help ensure the success of their cleanup and restoration efforts. Local, national and international scientists with expertise should be harnessed and supported in this work.
- *Administrative expertise* – Many groups lack the organizational experience to allow them to operate effectively and to tap into funds and expertise. Providing this support will enhance their effectiveness and reduce current levels of frustration and despair.
- *Commitment at the scale and timeframe needed* –There is a need for scientific, organizational, and financial commitment to rebuild the coral reefs and communities, on the scale and timeframe which will ensure that the job gets done and the communities and reefs get "back on their feet."

Coral Reefs

- *Removal of remaining debris* – As a matter of urgency, the remaining debris needs to be removed from the coral reefs and adjacent seafloor. Sites that have not yet been surveyed for debris and damage need to be assessed and cleaned up as soon as possible.
- *Repairing coral reefs* – Restore corals that need repairing. This includes reattaching seafans, recementing fragmented corals, reanchoring *Acropora* beds, and

reattaching coral fragments. The repair efforts need to be carried out scientifically and then monitored.

- *Restoration of coral reefs* – Coral reef restoration has an important role to play in recovery, but must be carefully considered and implemented. Damaged sites must be scientifically evaluated for restoration. Restoration should be considered in the broader context of maintaining reefs for biodiversity, fisheries, and shoreline protection; allowing reefs to recover from damage; and reducing the existing threats to coral reefs. We do not recommend high-intensity artificial structures for National Parks or healthy reef systems. We highly recommend that the reef cleanup, repair, and restoration efforts combine funding for local individuals or groups with appropriate scientific expertise.
- *Site-specific options* – We recommend several site-specific options for assessment and restoration. These are provided in separate reports to the region, scientists, and community groups.
- *Management plans* – We recommend that National Parks and other entities develop management plans and training for park staff that address the conservation and management of their coral reefs and marine environment, especially in relation to the tsunami damage and threats to recovery.
- *Natural events* – Tsunamis are natural events; historically, coral reefs have been damaged and have recovered from previous tsunamis. However, today, reefs are unable to recover from stress and are disappearing, largely because of human activities. Thus human intervention is needed to restore and sustain them. As a matter of grave concern and urgency, we recommend that policymakers and scientists work at the regional, national, and international level to create and implement policies that will stop the degradation and allow the reefs to recover.

Overview

The SE Asia tsunami, triggered by a massive earthquake off the coast of Sumatra on December 26, 2004, claimed more than 260,000 lives in 11 countries. It left 5 million people homeless, without income, and in need of basic services. Entire villages, thousands of homes, fishing boats, hotels, stores, hospitals, schools, factories, and infrastructure were literally smashed to pieces and dragged into the ocean. The scale of the tragedy is immense – this is the single worst tsunami in history. The socio-economic and environmental consequences are enormous. Because the coastal communities rely on the sea and its resources, the urgency for marine restoration, management, conservation, and sustainable recovery has drastically changed for all of these communities.

Coral reefs are the lifeblood of the communities that depend on them for food and income from dive tourism, fisheries, and other reef-related activities (see Box 1). Tsunami damage to the reefs was extensive. While some reefs escaped unscathed, most were impacted and some were completely destroyed by the destructive force of the waves. A tsunami is a natural event, but several compounding issues make the effects of this tsunami more critical to the reefs and communities. The tsunami damaged reefs over a huge area. These reefs were already under severe stress from human and other natural events including overfishing, pollution, and coral bleaching. Indeed the stress has been so great that scientists feared that large parts of the Indian Ocean might be without any living coral within 20 years. This troubling situation gives greater urgency to the assessment, recovery, conservation and management of the Indian Ocean coral reefs in the wake of the tsunami.

The tsunami created a crisis for people and their marine environment resulting in two major needs:

- The need of coastal communities to rebuild their livelihoods and relationship with the sea and its reefs in ways that promote healing and promise a future that is sustainable for people and reefs.

- The need for post-tsunami actions and policies that address the recovery, restoration, management and long-term protection of the region's coral reefs.

Family tries to return to fishing.

People and coral reefs are interdependent. What affects one will affect the other. Without healthy reefs, the prospect for long-term sustainable recovery is slim; without people to care for the reefs, the reef's long-term prospects are also in doubt.

The response to the environmental and humanitarian disaster will be most effective if it occurs at several levels. These include:

- *The community level* – The health of coral reefs is often determined by the actions of community members including, fishermen, local scientists, dive operators, developers and citizens, all of whom chose daily how they will study, use, or treat their coral reefs. Several individuals, including those whose lives were devastated by the tsunami, are already stepping up to meet the challenge of coral reef cleanup, restoration and management. Supporting the activities and building the capacity of these groups will greatly enhance the recovery and potential for long-term sustainability.

- *National and international level* – Major coral reef policies and management actions are set at national and international levels. Scientists, government agencies, and others have much to contribute to setting policies that will sustain reefs on a regional and global scale. With so many scientists and organizations dedicated to coral reef study and conservation, there is a wealth of information and talent available for the task.

The economic and environmental situation is severe. Thousands are still without income. Tourism, especially dive and other reef-related tourism, is down by well over 50 percent in many regions. The coral reefs continue to suffer degradation. But, out of this tragedy, there is a tremendous opportunity to create a new framework for people to interact with their marine environment. As people have become more aware of the reefs and their dependence on ocean systems, so too they are more aware of the actions they can take to sustain them. We need to respond to the energy and desire for recovery that has emerged in the tsunami-devastated communities and to support and channel it into actions that will help to restore lives and reefs.

About this Report

The Tsunami Reef Action Fund (TRAF) provides scientific and economic support to tsunami-devastated communities to help them restore their lives and reefs. TRAF traveled to the Thailand, Sri Lanka, and the Maldives in February-March and in July 2005 to assess the

damage and to provide support to local individuals and groups and TRAF has sent numerous scientists and recreational divers to assist with local efforts.

The central philosophy of the Fund is that people and coral reefs are inter-dependent. The Fund operates on the principle that scientific expertise coupled with sound natural resources policies and local community involvement are key to restoration and long-term sustainability.

This report discusses why this issue is of local and global concern. It provides information on the nature and extent of the damage to the reefs, including data from TRAF's own scientific assessments. It discusses what actions are being taken now and can be taken in the future as well as providing a framework for restoration and recovery. (Note: This is not a comprehensive report of damage in each country or region. Readers are referred to primary sources for more detailed information.) In separate reports, we have provided more specific assessment, information, and recommendations for the communities and sites that we are supporting or are working to assist.

We acknowledge and commend the energy and commitment of the scientists who responded quickly to the crisis and of the local individuals and groups (many of whom lost everything in the tsunami) who despite great hardship are working to rebuild their lives and the marine environment.

Angelfish swim in the "rainforest of the sea"

Box 1: Coral Reefs of SE Asia: Diversity, Importance, and Threats

Known as the rainforests of the sea, coral reefs are among the most productive and complex ecosystems on earth. Their diversity reaches its peak in the warm tropical waters of SE Asia where over 700 reef-forming corals and 4,000 reef fish have been recorded.

The Importance of SE Asia Coral Reefs

Asia's coral reefs have been an abundant and productive source of food for millennia. For communities throughout the tsunami-devastated region, coral reefs are a critical source of food – reef-associated fisheries provide as much as 65 percent of dietary protein. In several countries, including the Maldives, each person consumes on average over 100 kilos of fish annually. Because of their high productivity, the reefs are a major source of economic support. One study on a heavily used 68-square-kilometer reef in the Philippines found that the reef "employed" and supported 17,000 people. In addition to subsistence fishing, reef-associated fisheries are an important local and export industry. Typical wholesale prices for reef-associated fish range from $40 to $100 per kilo in Asia. Market prices are considerably higher.

Dive tourism and reef fisheries contribute a staggering $500 billion annually to SE Asia's economy (World Bank 2005). Worldwide, there are over 15 million certified recreational divers. Destination diving has become a major industry with most divers heading for warm and clear waters, which are found in abundance in SE Asia. The high diversity and spectacular structures of the region's coral reefs attract millions of divers annually. Centers of diving along the Andaman coast of Thailand, Indonesia, and the Maldives are renowned. More remote areas including Sri Lanka's east coast are growing in importance for divers and snorkelers. Several of these "centers of diving" were affected by the tsunami. More recently, the reef aquarium trade has seen rapid growth. This is a controversial practice although the industry argues that it is a low volume but high value trade. A kilo of aquarium fish from one island nation was valued at close to $500 in 2000.

Coral reefs and mangroves buffer coastal communities against the full impact of wave action. These reefs not only protect coastlines from the worst excesses of storm damage but they are also the source of sand which builds up and replenishes beaches. The role of healthy coral reefs in protecting coastlines and communities was clearly evident in the recent tsunami.

Existing Threats to SE Asia Coral Reefs

When the tsunami swept across the coral reefs of SE Asia, it rolled into coral reefs that were already threatened from natural and human impact. Pollution, coral mining, sedimentation, overuse, and unsustainable fishing, including dynamite fishing, have all taken their toll on the region's coral reefs. In addition, SE Asia reefs had suffered a major bleaching event in the late 1990's that was associated with the 1997-98 El Nino. In some areas, notably the Central Indian Ocean, up to 90 percent of the corals were affected.

The Effects of the SE Asia Tsunami on Coral Reefs

Extent of the Damage

Extensive areas of coral reef were damaged by the tsunami (GEF/World Bank 2005; Brosnan 2005). Shortly after tsunami, initial reports of severe damage and reef destruction were received from several countries including Thailand, Sri Lanka, Indonesia and India. Data are still being analyzed but initial figures are available (see table on page 21). The emerging pattern shows that damage varied considerably among reefs, ranging from tectonic uplifting of entire reefs so that the reefs are now completely exposed "on land," for example, in the Andaman and Nicobar Islands, to severe damage from mechanical or sand burial, as at Dutch Harbor in Sri Lanka, to minimal reef damage at Ko Surin in Thailand. One study found that 13 percent of 174 sites surveyed in detail in Thailand were heavily impacted, that is, 50 to 100 percent of the reef was damaged (Phongsuwan, Marine Biology Center, Phuket, Thailand, and a consortium of scientists and universities 2005). Of six sites surveyed for tsunami damage in Sri Lanka, 50 percent showed damage ranging from high-extreme damage, two had moderate damage and one had no detectable damage (NARA/ CORDIO/IUCN/GCMN/SLSAC 2005a). Of ten sites that we surveyed in Thailand, 60 percent were severely damaged by the tsunami and 40 percent suffered light to moderate damage. Of four sites that we visited in Sri Lanka, 50 percent were severely damaged (one was completely pulverized), and 50 percent suffered between light and moderate tsunami damage. Of four sites that we visited in the Maldives, one was buried by sand but the remaining suffered localized light to moderate damage.

Overturned coral head.

The extent of the damage depended on several factors, including:

- *Location* – Damage often depended on whether the reef suffered a direct hit, was located in the protective lee of an island, or was adjacent to beach area where sand was dragged onto the reef. Proximity to onshore development was also a factor. Inner reefs that were protected by outer reefs suffered less damage. Damage varied within single bays – the southern end of Patong Bay in Phuket Thailand suffered heavy damage while the northern side of the bay escape with almost no impact (Brosnan, personal observation; Phongsuwan MBC 2005 and a consortium of scientists and universities 2005).

- *Depth and Topography* – Deep channels focus waves. Consequently, reefs in the center or on the sides of channels often suffered severe damage as the tsunami was forced through the channel. For instance, Snapper Alley, located in the channel between Islands 8 and 9 in the Similan Islands, was badly damaged. Shallower reefs seem to have suffered more damage than deeper ones (except in channels or inlets). Where channels were created through reefs for shipping or other uses, damage was more severe

- *Reef Health and Reef Type* – Damaged reefs often suffered more destruction than healthy reefs. Damaged reefs were less resilient and had more dead coral heads and rubble, which the waves picked up and smashed onto adjacent living corals. Assessments in the Seychelles (Obura and Abdulla 2005) and our own personal observations suggest that reefs on a calcium carbonate base seem to have suffered more damage than corals on granitic substrates. Mortality and bioerosion resulting from the 1998 El Nino bleaching event may have contributed to the higher damage on calcium carbonate reefs.

Type of Damage

Debris on the Coral Reefs

The receding waves dragged debris onto the reefs and seafloor and created a major environmental and human safety crisis. TV sets, cars, fridges, corrugated metal, entire houses and their contents, and sheet rock all ended up on the reefs and sea floor. Additionally, large trees and other land vegetation were deposited on reefs. The damage continues – with each wave, the debris is rolled on the coral heads and causes more destruction. Fishing nets were dragged onto the reef and wrapped around corals where they continue to trap fish, threaten endangered turtles, and break fragile coral heads. The monsoons have worsened the situation by uncovering more debris and tossing it on the reefs and beaches.

TVs and other debris pose serious problems.

Overturned Corals

The force of the tsunami overturned coral heads. Massive corals, many the size of cars, were literally turned upside down. In some cases, as at the entrance to Loh Da Lum Bay in Phi Phi in Thailand, most of the massive corals were overturned. Other areas, including Snapper Alley, suffered similar damage and many of the large seafans were ripped out. On other individual reefs, such as Sheltered Bay on Similan 8 in Thailand, which was on the leeward side and protected from the tsunami's direct force, about five percent of the corals were overturned.

Corals shattered by the force of the wave.

Coral Breakage and Reef Destabilization

Corals were smashed by the force of the wave and by the debris carried in the wave. On some reefs, the damage was extensive and most of the reef was destroyed, such as on the reefs in Trincomalee Bay (Brosnan 2005; NARA/CORDIO/IUCN/GCRMN/SLSAC 2005a). On other reefs, the damage was more localized and less extensive, as in Hikkaduwa and other rocky reefs in Sri Lanka (Brosnan 2005; NARA/CORDIO/IUCN/ GCRMN/ SLSAC 2005a,b).

Plate corals were broken into fragments on several reefs. Massive table corals (some measuring over two meters in diameter) were picked up by the wave and thrown onto adjacent

reefs where they smashed or covered living corals. In some cases, living reefs are smothered by huge overturned table corals. Branching corals such as *Acropora* (elkhorn) were often the most severely impacted by the tsunami. Entire elkhorn reefs were pulverized as the waves roared across them (as at Phi Phi in Thailand and Trincomalee in Sri Lanka). On other reefs (as at Coral Island in Sri Lanka), the points of attachment of large branches were broken and, while the reef appears intact, it is no longer connected to its foundation. These reefs sway in the swell and are highly vulnerable to breakage and loss in surge and monsoon conditions.

Sand and Sediment Burial

The tsunami moved millions of tons of sand. Beaches were reduced by 75 percent in seconds. Much of the sand ended up on the reefs and, throughout the region, reefs have been fully or partially buried. In the Maldives, one reef, a monitoring site for scientists that was previously at ten meters, has been buried under three meters of sand. Reefs in Trincomalee and Phi Phi have been partially buried under meters of sand.

Corals buried in sand.

Tectonic Uplifting and Sinking

Tectonic uplifting raised several reefs so that they are now completely out of the water. Uplifting occurred in the Andaman and Nicobar Islands and in parts of Indonesia. These reefs are no longer “living coral reefs” but rather new emerged rock islands. Additionally, in some places, the tectonic shift lowered the seafloor, so that some corals are now one to four meters deeper that they were prior to the tsunami. We don’t know whether all these corals can survive the reduced light and other new conditions at these deeper depths. It is worth noting that some of these tectonic shifts have created new challenges for shipping.

Coral Reefs and Natural Environments Provided Protection

There is growing evidence that coral reefs, mangroves and sand dunes buffered the waves and protected the coast and people. The protective role played by healthy and intact coral reefs and other healthy natural habitats has now been reported and confirmed by several scientists and organizations (Brosnan, personal observation; Center for Conservation Research Sri Lanka 2005; IUCN 2005; World Bank 2005; UNEP 2005; Science Aug 2005,and others). Reef crests and coral structures absorb and dissipate the wave energy and act as buffer for the land. Where reefs were intact, there was often less damage and less loss of life on land. In the Seychelles, shoreline damage was greater where deep channels lead through the reef or up to the reefs and therefore focused and amplified the wave force. Damage was more severe on land in areas where channels were cut through fringing reefs.

The lesson is clear. Intact and healthy reefs are not a luxury. They are essential to coastal communities for their protective role. It is a service that they provide at no cost.

Recovery and Restoration

The sobering conclusion of scientists that large areas of the Indian ocean may be devoid of living reefs within two decades makes the recovery, restoration and conservation of these reefs in the aftermath of the tsunami an urgent matter.

On a local scale, recovery and restoration is needed throughout the region. Each situation needs to be assessed individually in order to determine the best course of action. Some reefs have suffered little damage and no action is necessary. Others will recover naturally if left alone. But numerous reefs need active restoration and management. Unfortunately, many reefs will not be “left alone” to recover and they face additional threats from ongoing or increased degradation following the tsunami. Tragically, these reefs may have survived the tsunami only to fall victim to subsequent human actions.

Coupled with reef assessment and restoration, there is a critical need for natural resources planning and activities that sustain the reefs and people. These include how to effectively integrate, develop, and manage conservation, fisheries, ecotourism, marine parks, and more. This is a deeper need and it existed before the tsunami, but the added environmental and human crisis created by the tsunami makes this issue more urgent.

Conserving Coral Reefs after the Tsunami: Activities and Recommendations

Debris Removal

The most immediate and practical need is to remove the debris from the reefs and surrounding seafloor and mangroves where it continues to damage reefs and sensitive habitats. In areas where there was significant coastal development (that is, hotels and resorts), the debris is more extensive than on reefs located offshore of subsistence villages. Debris removal is an ongoing need as the monsoons continue to uncover debris that was buried in sand and deposit it on the reef, seafloor and beach. Thus, in some situations, reefs that were cleaned up have to be revisited for additional cleanup (Sri Lanka Reef Debris Removal Reports, 2005). We suspect that reef cleanup from the tsunami will need to continue (although at a reduced level) for a couple of years.

Several efforts have been underway to remove debris. Some of these are government supported but many have been initiated and carried out by local individuals and community groups who lost homes and businesses in the tsunami. They have been supported in their work by varying amounts of local or international funds – TRAF has provided financial support to six efforts and has also sent scientific and recreational divers to assist in several projects (see Box 2). Additionally, hundreds of local and international volunteers have joined the cleanup efforts throughout the region. Removing debris is a major undertaking and is generally carried out in difficult and dangerous conditions – that is, in near zero visibility, with sharp metal objects poking out of the reefs, and often in currents or wave surge.

Fishing nets are highly destructive and they are particularly difficult to remove from coral reefs. Dragged onto the reef by the tsunami, they wrap tightly around corals and often extend for miles along the reefs. Care must be taken not to destroy corals and other marine life when the nets are being removed. In some cases, efforts have taken over a week to remove a net. Phongsuwan (personal communication 2005) reports that it took a team of 20 divers ten days to remove a net in the Phuket region of Thailand. The Maldives has a ban on net fishing and consequently net damage is not a problem in this country. In the aftermath of the tsunami, the benefits of this policy for the reefs is strikingly evident.

In some areas, much of the debris has been removed. For instance, Phongsuwan (personal communication, 2005) reports that 95 percent of the sites he has surveyed have been cleaned up. However, this is not the situation in many regions. Debris removal needs to continue in other sites such as Phi Phi Dive Camp (Hewett, personal communication). In some areas it has not yet begun because of the humanitarian crisis created by the tsunami and/or because of the monsoons. This is the situation in Khao Lak, Thailand, which was badly devastated by the tsunami.

Divers remove debris from coral.

Volunteer divers have been enormously helpful in debris removal. However, it is important that divers be competent to deal with the difficult working conditions and that they not exacerbate the problems by standing on the reefs or accidentally removing corals or other actions. Screening the volunteers and providing clear instructions is essential. Hewett at Camp Phi Phi in Thailand requires that volunteers have a minimum of 100 dives. The cleanup operation in Sri Lanka, which were conducted by Conservation and Dive Consortium, provides written instructions in English, Singhal and Tamil.

Scientists have a key role in providing technical guidance on several issues, including how to minimize damage to corals while removing debris, nets, and other debris; how to prioritize among reefs; how to deal with sediment; and by contributing their expertise on post-cleanup rehabilitation and conservation actions. Scientific information is often lacking in these community efforts and scientists can help to better ensure the success of these efforts if they are willing to reach out to project leaders. Non-scientist project leaders can equally benefit by seeking scientific support.

An important contribution of the debris-removal projects has been to uncover personal belongings, passports, and in some cases human remains. This has brought closure for many people who lost loved ones in the tsunami. It is important that divers have clear instructions on how to deal with such finds. We note that Hewett at Camp Phi Phi has developed an effective protocol for the volunteer divers who work at the camp.

Box 2: Tsunami Reef Action Fund: Tsunami Debris Removal from Coral Reefs

The Tsunami Reef Action Fund (TRAF) is supporting six major assessment and cleanup efforts in the region. These efforts are locally initiated and carried out, often by people who lost everything in the tsunami. TRAF has provided scientific expertise, divers, and funding to support local people and the cleanup. Andrew Hewett, Camp Phi Phi, has been running a volunteer-based cleanup effort for six months and has removed hundreds of tons of debris from the seafloor and adjacent reefs. This work is ongoing and will be moving into a repair and restoration phase shortly. In Sri Lanka, TRAF supported the Center for Conservation Research Sri Lanka to assess the damage to the National Parks and to a consortium of conservation groups and divers (IUCN, Sri Lanka/SubAqua clubs) who have removed tons of tsunami debris from reefs around the country. Our support provides funds for local people (who have lost income) and the cleanup effort. Additionally, local volunteers have contributed their time to clean up the debris from reefs. We are supporting and working with a local dive operator who is coordinating local fishermen in reef cleanup.

The lessons that we have learned and our recommendations:

- Removing debris is an urgent and important undertaking.
- It is a difficult and painstaking operation. Training for participants is necessary.
- Engaging the local community and providing support for local people is essential. This provides income and injects funds into the community (often this has been the only income for these people since the tsunami destroyed their livelihood). It indicates that the work and person carrying out the work is valued and it fosters a new approach to marine resource management.
- Local people, especially fishermen and divers or those who have worked with the sea, have valuable knowledge that can help locate debris and improve the assessment and cleanup plans.
- Scientific input is essential. Scientists provide an ecological assessment that helps to set priorities. They provide guidance to non-scientists on how to minimize damage to the reefs and their input increases the likelihood of long-term success for the reefs and provides an educational and empowering experience for those who participate.

Saving Coral Reefs: Immediate Recovery and Repair

Replacing Overturned Corals

Returning overturned colonies to their original positions can ensure the survival of individual coral heads. This effort was most beneficial in the immediate aftermath of the tsunami, especially for corals that were buried in sand and where little living tissue was exposed. Several scientists and volunteer groups (including TRAF) actively participated in this activity throughout much of the region. The time for replacing corals is mostly over. However, we were surprised to find that even after six months replacing overturned colonies was still a viable option on some shallow (one meter) reefs in clear water (as represented near Koh Pai or Bamboo Island in Thailand).

Repairing Damaged Corals

Simple remedies can be used to repair damaged reefs. These techniques can save corals and preserve the integrity of the reefs. Repairing massive cracked colonies, reattaching detached coral colonies directly with epoxy or marine cement, can be an effective local treatment to help repair damaged coral reefs. (For technique, see tsunamireefactionfund.org or sei.org.) For example, reattaching seafans ripped out by the tsunami, using marine epoxy or cement has been carried out in Thailand. TRAF provided technical assistance by supplying information, scientists, and training on how to reattach sea fans. Local scientists such as Niphon Phongsuwan (Marine Biology Center Thailand) and Sakanan Plathong (Prince Songlia University) and organizations (UNDP, Sea Foundation) led and coordinated the seafan recovery effort. Several other scientists including Dr Dwayne Meadows and Caroline Sachs (partially funded through TRAF) and other volunteers assisted. See Box 3.

Divers righting pieces of coral.

Reattaching the coral (using epoxy or cement) can stabilize the reef and prevent its destruction by wave action. This is particularly beneficial where the reef has been destabilized, for example, in areas where *Acropora* fragments have been broken off at their foundation and the entire reef is "floating" and at risk.

Box 3: Tsunami Reef Action Fund: Coral Reef Repair and Recovery

The Tsunami Reef Action Fund (TRAF) is providing assistance and scientific input to several groups on repairing and recovering corals damaged by the tsunami. This input includes techniques on how to reattach seafans and repair damaged or fragmented corals using epoxy or marine cement. Details can be found on the website tsunamireefactionfund.org or by contacting trafund@tsunamireefactionfund.org. It also includes evaluating the scale of the problem and what if any type of repair is worthwhile given the scale of the damage and available resources relative to other priorities and possible actions.

TRAF recommends that:

- Using epoxy or marine cement to reattach anchor points of *Acropora* beds can preserve the integrity of the reef and make it less vulnerable to destruction by wave action.
- Fragments can be reattached using marine epoxy or marine cement.
- Larger fragmented corals can be "re-glued" together to prevent loss of the individual fragments in sandy or wave-prone areas. On certain reefs, however, it is best to leave the fragments alone and some will recover.

Additionally, reattaching broken fragments to nearby substrate can help a coral reef to recover. In many locations where damage has been severe, there is an abundance of broken fragments that can be saved and reattached using marine epoxy or cement. The advantage of this effort is that the fragments are being replaced in the same local environment. This is an important consideration as fragments of some coral species do not respond well to being transplanted to other locations.

Larger Scale Coral Reef Restoration

Coral reef repair and restoration have important roles in post-tsunami recovery. But before any restoration takes place, it is essential that all stakeholders understand what is meant by restoration, what is possible, and what resources are needed for success. To date, coral reef restoration has been carried out on a limited spatial scale (up to a few hectares at most), which is often at the level of single reef system and usually in response to human damage such as ship groundings, development threats, and so on (for further information, see sei.org or tsunamireefactionfund.org). There have been no attempts to restore coral reef ecosystems on the scale that matches the extent of damage from hurricanes, let alone that of the SE Asia tsunami. This is not to say that large-scale reef restoration should not be studied or carried out, but rather that, as a science, it is in its infancy and should be approached with sufficient planning and resources. Large-scale restoration is a huge undertaking that requires major financial, administrative, technical, personnel, and long-term commitments. Indeed, in only very few instances has restoration of an entire ecosystem been attempted.

The South Florida Ecosystem Restoration (of the renowned Florida Everglades) illustrates the complexity and level of commitment necessary for a large scale restoration. Comprising 180 square miles of marshland and coastal bays, the severely degraded Everglades are currently being restored (Brosnan et al 2003). Recovery is estimated to take about 30 or more years and the estimated 2005 annual budget for restoration is $231million. This effort involves several Federal and State agencies, Tribes, stakeholder groups, and hundreds of scientists, engineers, and resource managers. It entails single- and multi-species planning, habitat changes, enforcement of new and existing environmental policies and laws, new engineering developments, performance measures to monitor restoration, and adaptive management to respond to natural- or human-caused unforeseen changes. It is, in short, an expensive and hugely coordinated effort. Coral reefs are as complex and as critical as the South Florida ecosystem. Any similar large-scale attempt for coral reefs will require the same level of attention, support, and integrated involvement of scientists, government, and stakeholders. Given the high stakes and extensive damage to reefs globally, we believe it is of value for coral reef scientists, policy makers and managers to evaluate and commit to reef recovery on this scale. However, it would be foolish to attempt any major restoration without with the appropriate support, consideration, or resources.

On a more limited spatial scale, coral reef restoration and repair has been successfully carried out worldwide. Several techniques are:

- Replanting fragments and nubbins (raised in nurseries)
- Transplanting large coral heads.
- Creating natural or artificial structures to provide settlement substrate.

(For more information on these techniques see tsunamireefactionfund.org)

Before any post-tsunami repair or restoration is undertaken, several factors need to be considered. These include:

- Extent of the damage
- Potential for natural recovery
- Barriers to natural recovery (for example, absence of suitable substrate)
- Other non-tsunami related threats that may negatively affect reef recovery (for example, pollution, onshore development, dynamite fishing have negative effects) or positive actions that may enhance recovery (e.g. management, addition of mooring buoys)

Additionally, there needs to be a clear understanding of the rationale and goals for restoration. While there is general agreement that coral reefs are a good thing, the reasons for creating, repairing or restoring reefs vary considerably.

Rationale and goals include:

Tourism and Diving

In many dive-tourism areas of SE Asia, coral reef restoration may be considered and carried out primarily to attract divers or snorkelers. In this situation, the effects of diving on the "restored" reef and on adjacent reefs need to be considered in the restoration planning. Is the reef being constructed for divers or to take pressure off damaged or more important reefs elsewhere?

Fisheries – Providing Fish Habitat

Where reefs are being restored for fishing, sustainable fishing practices need to be integrated into the approach. There is little value in restoring a reef if, for example, it is then vulnerable to pollution, dynamite fishing, or other unsustainable practices.

Coastline Protection

Reefs may also be restored to provide protection to the coastline against storms and flooding or to minimize or prevent erosion.

Post-Tsunami Healing for the Community

Reef monitoring and restoration can provide a forum for the community to engage in the conservation and stewardship of their natural resources. For some individuals, reef restoration becomes a way of healing and rebuilding their own lives after the tsunami (such as the JD Fund, Thailand). Contributing to reef restoration is a way to give back to the ocean, and establishing a new connection with the sea. The importance and value of this for the long-term health of coral reefs and people should not be underestimated.

Providing Alternative Sources of Income and Livelihood to Those Impacted by the Tsunami

There are opportunities to provide income to local individuals, such as fishermen, in reef cleanup and restoration. These opportunities not only help reef restoration but can also serve to reduce other impacts such as fisheries on the reefs.

Scientific Knowledge

For scientists and others, reef restoration can provide valuable information that improves our knowledge and ability to restore coral reefs. Every restoration effort can contribute to our

knowledge but only if there is an experimental approach and follow-up monitoring, analysis and reporting.

Increase Coral Reef Diversity, Abundance, and Recruitment

In some cases, scientists or the community can favor coral restoration or artificial reefs in order to augment the amount of natural coral in an area. This approach is often proposed when adjacent natural reefs are damaged or have a high proportion of dead coral resulting from human or natural causes. Often there are several goals, assumptions, and hopes inherent in these projects, such as increasing the amount of coral in order to provide an insurance against loss locally or globally (a mitigation/insurance approach), enhancing the ecosystem by facilitating coral development, increasing overall coral and fish recruitment into the area to promote diversity, creating restored or artificial reefs to engage the community in caring for their reefs, and to serve an educational purpose. These goals tend to be vague but fall under the catch-all of increasing biodiversity and awareness.

School of fish in a healthy reef.

Restoring reefs to maintain biodiversity, enhance fisheries, provide education are all worthy goals. Restoring reefs can create excitement in the community and engage a variety of stakeholders in the care of their reefs. This is exactly the interest that scientists and others hope to foster in the public. While it is important to harness that interest and energy, it is equally important that it be directed into projects that will be effective and meet the goals. Therefore, the needs, goals and potential for restoration must first be evaluated. Once these are understood, then clear objectives and appropriate methodologies should be developed. Strong scientific approaches and knowledge are essential to enhance the cost-effectiveness and likelihood of success. Any restoration plan should include monitoring and evaluation in order to determine whether the effort has been successful, to maintain community support and interest, and to identify any lessons learned in the process.

On a global scale, it is important for policymakers to remember that restoring a coral reef whether using natural substrate or artificial reefs will not compensate for poor reef management policies. This is why the recovery and restoration of coral reefs in the post-tsunami environment must be carried out in conjunction with sound reef management practices that are scientifically based, reflect sound policy approaches, and are subsequently supported through enforcement and incentives.

Conclusions and Recommendations

The SE Asia tsunami created a humanitarian and environmental crisis: five million people were left in need in basic services and without income. The reefs which provide the communities with 65 percent of dietary protein and contribute $500 billion in fisheries and dive tourism are covered in debris and damaged. There is a need and opportunity to restore the communities and the reefs on which they depend.

The TRAF approach is that people and reefs are inter-dependent. By supporting people and coral reefs we can help to rebuild the communities and create a sustainable future – one where these communities are independent and self-sufficient.

Our main recommendations are: Provide appropriate economic support locally to the community in order to restore their marine environment and provide the scientific guidance and training that will ensure the success of this venture and leave new skills in the community. In conjunction with this effort, there is a need for high level science-based and workable policies that address the ongoing threats to the region's reefs and which are implemented through enforcement and incentives.

For clarity, we are providing our specific recommendations under "community" or "coral reefs."

Community Restoration

- *Economic support* – Reef cleanup, restoration and management are urgent issues that affect the livelihoods and health of the community. To restore the reefs and communities, provide economic support by hiring local people to clean up, monitor, and engage in reef management. This will inject income into the community and have long-term humanitarian and environmental benefits.
- *Local support* – How can this support be best spent? Providing aid effectively is challenging. We recommend working with community organizations and individuals who have shown leadership, ability, and integrity. There are numerous scientists, NGOs, and local community members who are actively engaged in assessing and restoring their coral reefs and marine environment. We recommend supporting and building the capacity of these groups. This includes hiring reef cleanup coordinators, individuals who can be trained as technicians or scientists and who have useful skills sets that can be further enhanced through the program (such as boatmen, snorkelers, and divers). Additionally, we recommend fostering interactions among the different entities.
- *Scientific expertise* – In addition to financial support, these groups need scientific support. There is a need for a basic understanding of marine reef and nearshore ecosystems, reef-fisheries dynamics, and how to assess, clean up, restore, and manage coral reefs. Several community efforts have great intentions and commitment but severely lack the scientific underpinnings that will help ensure the success of their cleanup and restoration efforts. Some recognize this lack of knowledge and have sought and welcomed scientific input. Others still lack any scientific input. Recently, many scientists expressed their concern that reefs and communities are in danger from inappropriate or poorly-thought-out efforts to restore reefs - their fears are well-founded. Providing scientific expertise will minimize the likelihood of additional damage to reefs, provide the needed expertise, and will educate the community. Local, national and international scientists with the skills and expertise are available to help and this talent should be harnessed and supported

- *Administrative expertise* – Many of the community groups lack the organizational experience that allow them to operate effectively and to tap into funds and expertise. For instance, providing organizational assistance such as help with grant writing, how to establish a non-profit, and so on, is key. This will increase effectiveness and reduce the current levels of frustration and despair.
- *Commitment at the scale and timeframe needed* – The SE Asia tsunami has not been forgotten but it has faded from public awareness. However, for the people of SE Asia, their recovery is just beginning. There is a need for scientific, organizational, and financial commitment to rebuild the coral reefs and communities, which will ensure that the job gets done and the communities and reefs get "back on their feet." (This does not imply that assistance is provided "forever" – rather that the assistance makes a measurable difference in the recovery and can be phased out when the goals are achieved.)

Coral Reefs

- *Removal of remaining debris* – We recommend that, as a matter of urgency, the remaining debris be removed from the coral reefs and adjacent seafloor. Additionally, those sites which have not yet been surveyed or assessed for debris and damage need to be assessed and cleaned up as soon as possible. These activities should be carried out with support for the local community (such as divers, fishermen and others) and local trainee scientists (such as those employed and being trained by CCR Sri Lanka). This goal can be easily achieved through local community, environmental, and aid organizations. Moreover, this approach injects funds and leaves valuable skills with the community.
- *Repairing coral reefs* – Equally as a matter of urgency, we recommend that coral reefs be repaired. This includes reattaching seafans, recementing fragmented corals, reanchoring *Acropora* beds, and reattaching coral fragments. The repair efforts need to be carried out scientifically and then monitored. We highly recommend that the approach combine funding for local individuals or groups with appropriate scientific expertise.
- *Restoration of coral reefs* – Coral reef restoration has an important role to play in recovery. We recommend that damaged sites be scientifically evaluated for restoration. We recommend that restoration be considered in the broad context of maintaining reefs for biodiversity, fisheries, shoreline protection, etc.; allowing reefs to recover from damage; and reducing the existing threats to coral reefs. Restoration or artificial reefs may provide most benefit in areas where the reefs have been destroyed (from the tsunami or other causes), where there is need for shoreline protection, or where artificial reefs will be used for diving or fishing in order to take pressure of natural reefs. We do not recommend high-intensity artificial structures for National Parks or healthy reef systems. (As discussed in this report, restoration should not be attempted without careful consideration). Restoration should involve, support, and build capacity in the local community.
- *Site-specific options* – We recommend several site-specific options for assessment and restoration. These are provided in separate reports to the region, scientists, and community groups.
- *Management plans* – We recommend that National Parks and other entities develop management plans and training for park staff that address the conservation and

management of their coral reefs and marine environment, especially in relation to the tsunami damage and threats to recovery.

- *Natural events* – Tsunamis are natural events; historically, coral reefs have been damaged and have recovered from previous tsunamis. However, today, those reefs are severely damaged and even disappearing largely because of human activities. Around the world, corals are no longer recovering from “natural events.” Moreover, they cannot tolerate more onslaughts, whether natural or human-induced. Thus human intervention is needed to restore and sustain them. As a matter of grave concern and urgency, we recommend that policymakers and scientists work at the regional, national, and international level to create and implement policies that will stop the degradation and allow the reefs to recover. There are numerous talented scientists, organizations, politicians, and political groups who share a commitment to sustaining coral reefs and people. No single group (for example, only scientists) can make this happen alone; science, policy and management must operate in unison. The necessary skills and people can and must be harnessed for this large scale effort. This effort goes hand-in-hand with the local community work.

Tsunami Damage to Coral Reefs In SE Asia

Location	*Number of sites or reef area*	*Assessment results*	*Source*
Thailand, Andaman Coast	174 sites in 10 marine parks and one wildlife reserve	13% highly damaged, 21% slightly damaged, 40% little to no damage.	DMCR, 7 universities, MBC, NPD, Inst of Technology 2005
Thailand, Andaman Coast, from Similan to Phi Phi	10 sites	60% (6) severely damaged; 40% (4) light to moderate damage.	Brosnan 2005
Thailand Ko Surin (Surin Island)	6 regions (28km of reef)	Mean tsunami damage was 18%, and ranged from 0% to 62%.	Coral Cay Conservation 2005
Sri Lanka	6 sites	1 extremely damaged, 2 highly damaged, 1 moderate damage, I low damage and 1 no damage.	NARA/CORDIO/IUCN/ GCRMN/ SLSAC 2005 a
Sri Lanka	4 sites	Mechanical damage: 1 high; 1 moderate; 1 low and 1 no damage. Sand burial: 1 highly impacted, 1 moderate, and 2 not covered in sand.	NARA/CORDIO/IUCN/ GCRMN/ SLSAC 2005 b
Sri Lanka	4 sites	2 severely damaged, 1 moderately damaged, 1 lightly damaged.	Brosnan 2005
Maldives	4 sites	1 buried, 3 light damage (overturning and breakage).	Brosnan 2005
Maldives		Most damage on the eastern side of atolls. Damage mostly in the Northern Section and none south of the one-and-a-half-degree channel	Marine Research Center
Seychelles	Northern (5 sites) and Southern Islands	Northern Islands suffered high levels of damage (close to 100% damage). Southern granitic reefs light to moderate damage (<10%).	Obura and Abdulla 2005
India	Gulf of Mannar	Reefs around islands: little damage. 1-2% of branching corals. Patch Reef. Turbinaria corals, which comprise 25-40% of reef, are filled with 4-5cm of sand.	SDMRI-RRT 2005
India	Andaman and Nicobar Islands	North Sentinel, Middle and North Andaman: coral reefs uplifted and are now on land. Nicobar and Southern Andaman: reefs sunk in depth by 1-4m. All Areas: mechanical damage and sand burial reported ranging from light to severe.	Kulkarni 2005
Malaysia	Offshore reef islands	Erosion on reef tops, especially reef edge, sediment resuspension, and damage to reef tops. Damage greater on shallow and intertidal reefs.	Zulfigar Yasin and Aileen Tan Shau-Hwai 2005

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Acknowledgements

The Tsunami Reef Action Fund thanks its donors, advisors, scientists, volunteers, and especially the people and organizations of SE Asia who are working to rebuild their marine resources and communities.

Thanks to our supporters – Disney Wildlife Conservation Fund, SeaLife Cameras, Sustainable Ecosystems Institute, The San Joaquin River Parkway and Conservation Trust, California State University, Stanislaus Endangered Species Recovery Program, William Boggess, Deborah Brosnan, Evelyn Brosnan, Steven Courtney, Douglas DeMaster, Monica and Martial Depczynski, Lowell and Janice Diller, Jack and Elizabeth Dumbacher, Steven and Tina Engelfried, Kirsten Gilardi, Nina Fascione, Jerry and Phyllis Franklin, James Green, Rocky and Kaye Gutierrez, Patrick and Cathy Kelly, Stephen Kendrot, Teresa Klinger, Andy MacKinnon, Bill and Joan Murdoch, Peyton and Constance Owston, Allen Smith, Gary Taliafero, Daniel and Susan Varland, and Sara Vickerman.

Thanks to scientists, volunteers, divers, SE Asia groups, and others – Mark Hixon, Harold Hudson, Eko Lapp, Joanne Marston, Dwayne Meadows, Kim Powers, Lisa Sztukowski, Caroline Sachs, Brian Tissot, Natalie Turner, Mike Brown, Kevin Davis, Marianne Gilbert, Renee and Jason Gibb, Adam Levy Rogers, Lorene Meacham, Mark Mihelich, Allen and Ann Peront, Phuket Marine Biological Center (Thailand), Niphon Phongsuwan, Sakanan Plathong, Vittayen Muttamara, Center for Conservation and Research (Sri Lanka), Prithiviraj Fernando, Jennifer Pastorini, IUCN (Sri Lanka), Marten Meynell, Jerker Tamelander, Marine Research Centre (Male, Maldives), Abdul Azeez, Abdul Hakeem, Banyan Tree Resort (Maldives), Andrew Hewett, Stuart Robbens, Joe Hue, Jiharsa, Claudio Trento, Diving the Snake, and the many others who provided assistance to this work.

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